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Medicinal and poisonous plants 1

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R.H.M.J. Lemmens (Editors)

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Foreword

Although many people in rural areas in the tropics – including South-East Asia – rely on locally available plants for their daily health care, the importance of these plants has, until recently, been underestimated. This has now changed, partly because of the demand for plant-derived medicines, and partly because it is now known that medicinal and poisonous plants are a rich source of promising chemical compounds.The resulting resurgence of interest in medicinal plants in South-East Asia, particularly in Thailand and the Philippines, is also fuelled by interest in environmentally friendly plant-derived pesticides.
This renaissance of medicinal and poisonous plants has created a demand for detailed knowledge from new research and for an overview of existing published information. As interesting compounds are more likely to be found in plants with known medicinal uses, the best way to find new applications of plant-derived drugs would seem to be to combine local knowledge with the results of modern research on the properties of plant-derived medicines. It is here that this Prosea handbook volume on medicinal and poisonous plants is so valuable. It provides the latest information on the botanical, agricultural, chemical and medicinal aspects of these plants and, as such, will be an invaluable resource for those involved with medicinal and poisonous plants, whether working in research and industry or in education and extension.

Bangkok, June 1999

Professor Dr. Her Royal Highness Princess Chulabhorn Mahidol
President
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1 Introduction

1.1 Definitions

True to its title Prosea 12 is devoted to medicinal and poisonous plants used in South-East Asia. Following common practice in literature, the two categories of plants have been combined into one commodity group. This is because many poisonous plants are used medicinally; at lower doses their toxic constituents are often beneficial.

1.1.1 Systems of medicine

It is important to distinguish between three different types of medicine: traditional, herbal and pharmaceutical. A plant may be consumed as a medicinal tea by members of a community living in the area where the plant is indigenous, the same plant may be cultivated and processed in the country of origin into a formulation of a herbal medicine sold in western countries, and it may provide a lead compound for a pharmaceutical product. These systems of medicine are complementary in health care and can in no way substitute one another (Balick et al., 1996). In this volume, the role of the species in each of the three systems is distinguished whenever possible.

1.1.2 The importance of medicinal plants

Medicinal plants are of great economic importance. They are used as raw materials for the extraction of active constituents in pure form (e.g. quinine and quinidine from *Cinchona* bark), as precursors for synthetic vitamins (e.g. fixed oil for vitamin E) and steroids (e.g. *Dioscorea* and *Smilax* roots), and as preparations for herbal and indigenous medicines. Plants are not only the major source of energy-rich foods in most societies, but are also an indispensable source of vitamins and other substances promoting healthy growth. But note that though the consumption of certain plant parts may be prophylactic, e.g. scurvy is prevented by eating citrus fruits (in which vitamin C is the active factor), plant species with these properties are generally treated in other Prosea volumes, particularly Prosea 2: 'Edible fruits and nuts' and Prosea 8: 'Vegetables'.
The present volume covers only those species of plants whose medicinal uses and properties are described in the literature. The discovery of important medicinal properties (e.g. oncolytic properties of the alkaloids in *Catharanthus roseus* (L.) G. Don) in the last 40 years has resulted in thousands of scientific reports on South-East Asian medicinal plants. The few existing handbooks on medicinal plants of South-East Asia (e.g. Perry, 1980) only give information on

the plants' uses and properties, but the team of authors and editors responsible for this volume has combined the information in the reports and manuals with botanical and agronomic information.

Many plants used in medicine or as poison have other uses. In this volume, however, generally only those species with primarily medicinal or poisonous functions are dealt with.

This compilation of the published data will be especially useful to researchers developing new drugs. It is more efficient to screen plants used in traditional medicine, as these yield a much higher output of interesting substances than plants sampled at random. This is why many pharmaceutical companies incorporate ethnobotanical information into their research and development programmes. Much knowledge still only exists as oral tradition and many species still need to be investigated to find out their constituents and biological effects.

Numerous plant species are used in traditional veterinary medicine. Most small farmers in South-East Asia rely on herbal medicines to treat their sick animals, since these are easily available and affordable. Written information on veterinary uses is scarce; most information is still transmitted orally.

1.1.3 Aromatic plants

Many kinds of aromatic plants are traditionally used medicinally, usually prepared as teas. The volatile components of essential oils are often present in the preparations and these are often thought to be responsible for the biological activity.

It was sometimes difficult to decide which species should be covered in Prosea 12: 'Medicinal and poisonous plants', Prosea 19: 'Essential-oil plants', and Prosea 13: 'Spices' (the latter includes numerous aromatic plants). Wherever possible it is tried to avoid an overlap in the species treated in these 3 volumes, with the result that the final choice is somewhat subjective. Furthermore, though lower plants (fungi, algae, mosses, lichens and ferns) are sometimes also used medicinally, they have not been included in this volume, even when they have no other use; instead, they appear in Prosea 15: 'Cryptogams'. Several plant species used medicinally also produce dyes or tannins, and are treated in Prosea 3: 'Dye and tannin-producing plants'.

1.1.4 Poisonous plants used as medicine and pesticide

Only those poisonous plants used medicinally or as pesticides are dealt with in this volume. The pests that plant extracts can be used against are rodents, birds, insects, molluscs, nematodes, fungi, bacteria, algae, viruses and weeds. The preparations used to protect against these pests are known respectively as rodenticides, avicides, insecticides, molluscicides, nematicides, fungicides, bactericides, algaecides, virucides and herbicides. Though traditional applications of pesticides of plant origin were gradually ousted by chemical pesticides, there has recently been a resurgence of interest in plant-based pesticides. This is partly because chemical pesticides have been found to have disadvantages, including being health hazards to farmers and consumers. Furthermore, there is concern about the accumulation of residues in soil, groundwater and animals, and the build-up of resistance in pests. In contrast, plant-based pesticides are usually not accumulative, so are environmentally benign. Moreover, they are often highly selective, their toxicity to non-target mammals is usually low, and pests do not appear to develop resistance to them because these pesticides contain many active ingredients, even when derived from a single plant source (Chomchalow in Chomchalow & Henle, 1993). Examples of plant species used as a source of plant-based pesticides are neem (*Azadirachta indica* A.H.L. Juss.), derris (*Derris elliptica* (Wallich) Benth.), turmeric (*Curcuma longa* L.) and citronella (*Cymbopogon nardus* Rendle). However, because plant-based pesticides are so biodegradable they are rather unstable, which means that they have a short shelf-life, must be used soon after preparation, and have low persistence after application. Many plant-based pesticides are made domestically and more cheaply than chemical pesticides. Since only crude extracts are used to make them, such pesticides are definitely much less effective than chemical pesticides that have been formulated and purified to a high concentration.

1.2 How the medicinal and poisonous plants have been grouped

In 1996 a Prosea Task Force on Medicinal and Poisonous Plants was appointed to delineate the large commodity group and to propose how this group could best be dealt with in the Prosea handbook. The Task Force, which consisted of L.S. de Padua (University of the Philippines, chairwoman), R.H.M.J. Lemmens (Prosea Publication Office, the Netherlands, secretary), N. Wulijarni-Soetjipto (Prosea Network Office, Indonesia), N. Bunyapraphatsara (Mahidol University, Thailand), A.M. Latiff (Universiti Kebangsaan, Malaysia), Nguyen Tien Ban (Institute of Ecology and Biological Resources, Vietnam), Sjamsul Arifin Achmad (Institut Teknologi Bandung, Indonesia), R.P. Labadie (Utrecht University, the Netherlands) and D.K. Holdsworth (Norwich, United Kingdom) presented its report in March 1996.

It proposed that Prosea 12: 'Medicinal and poisonous plants' should consist of three parts, published separately. The three parts would essentially reflect the importance accorded to the species: the most important species would be treated in part 1, the least important ones in part 3. In spite of its shortcomings, this approach has important advantages over alphabetical treatment: it enables important and well-known medicinal and poisonous plants to be dealt with in greater detail than unimportant and lesser-known ones, and allows for any omissions from the first two parts to be made good in the third part. Preliminary lists for the 3 parts were drawn up more or less subjectively, based on existing handbooks on medicinal or useful plants for South-East Asia like Burkill (1966), Dharma (1981), Heyne (1927), Holdsworth (1977), Nguyen Van Duong (1993) and Quisumbing (1978). The list was finalized after being critically reviewed by the members of the Task Force.

The plants in Prosea 12: 'Medicinal and poisonous plants' are dealt with primarily by genus rather than by species. This is because the properties of different species within one genus and hence their uses are often similar. Furthermore, the genus approach reduces the large commodity group to manageable proportions. After each genus description, selected species are described briefly. If only one species of a genus is important in South-East Asia, however, it is dealt with as a species.

1.3 Role of medicinal and poisonous plants

Since time immemorial people have used plants and other materials that were not part of their usual diet to treat illness. They arrived at these treatments by trial and error and accumulated tradition and experience. All cultures have long histories of the use of plants in folk medicine, recorded in ancient herbals from which most of the present-day pharmacopoeias have been derived. Archaeological evidence for the use of herbal remedies goes back 60 000 years: in a Neanderthal cave burial site, excavated in Iraq in 1960, pollen from 8 plant species was found around human bones. These plants were evidently intentionally collected and placed there; 7 of them are medicinal plants still used today.
In the last 30 years there has been a resurgence of interest in the use of plants as medicines. However, although the world population is increasing and plant-rich habitats such as the tropical forests are dwindling steadily (Latiff, 1991) there appears to be no concerted effort in research and conservation. The renewed interest in medicinal plants is also clearly noticeable in South-East Asia and has resulted in research and development programmes in several countries, and also in joint efforts such as the Asian Network on Medicinal and Aromatic Plants (ANMAP).
Forests have long been regarded primarily as a source of timber, but now the value of non-wood forest products is becoming increasingly appreciated. Medicinal plants are important non-wood forest products and should therefore be a priority in forest protection measures. It is therefore gratifying that biodiversity prospecting and its policy implications for medicinal plants are now recognized as an important issue in conservation.

1.3.1 Traditional and modern medicine in South-East Asia

Below, the history, status and role of medicinal plants is described briefly for each country in South-East Asia; likely future developments are also noted. For practical reasons (the cross-border distribution of ethnic groups) the islands of Borneo and New Guinea are treated separately instead of under Malaysia, Brunei, Indonesia and Papua New Guinea.

Indonesia

The traditional use of plants for healing in Indonesia dates back to prehistoric times. The art and knowledge of the uses of plants as medicine have been handed down orally from generation to generation. Some plants still used in traditional medicine can be found depicted in reliefs on the walls of ancient temples in Java, such as those of Borobudur, Prambanan, Penataran and Sukuh. They include *Aegle marmelos* (L.) Correa, *Antidesma bunius* (L.) Sprengel, *Borassus flabellifer* L., *Calophyllum inophyllum* L., *Datura metel* L. and *Syzygium cumini* (L.) Skeels.
The earliest written references to the local uses of plants in Indonesia are in the early 16th Century reports of Portuguese explorers. The first endeavour to gather data on Java's medicinal plants was by Bontius (1658). His work includes some 60 plates of plants with descriptions of their healing powers and uses. Rumphius's work ('Herbarium Amboinense', 1741–1755), a special study

of the flora of Ambon (Moluccas) was more important. It describes hundreds of plants, giving extensive details on their medicinal use and properties. Horsfield (1816) published one of the first monographs on the medicinal plants of Java.

Many publications on medicinal plants appeared in the 19th and early 20th Century. Of these, Greshoff's publications (in the period 1890–1914) focused mainly on poisons but also included plants with medicinal properties. Kloppenburg-Versteeg (1907, 1911) wrote books in Dutch, giving hints and advice on using Indonesian plants. The second edition of Heyne's book on the useful plants of Indonesia (1927) gave extensive information on the medicinal uses. Since then, numerous papers and books have been published on the medicinal plants of parts and islands of Indonesia, but these usually either relate to one or a few species, or summarize recorded traditional uses in a confined region (e.g. Avé & Sunito (1990) for Siberut and Bell & van Houten (1993) for Central Seram). There have also been some books dealing summarily with larger numbers of medicinal plants from Indonesia, e.g. Kasahara & Hemmi (1995) and Syamsuhidayat & Hutapea (1991).

In rural areas, 'dukuns', i.e. persons with putative expertise in medical matters and who use medicinal plants in their preparations, still play an important role in primary health care. So-called 'jamus' – complex mixtures of herbs – are still widely and commonly used in Java. The ingredients are well pounded and mixed, and steeped in hot water. Alternatively, they may be dried, and then boiled when required, to yield a decoction for use. Jamus may be preserved in powder form, after drying over heat in an iron pan. Most jamus have a long history of traditional use and some have been tested empirically and shown to be effective. However, they are often not used as medicine for a given disease but to keep the body healthy, in a holistic approach. Sometimes they are used for cosmetic purposes. It is often recommended to take jamus regularly. The composition of a jamu used to treat a certain disease and having a certain standard name may vary, depending on the custom or view of the person preparing the mixture. Jamus are in general prepared and traded by women from Central Java, whose good healthy complexions advertise the efficacy of their products. Some jamus are given to livestock. It is estimated that 1000–1300 plant species are used in the preparation of jamus. Most of these are collected from the wild.

Manufactured products are also widely available over the counter throughout Indonesia. Jamus produced industrially have also been exported from Indonesia for a number of years in the form of powders and tablets. The knowledge on medicinal plants and jamus has been kept in families in the form of hand-written records. The original manuscript on Javanese traditional medicine, called 'serat kawruh bab jampi-jampi Jawi' and written around 1831 was kept in the library of the Surakarta Palace. It contains 1166 prescriptions, 922 of which are jamu preparations.

Research on medicinal plants has been conducted in Indonesia for more than 50 years. The studies have included the collection of samples, the inventory of genetic resources, ethnobotany, biotechnology, agronomy, chemical properties, pharmacological and toxicological screenings, product standardization, formulation and plant conservation. Several institutes working on medicinal plants have been established since 1950, as well as working groups and committees. Numerous scientific meetings have been organized on the subject.

Recent developments point to an increased interest in medicinal plants. A national working group on medicinal plants was established in 1990 as a follow-up to a national seminar. To promote the development and socialization of the use of medicinal plants, the Ministry of Health has issued lists of recommended medicinal species to be planted in family gardens. Gardens with medicinal plants have been established throughout the country. Various institutions have made a germplasm inventory of medicinal and aromatic plants (Wahid in Chomchalow & Henle, 1993).

Peninsular Malaysia

Traditional medicine has been important to Malaysians of all ethnic groups for centuries. The influence of the cultures of China, India and Java is strong. For instance, almost all the medicinal products sold in the Chinese community are imported from China, and the influence of Javanese medicine is still important among the local Javanese communities in Selangor. The classic work by Burkill (1935) is still the standard reference for traditional medicine.

Much of the knowledge on traditional medicine still dominant in the culture of various ethnic groups is unrecorded, and handed down from one generation to the next. The practitioners of traditional Malay medicine have vast knowledge about the identification and classification of plants, folk nomenclature and, above all, the medicinal properties. This knowledge has not yet been tapped systematically to develop medicines based on traditional remedies (Latiff, 1991). However, since 1981 researchers at the University Kebangsaan Malaysia have conducted many multidisciplinary projects on medicinal plants. Although the cultivation of medicinal plants was advocated to ensure a continuous and reliable supply of products for local consumption or export, no large companies have shown interest; small-scale cultivation for local consumption or sale has started, however (Latiff, 1991).

The approaches summarized by Latiff (1991) as being vital for future research in traditional medicine in Malaysia remain valid today. They are:

- An inventory and therapeutic classification of the medicinal plants used.
- The development of scientific criteria and methods for assessing the safety of medicinal plant products and their efficacy in the treatment of diseases.
- The introduction of national standards and specifications for identity, purity, strength and manufacturing practices.
- The designation of research and training centres for the study of medicinal plants.

Borneo

The original inhabitants of Borneo were probably the forest dwelling Punan people. Other groups, such as the Iban, immigrated over the centuries. In more recent history, Malay people have immigrated to coastal areas, followed by Chinese settlers later. The traditional medicine of these peoples of Borneo reflects their origins.

Many Chinese inhabitants of Borneo use imported dried herbs packaged in China, which have often been recorded as Chinese herbal medicine for several thousand years. These are supplemented to some extent by local plants. There are Chinese medicine shops in most coastal towns in Borneo. Malays recognize the similarities of the flora of Borneo and Peninsular Malaysia. Malay traditional medicine has only been recorded in this century.

Many of the non-Chinese people of Borneo have a tradition of a 'bomor' or 'shaman': persons who have accumulated the medicinal lore of their people, who are regarded as healers. These persons may still use incantations, invoke animistic spirits in trances and be well versed in local superstitions and native psychology. Above all, they use plants either from the rain forest or cultivated in their garden. In contrast to Chinese herbal medicine the plants used are invariably collected fresh and used externally or internally as decoctions. Though Malay medicine is similar in origin, it has been modified by the influence and teachings of Islam.

Until very recently, there have been few studies of the traditional medicine of the indigenous tribal peoples of Borneo. This still represents a challenge to botanists, pharmacologists, pharmacognosists, anthropologists and phytochemists. There were some studies of traditional medicine done by Dutch explorers when Indonesia was still a Dutch colony, but these were almost exclusively confined to the economically more important islands of Java and Sumatra. The difficulties of learning the languages of the people of Borneo contributed to the general lack of scientific studies. In the early 1990s, some inventories and bio-assay screening of medicinal plants used by the Kenyah Dayak people, under the auspices of World Wide Fund for Nature, resulted in a publication (Leaman et al., 1991).

The same might be said of British explorers in the former British colonies of North Borneo (present-day Sabah) and Sarawak. Traditional medicine was of little interest when western drugs and quinine could be imported. The establishment of the Sarawak Museum in Kuching led to an interest in ethnic cultures and in the medicinal properties of indigenous plants associated with these cultures. Recently some research has been done by the Sarawak Forest Department (unpublished), and a publication by Ahmad & Holdsworth (1994) is available. For Sabah, there are two recent publications by Ahmad & Holdsworth (1994, 1995). In Brunei some interest in publishing data on medicinal plants began in the early 1990s. There are several recent publications on the medicinal plants of Brunei (Holdsworth, 1991; Mohiddin, Wong Chin & Holdsworth, 1991, 1992). Recent studies by the staff of the Herbarium Bogoriense resulted in seminar reports on medicinal plants of Kalimantan in 1995. The increased cooperation of nations in the area should result in future joint studies of the medicinal plants and plant lore in different areas of Borneo.

New Guinea

There is a rich heritage of traditional knowledge on the use of plants as medicines in New Guinea. The first New Guineans, who possibly arrived from South-East Asia and settled some 60 000 years ago, may have brought medicinal plants with them, or the knowledge of how to use the familiar plants they found on arrival. This would have been followed over thousands of years by systematic trial and error experimentation in the coastal and highland areas. Plants that had effective medicinal properties would be used again, and in this way a local tribal pharmacopoeia would be built up.

A few scattered records of medicinal plants were made by explorers and botanists in Dutch, German and Australian New Guinea at the beginning of the 20th Century. The first collection of some importance was that of Father Futscher, a Catholic priest on New Britain in the 1950s. He collected about 80 plant species used as medicine, noted the local Kuanua language names and tried to identify the plants. The results were published in German in 1959. In the early 1970s many plants from Papua New Guinea were tested in the Chemistry Department of the University of Papua New Guinea (Port Moresby) for the presence of alkaloids. In 1973 it was decided to concentrate on testing traditional medicinal plants. It was shown that these plants – particularly those used internally to treat malaria and fevers – were more likely to contain alkaloids than plants chosen randomly. The medicinal plants collected were identified at the Papua New Guinea National Herbarium at Lae. In over 20 years of fieldwork, Holdsworth collected several thousand specimens of medicinal plants in many different areas of Papua New Guinea; their uses were noted, and the plants were identified, mainly at the PNG National Herbarium in Lae. To date, the survey has yielded over 600 species of medicinal plants. It is interesting to crosscheck the medicinal uses of the plants in different areas of New Guinea (with its numerous languages and consequently little exchange of information between tribal communities) and other tropical countries, by studying the available literature. A first survey was published in 1977 (Holdsworth, 1977), and a more complete overview is in preparation.

In New Guinea, fresh plant material is invariably used for medicinal applications. One plant is often used alone, and sap from its leaves or bark is drunk, or rubbed on the body. Decoctions of bark, twigs or fresh leaves are also drunk. Many traditional medicines have a strong or bitter taste, which suggests that they contain alkaloids, although other substances might account for this taste too. A healer may also choose plants for a treatment based on the Doctrine of Signatures, a practice favoured by many mediaeval physicians.

Traditional beliefs are strong in rural areas throughout New Guinea and healing methods that use medicinal plants are still widely practised. Most tribes have a traditional healer who has been trained by an elder close relative in the uses of certain effective and secret medicinal plants. Often the healer was regarded as a sorcerer and practitioner of traditional medical psychology. Papua New Guinea is currently experiencing rapid changes. Young men and women leave their villages to attend school and to seek employment in towns. They are not available to learn the traditions and medicinal knowledge of their relatives and ancestors, so many traditional customs and practices are disappearing in village communities or are being replaced. The demonstrative effectiveness of a shot of antibiotics and other modern medicines at the first aid post, health clinic or hospital has reduced reliance on plant medicines and is accelerating the disappearance of traditional medical practice in many areas. It is essential to record the traditional uses of medicinal plants before they are lost forever.

The Philippines

Plants have played an important role in traditional medicine in the Philippines since ancient times. When the Spaniards colonized the Philippines in 1521, they were suprised to find many medicinal plants. It is possible that Chinese traders who came to the Philippines before the Spaniards introduced their herbal medicines and traded them with the Filipinos for other goods. Several manuscripts written during the Spanish regime (1521–1898) survive; well known among these are Father Blanco's 'Flora de Filipinas' (1737), and 'Plantas Medicinales de Filipinas' by Trinidad Pardo de Tavera (1892). Much research on medicinal plants was conducted in the years of American occupation (1898–1935) at the University of the Philippines and at Government Laboratories, now the Department of Science and Technology. Guerrero led these scientific activities, and working with him were scientists such as Merrill, Brown, Elmer, Sulit, Valenzuela, Maranon, Santos, Concepcion and Quisumbing, all well known in the field of medicinal plants. It was during this period that Brown's 'Useful plants of the Philippines' and Quisumbing's 'Medicinal plants of the Philippines' were written, surveys were extended to unexplored regions and chemical analyses and clinical investigations were done. During the Second World War, Filipinos depended entirely on plants as sources of medicines, and came to realize not only that the Philippines abounds with a wide variety of medicinal plants, but also that research on these plants was still much needed.

Medicinal plants are part of the cultural heritage and the 'herbolario' (herb doctor) is a respected member in his community. The 'herbolario' and the 'hilot' (midwife) are traditional practitioners who learn and pass down their craft from generation to generation. They use plants for the treatment of diseases and to relieve pain and physical suffering. Traditional practice was coupled with native beliefs and superstition. The common belief was that disease is due to the presence of evil spirits in the human body which could only be removed by using some bitter-tasting substances, usually derived from plants. Although the practice of the traditional practitioners was empirical in nature, most of the original information on drug-producing plants was derived from them and forms the basis for recent scientific studies and for the present research and development programmes on medicinal plants.

When modern western drugs became available, many Filipinos, especially those in the urban centres, lost touch with their herbal heritage. It became very difficult for herbalists and researchers on medicinal plants to attract interest and support for their work, particularly for the wide acceptance of the use of these plants. The persistence and dedication of Filipino scientists to the efforts of providing adequate health care to poorer sectors of the population through intensive research and dissemination of information have brought about major changes in attitudes and in the health care system. Many western-trained doctors now prescribe herbal medicines for their patients, and medicinal plants continue to provide basic and alternative health care to the Filipino people, particularly in remote areas and islands where the lack of medicines is critically felt. As in most developing countries, herbal medicines still play a major role, with more than 80% of the population using herbal remedies. Dosage forms such as tablets, capsules, syrups, ointments, liniments, tinctures, lozenges, lotions and herbal teas are available, and herbal soaps, shampoos and other body care products are popular. Some of these products are even exported. Remarkable progress and new developments have taken place in recent years, strengthened by the active participation of government and private agencies. Some pharmaceutical companies have expanded into herbal medicines and body care products, and the government has established 4 factories in different regions to manufacture herbal medicines. As a result of intensive research, several medicinal plants are being promoted for use and cultivation in the countryside. Dissemination of information about medicinal plants and herbal products is actively pursued through publications, presentations, seminars, training programmes, exhibitions and educational displays. Many publications are available on Philippine medicinal plants, e.g. 'the National Formulary' by Concha (1978), 'the Guidebook on the proper use of medicinal plants' by Maramba, and the four volumes of 'the Handbook on Philippine medicinal plants' by de Padua, Lugod & Pancho. The population now has access to safe, effective and affordable herbal medicines, and meanwhile there is renewed and accelerating interest in the industrialization and exploitation of Philippine medicinal plants.

Thailand

Medicinal plants have constituted an important part of Thai traditional medicine since that system of medicine, which was adapted from the Ayurvedic system incorporating Thai culture and tradition, was introduced 700–1000 years ago. The earliest knowledge is not well documented, as only a few prescriptions survive. The system of traditional medicine was revised and compiled during the reigns of Kings Rama I and II of Ratanakosin in the 18th and early 19th Century. The prescriptions were recorded on the stone plaques and walls of the Wat Poh temple. Under King Rama V (1868–1910) the royal prescriptions were again compiled, revised and published, and this served as the basis for the Thai traditional medicine of today.

The use of medicinal plants fell sharply when western drugs became available. It is difficult to reverse the decline, because the texts on traditional medicine are too vague. Most of the texts contain the name of the plants, their indications and recipes, but lack detailed information on the preparation. This is probably because traditional doctors jealously guarded their knowledge. Most of the recipes are composed of many ingredients, and each ingredient is added for a specific purpose. At present, most doctors are trained in western medicine and the health care system relies almost totally on imported western drugs. This leads to the following problems:

- A large amount of foreign exchange is lost.
- The drugs are too expensive for people with low incomes.
- The ease of using modern medicines allows abuse.
- A shortage of drug supplies may arise in times of civil unrest.
- The government cannot provide equal health care between rural and urban areas, especially in terms of drug supply.

These problems prompted the government to consider revitalizing the use of local medicinal plants. The first development plan was set up in 1982. Studies by the Faculty of Pharmacy of the Mahidol University suggested that medicinal plants should be developed for use in primary health care, for the pharmaceutical industry and for export. Of these, the development for primary health care has been most successful, with about 55 plant species being promoted for use. The use of single species of plants was investigated, to make it easier to determine or trace the cause of any adverse effect that might occur.

The plants were selected carefully, using the following criteria:
- Only species for which there is scientific evidence of beneficial activity are selected, and only those with pharmacologically confirmed efficacy are recommended for use in primary health care.
- The plants must have passed toxicity tests, including mutagenic and teratogenic tests, or must also be used as food.
- The plants are used to treat symptoms for which self-diagnosis is possible.
- The method of preparation is simple.
- The plants are locally available, so as to ensure year-round supply.

Health workers were trained in the proper use of medicinal plants and their cultivation, and are responsible for encouraging their use at village level. The programme of developing medicinal plants for primary health care was successful in rural areas where there is no easy access to drugstores and hospitals. At present the government is preparing to add some medicinal plants to the national list of essential drugs. It is also drawing up good manufacturing practices for the factories preparing traditional medicine, to improve the quality of herbal drugs.

Development for export is progressing slowly, because there is no large-scale cultivation technology and also because of the rapid change in world demand. Medicinal plants are recommended as catch crops. Many of them can be grown in areas where the more common commercial crops cannot be cultivated, and they can play a role in forest conservation.

Vietnam

Up until the 18th Century the history of the Vietnamese traditional medicine, which goes back more than 2000 years, is interlarded with the names of famous physicians such as Tue Tinh (14th Century). Only two books from this period have survived: 'Nam Duoc Than Hieu' ('The miraculous effect of traditional medicine'), which includes 580 ingredients of traditional medicine, and 'Hong Nghia Giac Tu Y Thu' ('Hong Nghia's summary of using traditional medicine'), which covers 600 ingredients. In the 18th Century, Le Huu Trac added another 330 ingredients to the former book, and published it as 'Linh Nam Ban Thao' ('Linh Nam's traditional medicine book'). This formed the basis for traditional medicine in Vietnam. Since the beginning of the 19th Century there have been many publications on Vietnamese medicinal plants.

Since the mid-1950s, the Vietnamese government has stimulated research on medicinal plant resources for use in primary health care. From 1960 to date, over 200 species of medicinal plants have been commercialized. The plants are collected from natural resources or from cultivation in quantities in excess of 100 000 t/year. Most of them are used in traditional medicine forms such as pastes, powders, pills and liquids, but some plant compounds are extracted industrially, the total quantity being over 2000 t/year. The number of research and development institutes dealing with traditional medicine is increasing, as is their input, and the availability of experienced physicians is further helping increase the popularity of traditional medicine. The Vietnamese system of traditional medicine has contributed greatly to community health care.

1.3.2 Production and trade

Statistics on international trade usually refer to commodity groups. Exact figures for individual plant drugs can be obtained for only a few cases. Often it is not even possible to distinguish between medicinal plants used in the pharmaceutical industry and plant species used in other industries. Medicinal and aromatic applications are lumped together (e.g. *Piper nigrum* L., *Zingiber officinale* Roscoe). According to trade figures of the United Nations Conference on Trade and Development, the international trade in plant-based drugs has a value of US$ 800 million annually, on average. China is by far the leading country: between 1992 and 1995, its average annual exports were more than 120 000 t, with a value of over US$ 250 million. India followed (33 000 t, US$ 46 million), and then Germany (14 000 t, US$ 68 million). Singapore exports the largest amount of plant-based drugs of the South-East Asian countries: 13 200 t annually with a value of US$ 54 million in the period between 1992 and 1995. Thailand is also amongst the top 12 countries in the world: its annual exports are 3300 t, with a value of US$ 7 million (Lange & Schippmann, 1997). The export value of Indonesian medicinal plants amounted to just US$ 2 million in 1991, whereas the internal market was worth US$ 45 million. The major countries importing plant-based drugs are Hong Kong (China) with 77 000 t worth US$ 134 million annually between 1992 and 1995, Japan (43 000 t, US$ 114 million) and Germany (43 000 t, US$ 96 million). Singapore is market leader in South-East Asia with an average annual import of 7300 t and a value of US$ 36 million.

However, the trade in medicinal plants is vast and largely unmonitored. Moreover, most people in developing countries depend on the direct use of plants for their health care, and thus the total trade in plant-based medicines may be a hundred times more than the volume of the international trade.

1.4 Phytochemistry

Phytochemistry deals with the chemistry of plant metabolites and their derivatives. The metabolic system of a plant may be regarded as being constituted of regulated processes within which biochemical conversions and mass transfer take place. Our understanding in this field has advanced to a stage in which definite metabolic processes, biosynthetic pathways and their interconnection are distinguished and studied in the context of their function and genetic control.

The metabolic performance of living organisms can be distinguished into primary metabolism and secondary metabolism. Primary metabolism is associated with fundamental life processes common to all plants. It comprises processes such as photosynthesis, pentose cycle, glycolysis, the citric acid cycle, electron transport, phosphorylation and energy regulation and management. Primary metabolites are produced and converted molecular entities, that are needed in anabolic pathways to build, maintain and reproduce the living cell. In catabolic pathways, primary metabolites (and food products) provide the chemical energy and precursors for biosynthesis.

Primary and secondary metabolism are interconnected in the sense that the biosynthesis of accumulating secondary metabolites can be traced back to ubiquitous primary metabolites. However, in contrast to primary metabolites, secondary metabolites represent features that can be expressed in terms of ecological, taxonomic and biochemical differentiation and diversity. The biosynthesis and accumulation of secondary metabolites provide a basis for biochemical systematics and chemosystematics. In addition, the wide molecular diversity of secondary metabolites throughout the plant kingdom represents an extremely rich biogenic resource for the discovery of novel drugs and for developing innovative drugs. Not only do plant species yield raw material for useful compounds; the molecular biology and biochemistry provide pointers for rational drug development.

Primary and secondary metabolites can be classified on the basis of their chemical structure into much the same categories of chemical compounds: carbohydrates, lipids, amino acids, peptides, proteins, enzymes, purine and pyrimidine derivatives. Within such compound classes, secondary metabolites generally show greater individuality and diversity in their molecular structure than primary metabolites. On the other hand, certain compound classes appear to be extraordinarily rich in secondary metabolites. Examples are the structurally diverse groups of alkaloids, phenolics, acetogenins and terpenoids. Ubiquitary primary metabolites belonging to these compound classes seem to be restricted to only a limited number of key compounds functioning as biosynthetic precursors.

Most of the plant compounds that have been found to be medicinally useful and interesting tend to be secondary metabolites. Nonetheless, the discussion of compound classes that follows has been arranged according to chemical structure classes usually clustered as such.

1.4.1 Carbohydrates

The first products plants produce by photosynthesis are carbohydrates. They are formed from water and carbon dioxide and can be grouped into sugars and polysaccharides. The sugars are either monosaccharides such as glucose and fructose, or oligosaccharides containing up to 5 or 6 monosaccharide units. Monosaccharides are classified according to the number of carbon atoms they contain; thus, trioses, tetroses, pentoses, hexoses and heptoses are C_3 to C_7 compounds. The polysaccharides are macromolecules, containing a large number of monosaccharide residues.

Carbohydrates constitute a large portion of plant biomass, e.g. cellulose as part of the cellular framework, and starch as a food reserve.

Sugars can unite with a wide variety of compounds to form glycosides, increasing the water solubility of the compounds. Glycosides vary in chemical stucture and pharmacological activity due to their aglycone component.

In addition to their use as bulking agents in pharmaceuticals, carbohydrates have recently been recognized to have useful pharmacological properties. Several polysaccharides exhibit immunomodulatory, antitumour, anticoagulant (e.g. heparin), hypoglycaemic or antiviral activities. The various carbohydrate products traded include fibre, cellulose and its derivatives, starch (glucose polymers) and its derivatives, dextrins, fructans (fructose polymers; e.g. inulin), algenic acids, agar and gums.

1.4.2 Lipids

1.4.2.1 Vegetable oils

Vegetable oils are major sources of β-sitosterol, which is a steroid drug precursor. One vegetable oil, obtained from groundnut, yields lecithins, which are used to enhance food digestibility. Lecithins are also used in pharmaceutical formulations. Recently, some vegetable oils have been found to be rich in γ-linolenic acid (see Figure 1), which is the precursor of prostaglandins, leukotrienes and thromboxanes. All these compounds are involved in platelet aggregation and inflammatory processes. Only members of *Onagraceae*, *Saxifragaceae* and *Boraginaceae* contain γ-linolenic acid.
Vegetable oils are significant in both the food and pharmaceutical industries. Some are used as solvents for lipid-soluble drugs such as vitamins and antibiotics. Others, e.g. almond oil and olive oil, are used in cosmetics. Castor oil is well known for its purgative activity, but has fallen out of favour because of its unpleasant taste.

1.4.2.2 Acetogenins

Acetogenins are long-chain aliphatic compounds with 35–39 carbon atoms, ending with a γ-lactone, most often unsaturated and cyclized into one or two tetrahydrofuran rings that may or may not be adjacent. They are characteristic of *Annonaceae* (e.g. *Annona*, *Goniothalamus*, *Rollinia* and *Uvaria*). The potential application of acetogenins is linked to their antitumour (e.g. asimicin, bullatacine), antibacterial (e.g. cherimolin) and insecticidal (e.g. asimicin, annonin, annonacin) properties. See Figure 2 for the structure of annonacin, as an example of an acetogenin.

1.4.3 Amino acids and their derivatives

Amino acids are constituents of peptides, proteins and enzymes, but also the precursors of a large variety of secondary metabolites including alkaloids and phenolic compounds, which are both discussed separately.

1.4.3.1 Amino acids

The function of amino acids is not only for protein synthesis; they are also considered to be a form of nitrogen storage (e.g. cannovanine, hemoarginine) and a germination inhibitor. The few studies of the pharmacological activities of amino acids include reports of curcubitine being used as taeniacide. Many toxic amino acids have been identified; examples include β-(γ-L-glutamylamino)proprionitrile and γ-N-oxalyl-L-α,β-diaminoproapionic acid which are responsible

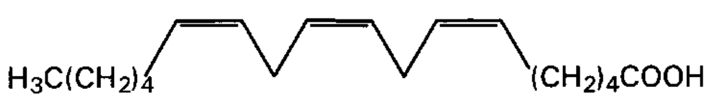


Figure 1. Structure of γ-linolenic acid.

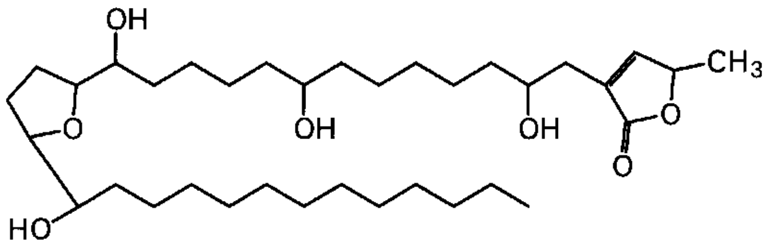


Figure 2. Structure of annonacin.

for the toxicity of grass pea (*Lathyrus sativus* L.) that brings about osteolathyrism and neurolathyrism in livestock, and mimosine from *Leucaena* inhibiting protein and nucleic acid synthesis which results in livestock losing appetite and weight, and their growth being inhibited.

1.4.3.2 Cyanogenic glycosides

Cyanogenic glycosides are compounds derived from amino acids. Hydrolysis of these compounds by enzymes or acids yields hydrocyanic acid, a toxic principle. Biosynthetically, the aglycones of cyanogenic glycosides are derived from L-amino acids. Cyanogenic glycosides are prevalent in the families *Rosaceae*, *Leguminosae*, *Gramineae*, *Araceae*, *Euphorbiaceae* and *Passifloraceae*. Examples are linamarin, amygdalin and prunasin.

1.4.3.3 Sulphur-containing compounds

The sulphur-containing compounds of pharmaceutical significance are allein, allicin, ajoene and other related compounds isolated from garlic. Allicin and ajoene (the latter is a condensation product of allicin) exhibit many biological activities, including antihypercholesterolaemic, antiplatelet aggregation, antihypertensive, fibrinolytic and antifungal activities. Recently, diallyl cysteine, an odourless active ingredient of garlic, was found to be biosynthesizable.

1.4.3.4 Lectins

Lectins are proteins or glycoproteins that are able to bind with the carbohydrate moiety on cell membranes in a specific and reversible fashion, without displaying enzymatic activity. Most lectins in higher plants are located in seeds. They are commonly found in legumes such as groundnut, soya bean and common bean.

Some lectins have the ability to agglutinate red blood cells of a specific blood group. These lectins are referred as phytohaemagglutinin. The haemagglutination activity is important in immunological studies. Some lectins are toxic, e.g. ricin from castor (*Ricinus communis* L.) seeds and abrin from jequirity bean (*Abrus precatorius* L.) seeds.

1.4.3.5 Enzymes

Plant-derived enzymes used as drugs include papain and bromelein. Both are proteolytic enzymes useful as an anti-inflammatory drug. Ficin has similar properties.

1.4.4 Alkaloids

It is not easy to define the term 'alkaloid' precisely, since there is no sharp border between alkaloids and naturally occurring complex amines. At present, the term is used for plant-derived compounds containing one or more nitrogen atoms (usually in a heterocyclic ring), and usually having a marked physiological action on humans or animals. The term 'proto-alkaloids' or 'pseudo-alkaloids' is sometimes applied to compounds that lack one or more of the properties of the typical alkaloids, e.g. the nitrogen in a heterocyclic ring system; examples include mescaline and ephedrine. To avoid problems with this common definition of alkaloids, some authors propose a more narrow definition: an alkaloid is a cyclic organic compound containing nitrogen in a negative oxidation state, which has limited distribution in living organisms.

Based on their chemical structures, alkaloids are divided into several subgroups: non-heterocyclic alkaloids, and heterocyclic alkaloids which are again divided into 12 major groups according to their basic ring structure. Figure 3 shows some examples; mescaline is an example of a non-heterocyclic or pseudo-alkaloid, tetrandrine of a bisbenzylisoquinoline alkaloid and solasodine of a triterpene alkaloid. Free alkaloids are soluble in organic solvents such as ether or chloroform. Alkaloids will furthermore react with acids to form water-soluble salts. There are a few exceptions to this general rule. In certain alkaloids, e.g. in ricinine, the lone pair of electrons on the nitrogen atom can be protonated. Another example is berberine, a quaternary ammonium alkaloid; the free base is already water-soluble. Physically, most alkaloids exist in solid form, but some are liquid, e.g. nicotine.

Alkaloids in plants are believed to be waste products and a nitrogen source. They are thought to play a role in plant protection and germination, and to be plant growth stimulants. Alkaloids are more common in dicotyledons than in monocotyledons; families rich in them are *Amaryllidaceae*, *Liliaceae* s.l., *Apocynaceae*, *Berberidaceae*, *Leguminosae*, *Papaveraceae*, *Ranunculaceae*, *Rubiaceae* and *Solanaceae*.

Many alkaloids are pharmaceutically significant, e.g. morphine as a narcotic analgesic, codeine in the treatment of coughs, colchicine in the treatment of gout, quinine as an antimalarial, quinidine as an anti-arrythmic and L-hyoscyamine (in the form of its racemic mixture known as atropine) as antispasmodic and for pupil dilation.

1.4.5 Phenols and phenolic glycosides

Phenols probably constitute the largest group of secondary plant metabolites. They range from simple structures with one aromatic ring to complex polymers such as tannins and lignins. Examples of phenolic classes of pharmaceutical interest are (1) simple phenolic compounds, (2) tannins, (3) coumarins and their

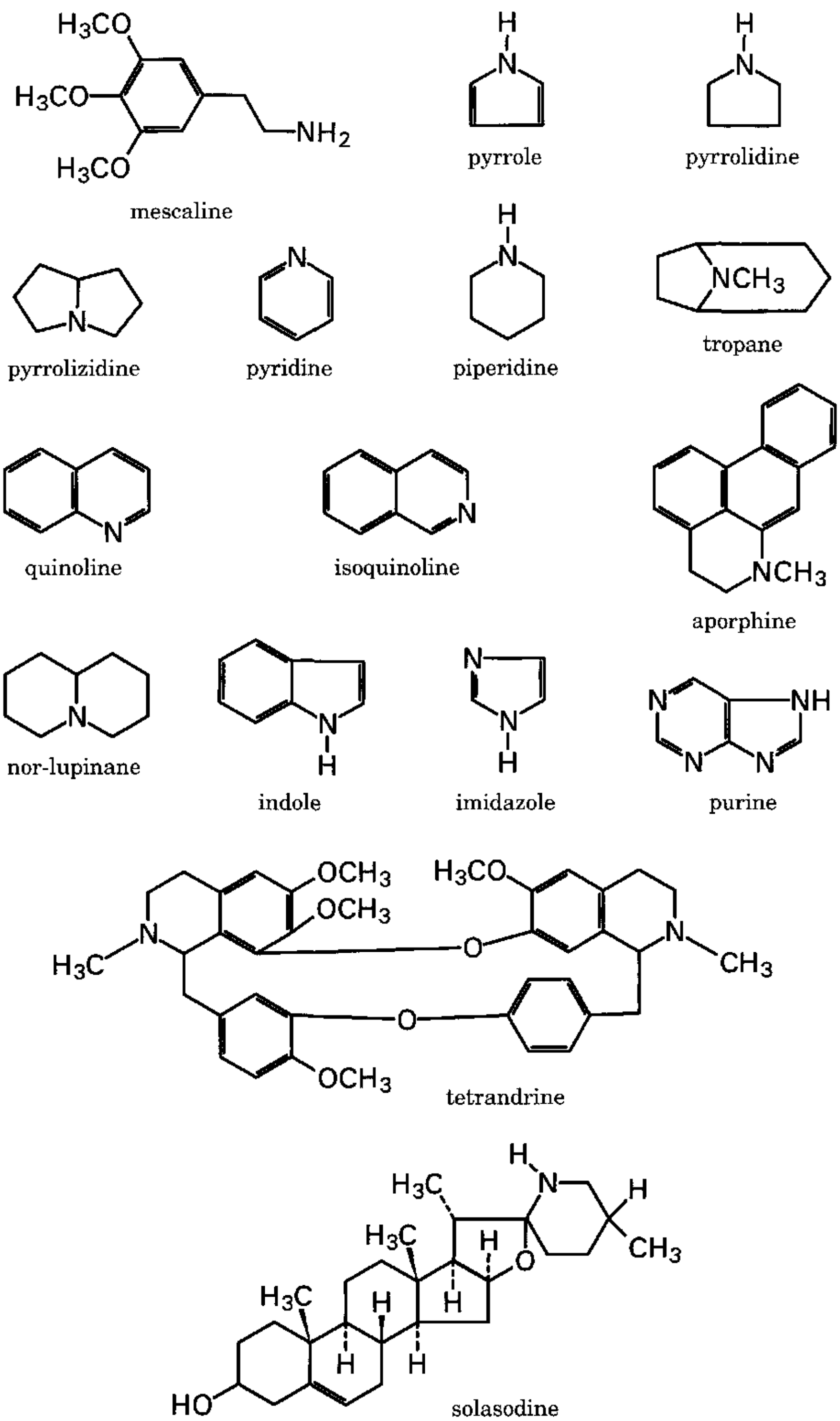
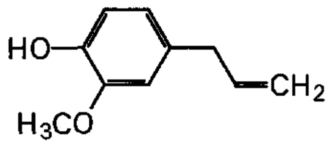
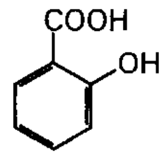


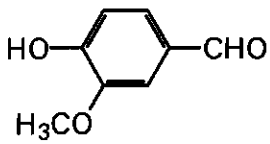
Figure 3. Alkaloids: basic structures and some examples.



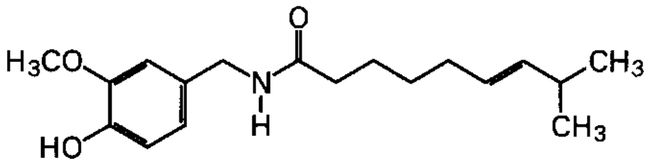
eugenol



salicylic acid



vanillin



capsaicin

Figure 4. Examples of simple phenolic compounds.

glycosides, (4) quinones, (5) flavonoids, (6) anthocyanins, (7) phloroglucinols, and (8) lignans and related compounds. These phenolic compounds are biosynthesized via the shikimic acid or acetate pathways.

1.4.5.1 Simple phenolic compounds

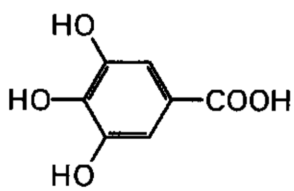
Compounds in this group have a monocyclic aromatic ring with an alcoholic, aldehydic or carboxylic group. They may have a short hydrocarbon chain. Figure 4 shows some examples; capsaicin is a vanillyl amide of isodecenoic acid. Eugenol is widely used in dentistry due to its antibacterial, anti-inflammatory and local anaesthetic activities. Vanillin is commonly used as a food flavouring. For salicylic acid anti-inflammatory properties have been reported. Capsaicin, a compound isolated from *Capsicum*, is now marketed as an analgesic.

1.4.5.2 Tannins

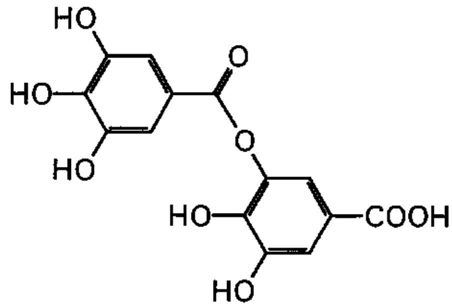
The chemistry of tannins is complex. The distinction made in the literature between hydrolysable tannins and condensed tannins is based on whether acids or enzymes can hydrolyse the components or whether they condense the components to polymers. Although not watertight, this distinction largely corresponds to groups based on gallic acid and those based on flavane-related components. Numerous vegetable tannins have been discovered, but only the major tanning constituents of the most important groups of tannins are listed here, i.e. the group of gallotannins and ellagitannins, and the group of proanthocyanidins. Gallotannins and ellagitannins are esters of gallic acid or its dimers digallic acid and ellagic acid with glucose and other polyols. Proanthocyanidins are oligomers of 3-flavanols (catechins) and 3,4-flavandiols (leucoanthocyanidins); see Figure 5 in which R = H or OH.

Tannins are able to react with proteins. On being treated with a tannin, a hide absorbs the stain and is protected against putrefaction, thereby being converted into leather. For more information, see Prosea 3: 'Dye and tannin-producing plants'.

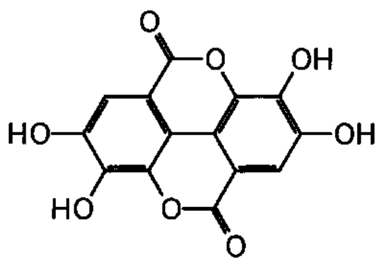
Though tannins are widespread in plants, their role in plants is still unclear. They may be an effective defence against herbivores, but it is likely that their major role in evolution has been to protect plants against fungal and bacterial attack. The high concentrations of tannins in the non-living cells of many trees (heartwood, bark), which would otherwise readily succumb to saprophytes, have been cited in support of this hypothesis. Some authorities consider tannins to be waste products, and it has also been suggested that leaf tannins are active metabolites used in the growing tissues. However, tannins in different plant species probably have different functions.



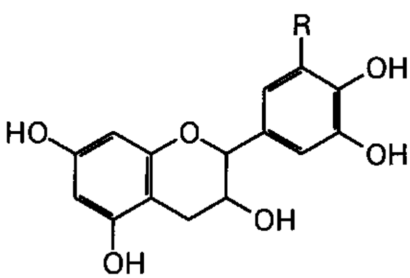
gallic acid



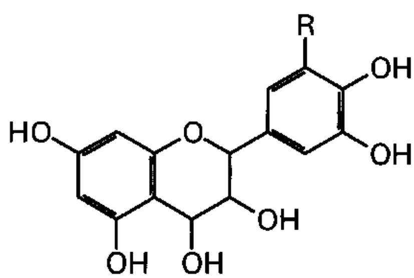
m-digallic acid



ellagic acid



3-flavanol



3,4-flavandiol

Figure 5. Structures of some tannins.

Tannins are used against diarrhoea and as antidotes in poisoning by heavy metals. Their use declined after the discovery of the hepatotoxic effect of absorbed tannic acid. Recent studies have reported that tannins have anti-cancer and anti-HIV activities.

1.4.5.3 Coumarins and their glycosides

Coumarins are benzo-α-pyrone derivatives that are common in plants both in a free state and as glycosides. They give a characteristic odour of new-mown hay and occur, for instance, in many *Leguminosae*. They are biosynthetically derived via the shikimic acid pathway. Figure 6 shows the structure of coumarin. Common derivatives are umbelliferone, herniarin, aesculetin, scopoletin, fraxin and chicorin.
The biological activities reported are spasmolytic, cytostatic, molluscicidal, antihistaminic and antifertility.

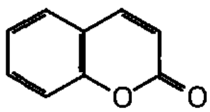


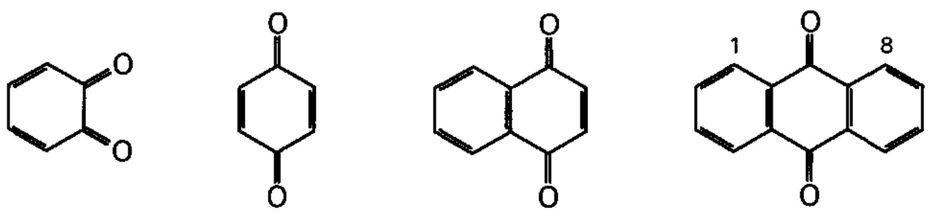
Figure 6. Structure of coumarin.

1.4.5.4 Quinones

Quinones are oxygen-containing compounds that are oxidized homologues of aromatic derivatives and are characterized by a 1,4-diketo-cyclohexa-2,5-diene pattern (paraquinones) or by a 1,2-diketo-cyclohexa-3,5-diene pattern (orthoquinones). In naturally occurring quinones, the dione is conjugated to an aromatic nucleus (benzoquinones) or to a condensed polycyclic aromatic system: naphthalene (naphthoquinones), anthracene (anthraquinones), 1,2-benzanthacene (anthracyclinones), naphthodianthrene (naphthodianthrone), pyrelene, phenanthrene and abietane-quinone. See Figure 7.
Naphthoquinones and anthraquinones have some importance medicinally; see below.

Naphthoquinones

Naphthoquinones are yellow or orange pigments from plants. Most are 1,4-



orthoquinone paraquinone 1,4-naphthoquinone 9,10-anthraquinone

Figure 7. Basic structures of some quinones.

naphthoquinones; 1,2-naphthoquinones are rarely found. Hydroxyl and methyl substitutions at C-2 are common. Biosynthetically, the naphtoquinones are almost exclusively derived via the shikimic acid pathway.
The occurrence of naphthoquinones is limited in fungi and sporadic in Angiosperms. They are found in species of the families *Bignoniaceae*, *Ebenaceae*, *Droseraceae*, *Juglandaceae*, *Plumbaginaceae*, *Boraginaceae*, *Lythraceae*, *Proteaceae* and *Verbenaceae*.
The pharmaceutical significance of this group of quinones is limited. Plumbagin exhibits antibacterial and cytotoxic activities. Lawsone from henna (*Lawsonia inermis* L.) is a powerful fungicide and hair colourant.

Anthraquinones

Anthraquinones are characterized by the presence of phenolic and glycoside moieties, derived from anthracene, and have a variable degree of oxidation. They have a common double hydroxylation in the positions 1 and 8 (see Figure 7). The glycosidic linkage may be C- or O-bonding. The anthraquinones are mostly biosynthesized via the acetate pathway, although some examples may be derived via the shikimic acid pathway.
Anthraquinones are found in species of the families *Rubiaceae*, *Leguminosae*, *Polygonaceae*, *Rhamnaceae*, *Ericaceae*, *Euphorbiaceae*, *Lythraceae*, *Saxifragaceae*, *Scrophulariaceae* and *Verbenaceae*. In monocotyledons, they are found only in *Liliaceae* s.l.
Anthraquinones isolated from plants with laxative activity include sennosides, aloins and emodin. The therapeutic use of anthraquinones as laxatives is very well recognized. The products are sold commercially. Common medicinal plants which contain anthraquinones are *Senna* and *Aloe* species.

1.4.5.5 Flavonoids

Flavonoids are the compounds responsible for the colour of flowers, fruits and sometimes leaves. Some, such as chalcones and flavonols, are yellow. The name refers to the Latin word 'flavus', which means yellow. Some may contribute to the colour by acting as co-pigment. Flavonoids protect the plant from UV-damaging effects and play a role in pollination by attracting animals by their colours.
The basic structure of flavonoids is 2-phenyl chromane or an Ar-C_3-Ar skeleton. Biosynthetically they are derived from a combination of the shikimic acid and acetate pathways. Small differences in basic substitution patterns give rise to several sub-groups; in the plant flavonoids can either occur as aglycones or as O- or C-glycosides. See Figure 8 for basic structures.
Recently, flavonoids have attracted interest due to the discovery of their pharmacological activities as anti-inflammatory, analgesic, antitumour, anti-HIV, antidiarrhoeal, antihepatotoxic, antifungal, antilipolytic, anti-oxidant, vasodilator, immunostimulant and anti-ulcerogenic. Examples of biologically active flavonoids are hesperidin and rutin for decreasing capillary fragility, and quercetin as antidiarrhoeal.

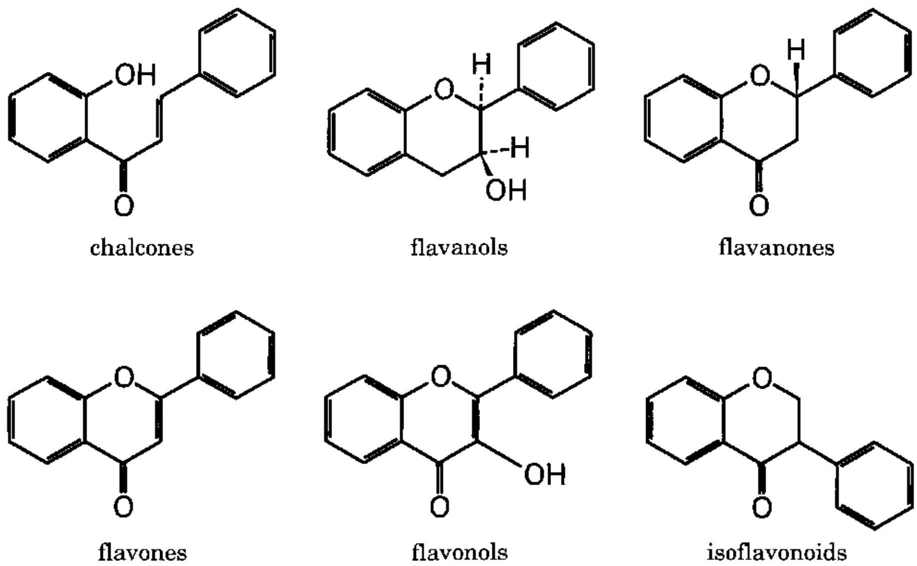


Figure 8. Basic structures of some flavonoids.

1.4.5.6 Anthocyanins

Anthocyanins are the compounds responsible for the red, pink, mauve, purple, blue or violet colours of most flowers and fruits. These water-soluble pigments occur as glycosides (anthocyanins sensu stricto) and their aglycone (anthocyanidins). They are derived from the 2-phenyl benzopyrylium cation, more commonly referred to as the flavylium cation. Cyanin (see Figure 9) is an example of an anthocyanin.

Anthocyanins are found in all Angiosperms, except for most species of the order *Caryophyllales*: only species of the families *Caryophyllaceae* and *Molluginaceae* contain them; in other families (e.g. *Chenopodiaceae, Cactaceae*), the pigmentation is due to betalains.

The application of anthocyanins is as food additive, e.g. in beverages, jams and confectionary products. The pharmacological activities are similar to flavonoids; for instance for decreasing capillary permeability and fragility, and as anti-oedema.

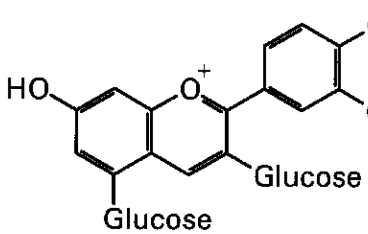


Figure 9. Structure of cyanin (cyanidin-3,5-diglucoside), as an example of an anthocyanin.

1.4.5.7 Phloroglucinols

Phloroglucinols are derivatives of 1,3,5-trihydroxybenzene, which e.g. are found in *Cannabis sativa* L., a well-known stimulant of the central nervous system.
Tetrahydrocannabinol and its derivatives influence behaviour, inducing euphoria and relaxation at low doses, but at higher doses, they may induce anxiety, sometimes to panic proportions. Sometimes hallucination and tinitus are observed. Other effects are bronchodilation and a lowering of intra-ocular pressure.

1.4.5.8 Lignans and related compounds

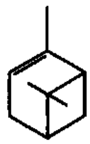
Lignans and related compounds are derived from condensation of phenylpropane units. Formerly, the term referred to compounds whose skeleton results from bonding between β-carbons of the side chain of two units derived from 1-phenylpropane (8-8' bond). Neolignans are also condensation products of phenylpropanoid units, but the actual bond varies and involves no more than one β-carbon (8-3', 8-1', 3-3', 8-0-4' for example). The term 'oligomers' is incorrect; designated lignans or neolignans result from the condensation of 2–5 phenylpropanoid units (e.g. sesquilignans and dilignans, lithospermic acid). Norlignans are probably specific to gymnosperms and have a C_{17} skeleton.
Lignins are substances deposited at the end of the formation of the primary and secondary cell walls. Chemically, they are polymers arising from copolymerization of alcohol with a p-hydroxycinnamic structure (p-hydroxycinnamyl, coniferyl or sinapyl alcohol). Lignins are always combined with polysaccharides.
The pharmacological activity of lignans is antitumour. Kadsurenone, a neolignan, exhibits anti-allergic and antirheumatic activity. The major application of lignins is as a precursor of vanillin, which is widely used in the food industry.

1.4.6 Terpenoids and steroids

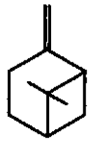
Terpenoids and steroids are derived from isoprene (a 5-carbon unit), which is biosynthesized from acetate via mevalonic acid.

1.4.6.1 Monoterpenes

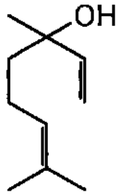
Monoterpenes are the most simple constituents in the terpene series and are C_{10} compounds. They arise from the head to tail coupling of two isoprene units. They are commonly found in essential oils. Iridoids and pyrethrins are included in this group. Examples of monoterpenes found in essential oils are shown in Figure 10.
Iridoids are monoterpenes characterized by a cyclopenta [C] pyranoid skeleton, also known as the iridane skeleton (cis-2-oxo-bicyclo-[4,3,0]-nonane). Secoiridoids, which arise from iridoids by cleavage of the 7,8-bond of the cyclopentane ring, are also included in the iridoids. Examples of secoiridoids are the bitter constituents of gentian, e.g. gentiopicroside, amarogentin and esters of sweroside and swertiamarin.



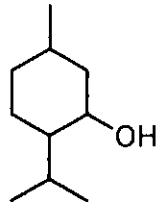
α-pinene



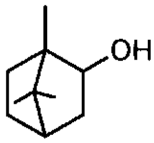
β-pinene



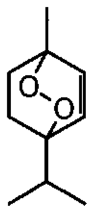
linalool



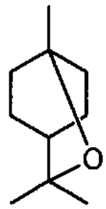
menthol



borneol



ascaridole

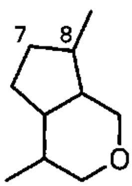


1,8-cineole (eucalyptol)

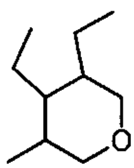
Figure 10. Examples of monoterpenes.

Pyrethrins are irregular monoterpenes arising from the non-classic coupling of isopentenyl pyrophosphate and dimethylallyl pyrophosphate. Some are found in essential oils. Figure 11 gives the basic structures of iridoids and secoiridoids and an example of pyrethrins.

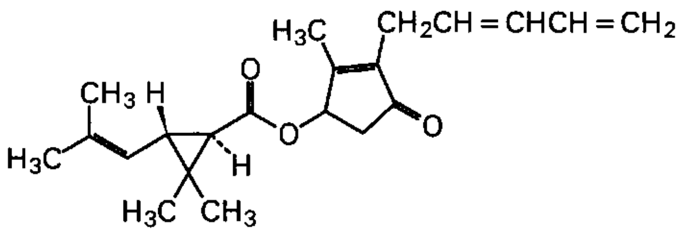
The pharmacological properties of iridoids are quite limited: the iridoid-containing drugs currently used do not yield any major active principle. However, there are reports on analgesic and anti-inflammatory activities of some iridoids, e.g. harpagoside. Pyrethrins are toxic for coldblooded animals such as fish, amphibians and insects. They are widely used as insecticides.



iridoid

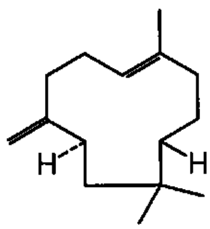


secoiridoid



pyrithrin I

Figure 11. Basic structures of iridoids and secoiridoids, and the structure of pyrithrin I as an example of pyrethrins.


β-caryophyllene

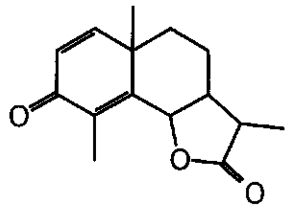

α-santonin

Figure 12. Examples of sesquiterpenes.

1.4.6.2 Sesquiterpenes

Sesquiterpenes are also constituents of essential oils of many plants, e.g. bisabolol, humulene and caryophyllene. Figure 12 shows two examples of sesquiterpenes. Sesquiterpenoid lactones are well known as bitter principles. They occur in fungi, bryophytes and angiosperms (especially common in *Compositae)*.

Sesquiterpenes possess a broad range of biological activities due to the α-methylene-γ-lactone moiety and epoxides. Their pharmacological activities are antibacterial, antifungal, anthelmintic, antimalarial and molluscicidal. Examples are santonin used as an anthelmintic and artemisinin as an antimalarial.

1.4.6.3 Diterpenes

Diterpenes constitute a vast group of C_{20} compounds arising from the metabolism of 2E,6E,10E-geranylgeranyl pyrophosphate. They are present in some animals and plants; they are particularly abundant in the orders *Lamiales* and *Asterales*.

Diterpenes have some therapeutic applications. For instance, taxol (see Figure 13) and its derivatives from *Taxus* are anti-cancer drugs. Other examples are forskolin, with antihypertensive activity, zoapatanol, as an abortifacient, and stevioside, as a sweetening agent.

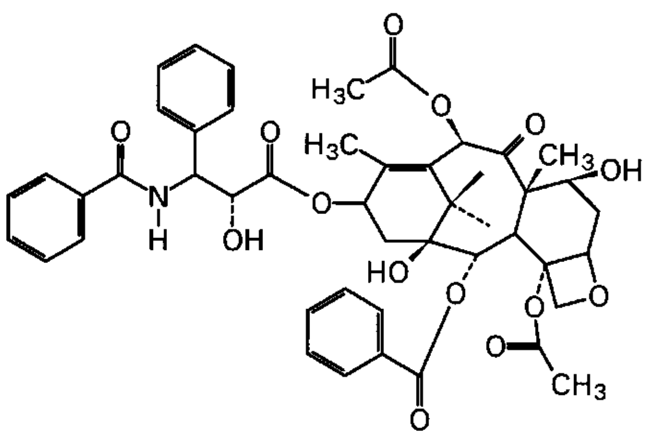


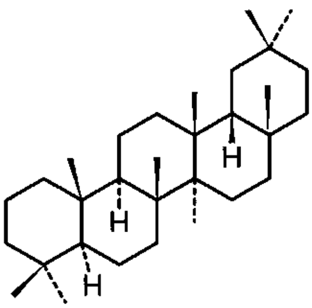
Figure 13. Structure of taxol as an example of a diterpene.

1.4.6.4 Triterpenes and steroids

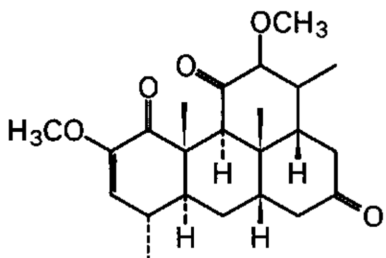
Triterpenes are C_{30} compounds arising from the cyclization of 3S-2,3-epoxy,2,3-squalene. The basic skeletons are shown in Figure 14: oleanane is an example of a pentacyclic triterpene, quassin of a tetracyclic triterpene and testosterone of a steroid. Tetracyclic triterpenes and steroids have similar structures, but their biosynthetic pathway is different. Steroids contain a ring system of three 6-membered and one 5-membered ring; because of the profound biological activities encountered, many natural steroids together with a considerable number of synthetic and semi-synthetic steroidal compounds are employed in medicine (e.g. steroidal saponins, cardioactive glycosides, corticosteroid hormones, mammalian sex hormones).
The pharmaceutical applications of triterpenes and steroids are considerable. Cardiac glycosides have been used in medicine without replacement by synthetic drugs. Saponins from ginseng and liquorice exhibit many therapeutic effects.

Saponins

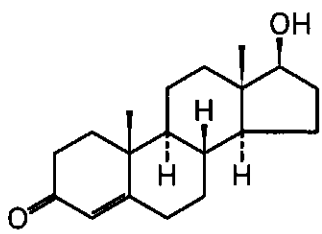
Saponins constitute a vast group of glycosides which occur in many plants. They are characterized by their surfactant properties; they dissolve in water and, when shaken, form a foamy solution. Saponins are classified by their aglycone structure into triterpenoid and steroid saponins; most triterpenoid saponins are derivatives of one of the triterpenes oleanane, ursane and lupane, while steroid saponins generally possess the typical steroid skeleton enlarged with 2 extra rings E, a furan structure and F, a pyran structure, respectively. Examples of 2 aglycones are shown in Figure 15. In saponins, sugar and/or uronic acid residues are attached to the aglycones via the C-3 hydroxyl group.



oleanane

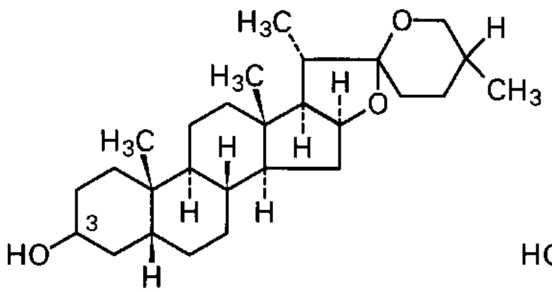


quassin

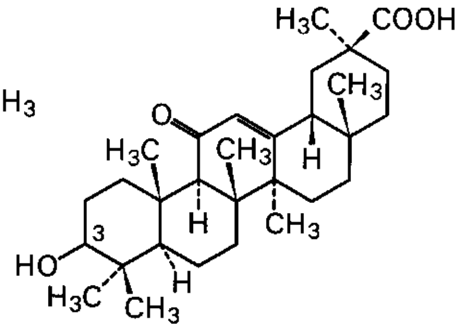


testosterone

Figure 14. Basic structures of triterpenes and steroids.



smilagin



glycyrrhetic acid

Figure 15. Structures of two saponins (aglycone structure).

Most saponins have haemolytic properties and are toxic to coldblooded animals, especially fish. The steroidal saponins are important precursors for steroid drugs, including anti-inflammatory agents, androgens, oestrogens and progestins. Well-known steroid sapogenins are diosgenin from *Dioscorea*, hecogenin from *Agave* and smilagenin from *Smilax*.
Triterpene saponins exhibit various pharmacological activities: anti-inflammatory, molluscicidal, antitussive, expectorant, analgesic and cytotoxic. Examples include the ginsenosides, which are responsible for some of the pharmacological activity of ginseng, and the active triterpenoid saponins from liquorice.

Cardiac glycosides

The aglycone part of cardiac glycosides is a tetracyclic steroid with an attached unsaturated lactone ring that may have 5 or 6 members. Cardiac glycosides are classified into two groups according to the lactone ring: the C_{23} cardenolides with an α,β-unsaturated d-γ-lactone (= butenolide), and the C_{24} bufadienolides with a di-unsaturated γ-lactone (= pentadienolide). The sugar moiety is normally attached via de C-3 hydroxyl group of the aglycone. The majority of the saccharides found in cardiac glycosides are highly specific. They are 2,6-dideoxyhexoses, such as D-digitoxose, L-oleandrose or D-diginose. These sugars give a positive reaction with the Keller-killiani reagent.
Cardiac glycosides have been used as drugs for the treatment of cardiac insufficiency. An example is digitoxin from *Digitalis*, where the sugar moiety is attached to the aglycone digitoxigenin (see Figure 16) via the C-3 hydroxyl group.

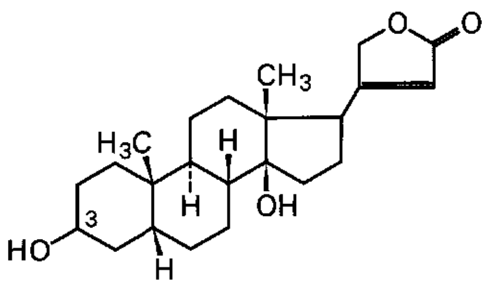


Figure 16. Structure of digitoxigenin.

1.4.6.5 Carotenoids

Carotenoids contain 8 isoprene (C_{40}) units that are responsible for the yellow or orange colour of some vegetables and fruits. Among these compounds, the hydrocarbons are collectively referred to as carotenes and the hydroxylated derivatives as xanthophylls. Carotenoids are either acyclic (e.g. lycopene) or comprise one or two pentacyclic or hexacyclic rings at one end or the other (e.g. β,ψ,-carotene), or at both ends (e.g. β,β-carotene).
Carotenoids became interesting agents after the discovery of a negative correlation between the plasma concentration of β-carotene and the prevalence of certain forms of cancer. Some doctors prescribe β-carotene for cancer patients. Furthermore, in the intestine β-carotenes are converted to retinol (vitamin A). They can be used for the treatment of photosensitization, retinal disease and glaucoma. Carotenoids are also safe colouring agents for food and cosmetics.

1.5 Biological and pharmacological activity and therapeutical applications

Among the many classical examples of biological action of plant material in man are the different tastes (sweet, bitter, sour, astringent), sensations (irritating, itchy, pungent, acrid) and the types of euphoria and hallucinations. However, only recently biological activity is understood in terms of molecular interactions. Plants and plant constituents have a key position in the advancement of modern studies and knowledge on biological activity of substances. There are several reasons for this. Firstly, plant species, whether traditionally used or not, continue to be important sources of food, medicines and supplementary health products. Secondly, the bioactive plant compounds are themselves products (or derived products) of metabolism, and hence function in life processes in a similar way to compounds that operate in humans and animals. Researchers hoping to develop drugs from plants need to understand the basics of such functions and mechanisms in relation to the bioactive molecular entities. Thirdly, plants also yield products which are auxiliaries in medicine and pharmacy and sustain or condition pharmacological activity and therapeutic efficacy. In addition, a series of these auxiliary substances are used in biomedical research and in clinical tests.
Testing the biological activity of medicinal or potentially medicinal plant material demands a special approach. Investigations may be focused on understanding the bioactivity of a compounded plant extract or simply directed at isolating a single bioactive chemical compound. In the latter case, results often lead to oversimplification or wrong explanations of the bioactivity of extract preparations. On the other hand, thorough studies on single bioactive constituents provide important information for plant drug research. However, the much more complex array of molecular interactions and bioactivity mechanisms that arises from plant extracts represents a much greater and more fascinating challenge to science.

1.5.1 Factors affecting biological activity

Various aspects of bioactivity apply to any chemical, whether of natural or synthetic origin. These aspects will now be described briefly. They fall into three categories (Gringauz, 1997; Gubernator & Böhm, 1998; Krogsgaard-Larsen & Bundgaard, 1991):

- Physicochemical properties such as solubility, partition coefficients and ionization.
- Chemical parameters such as resonance, inductive effects, oxidation–reduction potentials, types of bonding and isosterism.
- Spatial considerations such as molecular dimensions, interatomic distances and stereochemistry.

1.5.1.1 Physicochemical properties

These relate to the transport of the bioactive compound to its site of action, usually a receptor or other biomacromolecule at cellular or subcellular level. Under experimental (in vivo or clinical) or real life conditions the extent to which a drug passes through semipermeable membranes before reaching its site of action depends on its solubility. Under in vitro conditions many of these barriers are absent. In vitro bioactivity therefore represents only a stage in the basic assessment of pharmacological effects. In plant drug research, the solubility of active constituents may be revealed from extraction procedures. Extraction programmes separate lipophilic constituents from water-soluble compounds. Further fractionation of an extract may lead to further refinement of physicochemical properties. After the bioactive molecular entity has been identified, detailed data on solubility, partition coefficients and the electrolytic behaviour can be determined. Solubility characters are closely related to drug absorption, and the degree of absorption is an important determinant of drug action. Many bioactive plant constituents are weak acids and bases, and their degree of ionization, when dissolved, is of great importance to their bioactivity. As a rule, the ionic form is more water-soluble.

These factors are important when bioactivity is regarded in the context of drug distribution between intestine and plasma, between kidney tubules and urine, and between plasma and other body compartments. Generally, but simplified, one may say that only the lipid-soluble and undissociated forms of a bioactive molecule will pass through membranes. However, at the site of action, bioactive compounds may generate their action by binding to a receptor on the cell membrane.

1.5.1.2 Chemical parameters

The structural features of a compound can be related to its pharmacological properties, either qualitatively or quantitatively. The principles, concepts and numerical rules governing qualitative and quantitative relationships between structure and activity help explain the pharmacological activity of a new compound, which is why it is important to elucidate the structure of a newly isolated plant compound. The basic aspects of molecular structures involved in bioactivity include:

- *Resonance*. This is the phenomenon that a molecule can be represented by two or more structures that differ only in their electron, but not atomic, arrangement. So, electron density and electron distribution patterns help explain the molecule's reactivity and hence its molecular interaction and bioactivity.

- *Inductive effects.* These are measurable electrostatic phenomena caused by actual electron shifts or displacements along chemical bonds. Either negative or positive inductive effects may lead to changes in bioactivity.
- *Oxidation–reduction potential.* This phenomenon represents the tendency of a compound to lose electrons (oxidation) or gain electrons (reduction). Without electron transfers, various systems in the living cell would not function. Through the nature of their chemical structure, bioactive compounds may affect these systems. Note that bioactive compounds derived from plant sources function in enzyme systems in the plant which are similar to those in the humans or animals treated.
- *Types of bonding.* Basically the phenomenon of biological activity is concerned with covalent and noncovalent molecular interactions. Firstly, covalent bonds (single, double and triple bonds) are common to all biomolecules. Under the physiological conditions of living organisms, covalent bonds form enzymatically. As a rule, however, further biochemical functionality of biomolecules proceeds through noncovalent interactions. Hydrogen bonds, ionic forces, hydrophobic (or lipophilic) bonding, and charge–transfer interactions, all representing noncovalent interactions, are also common to functional life processes. Thus bioactivity as encountered when a given compound, whether biogenic or xenobiotic, comes in contact with a living system (in vitro, in vivo, clinically, or unintentionally) interferes with ongoing life processes. However, the molecular interactions will still be in terms of covalent or noncovalent principles. Agents that affect physiological functions by forming irreversible covalent bonds with target biomacromolecules are usually very toxic at cellular level, and would be difficult to control clinically and medically. So in plant drug research, constituents that exert their activity through much weaker and reversible bonding processes are much more desirable. Noncovalent and reversible covalent binding of target molecules are preferable and, moreover, are characterized by equilibrium thermodynamics (Gubernator & Böhm, 1998). Association constants can be determined and are reproducible. In the case of high-molecular weight ligands (e.g. a large bioactive plant molecule) the association rate of these ligands with the target biomolecule slows down and it becomes unpractical to determine an equilibrium. In cases of reversible covalent interactions, measurable activity constants (e.g. IC_{50} values = concentration giving 50% inhibition) are very dependent on experimental conditions such as the concentration of constituents, incubation time, temperature, acidity, etc. The systematic search for desirable plant ligands not only strives for bioactivity through reversible covalent or noncovalent interactions, but also for selectivity. The latter conditions the specificity of action, and reduces toxicity and side-effects. From the vast number of studies of biological and pharmacological activity and its molecular basis, it is clear that it is still a long way to total understanding and sufficient explanations.

1.5.1.3 Spatial considerations

It appears important to have good steric and electronic complementarity between ligand and target biomolecule (Gubernator & Böhm, 1998). A bioactive compound interacting with DNA, a receptor molecule or an enzyme fits sterically into a binding pocket, the space sterically provided by these targets. The molecular dimensions, interatomic distances, arrangements of electrons and the stereochemical properties of both ligand and target are decisive. In other words, a molecular 'docking' mechanism is at the basis of biological and pharmacological activity. This is illustrated by an example.

(–)-Huperzine A is a potent and reversible inhibitor of acetylcholinesterase. However, this plant compound does not show muscarinic effects. The lack of these undesirable side-effects suggests that (–)-huperzine A has potential for treating 'cholinergic insufficiency' disorders, such as Alzheimer's disease. This compound has been isolated from the club moss *Huperzia serrata* (Thunb. ex Murray) Trevisan (synonym: *Lycopodium serratum* Thunb. ex Murray), which is used medicinally (Raves et al., 1997). See Figure 17 for the structure diagram. The (–) isomer of this chiral molecule has a more potent bioactivity than either the (+) isomer or the racemic mixture.

Such detailed molecular orientation and interaction data are not available for most known bioactive plant ligands. However, the target biomolecule of many other plant compounds is known, and, if not, the pharmacological effects have been studied (Bierhaus et al., 1997; Colegate & Molyneux, 1993; Hassig et al., 1997; Hung et al., 1996; Raves et al., 1997). Table 1 gives examples of plant ligands whose target biomolecules are known.

1.5.2 Bio-assaying

1.5.2.1 Requirements for screening medicinal plant material

The biological and pharmacological effects caused by ligand–target interactions can be studied and assessed in specifically designed bio-assays. The huge range of bio-assay literature cannot be covered within the scope of this brief treatise, but a few essential remarks are in place here. When searching for plant ligands that are not only effective but also selective, specific and reversible in their interactions, bio-assays should meet certain requirements.

Firstly, one or more appropriate assays should be selected or developed for initial screening of extracts. 'Appropriate' means rapid and simple to perform, and functional and specific in their goal. The functions of the biochemical factors involved under physiological and pathophysiological conditions must be clear. In other words, bio-assaying is a way to relate bioactivity to factors and conditions relevant to disorders and homeostasis. As a result, bio-assaying

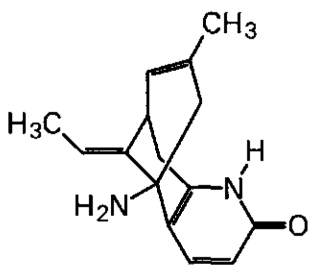


Figure 17. Structure of huperzine A.

Table 1. Examples of plant ligands with known target molecules.

Target category	Target biomolecule	Plant ligand
Enzymes	Acetylcholinesterase	Physostigmine
	Adenylate cyclase	Forskolin
	Cyclooxygenase	Salicylic acid
	Glycosidase I	Castanospermine
	Histonedeacetylase	Butyric acid
	Mannosidase I	Deoxymannojirimycine
	$Na^{+}K^{+}$ ATPase	Cardiac glycosides
	Trypanothione reductase	Kukoamine A
Receptors	Acetylcholine receptor	Hyoscyamine, atropin
	Adrenergic receptors	Ephedrine, cathinone
	– Agonists	Reserpine
	– Blocking	Morphine
	Opiate receptors	Kadsurenone
	PAF-receptor	
Nucleic acids	DNA	Xanthotoxin
Other proteins and glycoproteins	Transcription factor AP-1 and NF-kappa B	Curcumin

Various sources.

should result in a closer understanding of a biological or pharmacological effect of a single compound. By giving an integral picture of interactions and effects, bio-assaying elucidates the pharmacological actions of plant extracts and their ethnomedical uses.

In the initial stage, in vitro testing should have priority over in vivo studies using laboratory animal models. Such a decision can be based on purely scientific as well as economic and ethical reasons. In vivo studies may be preferable at later stages of research, but this depends on the amount and nature of evidence of bioactivity already collected by means of in vitro studies, and the quest for additional information under life conditions. A bioactive plant compound and a bioactive plant preparation that are candidates for therapeutic application will still have to undergo extensive clinical and toxicological screening programmes before they can be registered as medicines.

Medicinal plant material is screened for bioactive compounds for many different considerations and using a variety of approaches ranging from selecting plant sources randomly to more systematic approaches. Some background features of screening approaches are listed below (Bierer et al., 1996; Colegate & Molyneux, 1993; Sills, 1996):

- *Phytochemistry directed screening approaches.* The typical feature of such approaches is that isolation and structure elucidation studies always precede work on biological activity as two unconnected experimental stages. The focus may be on a specific class of compounds (e.g. alkaloids), or a specific subgroup of compounds, or even a subgroup within a certain plant family or genus. Such approaches may have been inspired by pharmacological data on

related substances or by ethnomedical data, but usually there is no direct correlation with the research approach.
- *Ethnomedicine and ethnobotany directed screening approaches.* These follow up clues on bioactivity that have been derived from evaluative studies on traditional medicine and folkloric practices. In the set-up, the choices made for bio-assaying are strongly influenced by pharmaceutical, medical, health and cultural considerations.
- *Randomized screening approaches.* The most characteristic feature of these approaches is the absence of any clues. The plant material is simply a carrier of potential bioactive substances. Randomly selected and collected plant samples are extracted according to general protocols, and subjected to specialized bio-assays.
- *Integral screening approach.* Basically the bioactivity of a plant ligand should be seen and explored within the full context of its phenomenal existence, i.e. its biology, biochemistry, molecular biology, chemistry and biophysics. The approach is based on all life-science aspects and on the biocultural empirical experience with a plant source. A disease, a medical indication or an illness is usually the starting-point for the bio-assay. From the pathophysiology of a disease the relevant in vitro bio-assays and in vivo models are derived and refined. Furthermore, the experimental part of the bioassay involves bioactivity-guided fractionation and isolation. This method represents a very appropriate and rational link between the detection of bioactivity and phytochemical methods.

1.5.2.2 Common pharmacological screening methods

There are many types of pharmacological screens, most of which have to be carried out in a well-equipped laboratory. There are screens for specific bacteria, fungi, protozoa, intestinal worms, viruses and spirochaetes. The efficacy of compounds against specific health problems such as cancer and inflammation is also often probed, and the effect on various physiological and anatomical systems such as reproduction, digestion and circulation can be judged. The brine shrimp screen, the antibacterial screen, the brewers' yeast screen and the Hippocratic screen are commonly applied simple techniques.

Brine shrimps are small aquatic animals that can be grown in solutions resembling seawater. In order to test the potential toxicity of a plant - and thus its probability of containing an anti-cancer agent - measured amounts of plant extract are added to containers holding known numbers of brine shrimps. The surviving brine shrimps are counted after 6 hours and 24 hours, and the acute and chronic LD_{50} values are calculated, respectively; this corresponds to the concentration of the compound in solution that kills 50% of the brine shrimps.

Bacteria can be grown on agar medium in Petri dishes. When measured amounts of a plant extract are placed on paper disks set on the surface of the bacteria-inoculated agar under sterile conditions, after 18–24 hours bacteria-free circles can be observed around some of the paper disks, indicating that the extract has inhibited the microbes. Plant extracts can be tested for phototoxic and fungicidal activity against brewers' yeast (*Saccharomyces cerevisiae*).

These tests yield much less information than the sophisticated assays that are done in fully equipped laboratories, and can only detect a limited range of biological activities (Martin, 1995).

Hippocratic screening is a simple observational technique. Only crude plant material is used. Dried plant material is chopped and run through a mill. The resulting powder is suspended by trituration in a sterile 0.25% agar solution in double-distilled water, and injected intraperitoneally into rats. Only rats can be used for Hippocratic screening of crude natural products because they effectively resist both infection and peritonitis. A log-dose series of injections is made, ranging from 1 g/kg downwards, and the presence or absence of a large number of symptoms is recorded within certain intervals. The result is a unique pharmacological 'fingerprint' for each class of drug. Virtually all known drug types can be detected as active by the Hippocratic screen conducted in rats, with the exception of the various chemotherapeutic drugs such as antibiotics (Malone, 1981).

1.5.3 Surveys of bioactivity, pharmacological and therapeutic categories

There is a need for comprehensive surveys to cope with the enormous expansion of information on diverse types of bioactivity and novel bioactive structures. There are published surveys on ligand–target interactions, in pharmacological categories and at the level of pharmacotherapeutical grouping. Examples of ligand–target categories are: inhibitors of HIV-1 reverse transcriptase, inhibitors of acetylcholinesterase, inhibitors of protein kinases and inhibitors of glycosidases.

Examples of pharmacological categories are: agents acting at synaptic and neuroeffector junctional sites, agents acting on the central nervous system, agents affecting renal and cardiovascular function and agents interfering with inflammatory processes.

Examples of pharmacotherapeutic groups are: emetics, analgesics, anti-inflammatories, anaesthetics, anti-cancer drugs, psychoactive drugs and anti-AIDS drugs.

Table 2 lists some plant compounds with their bioactivity categories.

1.5.4 Future developments in research on bioactivity

Future advances in plant drug research will provide information on bioactivity in terms of molecular interactions with target biopolymers on a broad scale, all this within the context of homeostasis and pathophysiological conditions. Developments in the fields of genetics, molecular biology, bioinformatics and techniques used in determining the steric structure of plant metabolites and target macromolecules appear important today. In addition, fundamental understanding of molecular biodiversity seems important in the process of using plants as resources for drug development. Some animal models will be replaced by testing on cell cultures, because new techniques of culturing cells and tissues have become available. These new testing methods require smaller amounts of test compounds and will provide information at cellular level. This will lead to extensive studies on medicinal plants.

Table 2. Examples of plant compounds with their bioactivity.

Plant source (origin)	Compound name	Bioactivity pharmacological therapeutic category
Areca catechu L. (Asia)	Arecoline	Cholinergic agonist, veterinary anthelmintic
Andrographis paniculata Nees (Asia)	Andrographolide	Antibacterial
Curcuma longa L. (Asia)	Curcumin	Choleretic, anti-oxidant, anti-inflammatory, apoptosis inducer, inhibitor of angiogenic differentiation
Hypericum perforatum L. (Europe)	Hypericin	Protein kinase C-inhibitor, photodynamic antiviral agent
Phyllanthus myrtifolius Moon (Sri Lanka)	Phyllamycin B	HIV-1 RT inhibitor
Phyllanthus myrtifolius Moon (Sri Lanka)	Retrojusticidin B	HIV-1 RT inhibitor
Physostigma venenosum Balf. (Africa)	Physostigmine	AChE inhibitor, parasympathomimetic, miotic in primary glaucoma
Picrorhiza kurrooa Benth. (Asia)	Apocynin	Multiple-immunomodulator, inhibition of: – STZ-induced ROS – platelet aggregation – TNFα release
Pilocarpus jaborandi Holmes (South America)	Pilocarpine	Cholinergic agonist, miotic in glaucoma
Zanthoxylum zanthoxyloides (Lamk) B. Zepernick & F.K. Timler (Africa)	Fagaronine	HIV-1 RT inhibitor

Various sources.

1.6 Botany

1.6.1 Plants used in medicine

The World Health Organization has compiled a list of more than 21 000 plant species purportedly used globally in medicine. It is estimated that 2000–3000 species are used for medicinal purposes in South-East Asia. The number of medicinal plants in Indonesia is estimated at 1000, out of a total flora of 28 000 species. In Malaysia, approximately 1200 trees, shrubs and herbs of the about 12 000 species have been reported to have traditional medicinal properties (Soepadmo, 1991). The number of medicinal plant species in Philippine handbooks (e.g. Quisumbing, 1978) is about 850, out of a total number of higher plant species in the Philippines roughly estimated as 8000. It is estimated that there are more than 10 000 plant species in Thailand, of which about 1800 are listed as medicinal in the Thai Traditional Materia Medica. However, only 1100 of these are botanically identified. Over 1800 plant species have been identified in Vietnam as useful for medicinal purposes. Medicinal plants are also numerous in adjacent regions. In India, the number of plant species used in traditional medical systems is estimated at 1100–1500, and about 700 species of medicinal plants grow wild in Nepal. An estimated 300 plant species are used in traditional medicine in Pakistan, and about 550 flowering plants in Sri Lanka.

1.6.2 Weedy and forest species

Approximately half (125000) of the world's flowering plant species live in tropical forests. The tropical rain forests continue to support a vast reservoir of potential drug species. They can provide natural product chemists with invaluable compounds or starting points for developing new drugs. Less than 1% (Balick et al., 1996) of tropical species have been studied for their pharmaceutical potential; this proportion is even lower for species confined to the tropical rain forest. To date, about 50 major drugs have come from tropical plants. The existence of undiscovered pharmaceuticals for modern medicine has often been cited as one of the most important reasons for protecting tropical forests, so the high annual extinction rate of an estimated 3000 plant species is a matter of great concern.

It is notable that the more important medicinal and poisonous plants include many weedy species. It seems most likely that this is because these species are so widely ditributed and common that they are the most obvious plants to be tried for medicinal purposes. Also, their toxic effects manifest comparatively easily because of the presence of livestock. The weeds include species that are pantropical or even cosmopolitan (e.g. *Achillea millefolium* L.), and that therefore occur in regions where research on medicinal plants is more common than in South-East Asia (e.g. in India, China and Europe). There is thus much literature on these species and they are more highly valued.

More advanced defence mechanisms by secondary metabolites to prevent browsing by livestock might also account for the high proportion of weedy species among the more important medicinal plants.

1.6.3 Chemotaxonomy

The medicinal and poisonous plants in South-East Asia form an extremely diverse group taxonomically. Some families are, however, comparatively rich in species used medicinally, usually because of the common occurrence of certain types or classes of chemical compounds. Examples are *Apocynaceae* and *Menispermaceae* with their alkaloids, and *Compositae* and *Umbelliferae* that contain essential oils.

The great diversity in the taxonomy of medicinal and poisonous plants is also reflected in the growth forms, which range from small herbs to large trees, and in life cycles, ranging from annuals (e.g. *Artemisia annua* L.) to slow-growing trees (e.g. *Cinchona* spp.).

No study of medicinal plants can be started without a proper botanical identification of the species. As there is a relationship between taxonomy and the chemical profile, taxonomic botany is important when attempts are made to find a species that yields a desired substance. A certain compound (or a compound close to it) is more likely to be present in a species related to a species known to contain this compound. Taxonomic studies can therefore help predict the presence of active substances in certain groups of plants (Hedberg in Leeuwenberg, 1987). Constraints are the lack of herbaria and qualified botanists in many tropical countries.

It is essential to use the correct scientific name of medicinal plants. Vernacular names are often very confusing. Erroneous namings are quite common. It should be compulsory for a voucher specimen to be deposited in a public herbarium accompanying a scientific publication on medicinal plants or their compounds.

Plants to be evaluated for medicinal properties (e.g. for anti-cancer activity, as has been done for a long time by the National Cancer Institute, United States) should cover a wide taxonomic range as this will provide a great diversity of types of chemical structures, thereby increasing the likelihood of finding active compounds.

1.7 Ecology

Temperature, rainfall, photoperiod and altitude are factors of great importance for the development of plants. The day length may considerably influence the growth and yield of constituents. *Mentha* ×*piperita* L., for instance, does not grow well under short-day conditions. Most medicinal plants in cultivation need plenty of sun to be of high quality. Most aromatic herbs do not tolerate more than half-day shade, and for these plants the sunniest sites should be chosen in somewhat cool and cloudy climates, though a shady site is acceptable in sunnier climates. Altitude may have a definite effect on growth and on yield of constituents. For example, *Cinchona*, grows slowly at altitudes above 2000 m, and the quinine yield is low when cultivated at altitudes below 800 m. A number of medicinal plants thrive best at high altitudes, and some species only flower at higher elevations and never in the lowland.

Many medicinal plants are easy to grow because they are tolerant of and adaptable to poor conditions. However, unfavourable climatic conditions can cause the synthesis and accumulation of excessive levels of undesirable compounds and/or low levels of desirable compounds. In oil-yielding plants, for instance, poor oil quality may result. Alkaloid yields are affected by environmental factors such as altitude, temperature, moisture, light, soil type, together with handling after harvest and genetic factors. In many alkaloid-yielding plants (e.g. *Datura metel* L.), the alkaloid content peaks in the dry season and is lowest in the rainy season.

The soil requirements vary with the species. Certain species, like most *Zingiberaceae*, prefer loose, moist and humus-rich soils with a pH of 6–7.5, while others e.g. most *Labiatae*, thrive best in dry, well-drained and sandy soils enriched with organic matter. Most medicinal plants are intolerant of waterlogging. In general, alluvial and clayey soils that are slightly acid and have a good water-retaining capacity are suitable for growing medicinal plants in regions with not too much rain.

1.8 Agronomy

1.8.1 Production systems

Medicinal plants are often collected from the wild. Many medicinal plants, especially the aromatic herbs, are grown in home gardens but some are cultivated as field crops, either in sole cropping or in intercropping systems, and rarely as plantation crops.

1.8.1.1 Collection of medicinal plants from the wild

In most countries, the collection of medicinal plants from wild sources is still the rule. Although the natural flora has been used as the major source of medicinal plants throughout history, it is neither possible nor desirable to base a medium-scale industry on it. Attempts to do this have caused depletion of species and even eradication. Furthermore, the quality of raw material obtained from spontaneous growth may vary considerably with respect to their constituents. It is possible to use the wild flora in a way that enhances and preserves the plant resources, but this requires strict regulations and control. Such use must be preceded by an evaluation of the abundance of selected species within a large area, resulting in recommendations about how much raw material may be harvested in a certain area. Local people often transplant and cultivate wild medicinal plants in and around their homes and villages.

1.8.1.2 Cultivation of medicinal and poisonous plants

Several countries in South-East Asia including Indonesia, the Philippines, Vietnam and Thailand grow medicinal crops for domestic use and for export. The number of medicinal crops grown varies from country to country. Although cropping of medicinal and poisonous plants is common practice, it is usually on a small scale. Large-scale cultivation is dictated by the requirements of the pharmaceutical industry, the main user of the raw material.

The demand for medicinal plant material is fickle; large-scale cultivation often brings down the price, and the market situation often changes drastically when the industry's search for cheaper alternative source materials for drugs is successful. The great variation in the demand and supply have acted as a damper to developing efficient crop production systems. Moreover, many medicinal plants are labour-intensive in propagation, husbandry, harvesting, post-harvest processing and packing. On the other hand, pharmaceuticals are often commodities of high value and low bulk, which makes them attractive crops for small-holder farmers in communities where transport constraints restrict bulky cash crops.

South-East Asia has a long practice of traditional farming systems, but these have not been developed to include medicinal and poisonous crops. Commercial cultivation of medicinal crops has to be based on a sound scientific footing. However, research carried out on cropping systems including medicinal crops is rather limited in South-East Asia, whereas very little scientific information is available on the medicinal crops themselves. Farmers in India have long grown complementary crops to derive maximum benefits of existing soil mois-

ture and nutrients. In cropping systems based on opium poppy in India, groundnut and black gram proved a profitable combination which is recommended to the growers. The results of trials with *Rauvolfia serpentina* (L.) Benth. ex Kurz in India showed that the yield was highest when grown as a sole crop and that intercropping often depressed yields considerably. However, it is reported that vegetable crops, soya bean, garlic and onion have little effect on root yields of *Rauvolfia* and add to the overall economy of the system.
There is extensive experience with the cultivation of *Cinchona* in Indonesia, although this crop has declined in importance since the Second World War. The cropping system practised is a long-term one, with a cutting cycle of 7–8 years, leaving a coppice to produce new shoots. Leguminous cover crops are sometimes planted in between the *Cinchona* rows or on the contour to prevent erosion, but *Cinchona* may also be cultivated under the shade of spared rain forest trees.
The success of a new crop in a cropping system depends upon its growing period, soil nutrient and irrigation requirements, disease and pest tolerance or resistance, and its yield. For example, mint (*Mentha* spp.) and opium poppy (*Papaver somniferum* L.) make heavy demands on irrigation and fertilizers, whereas psyllium (*Plantago* spp.) and periwinkle (*Catharanthus roseus* (L.) G. Don) need light irrigation and less fertilizer. *Cinchona* produces an economic yield from 7 years after planting onward, whereas jasmine (*Jasminum*), also a perennial crop, starts yielding already from the second year onward, and *Rauvolfia* after 18 months. Some species are grown as annual crops, e.g. opium poppy, mint and psyllium. These annuals may rather easily fit into existing crop rotations and modes of cultivation.

1.8.2 Propagation

Several species are mostly propagated by seed. Examples are found amongst commercially important crops like hemp (*Cannabis sativa* L.), coca (*Erythroxylum novogranatense* (Morris) Hieron.) and opium poppy (*Papaver somniferum* L.). Disadvantages of this method of propagation may be the great genetic diversity of the progeny and the rapid decrease in seed viability that sometimes occurs. Some species, e.g. *Mentha arvensis* L. and *Erythroxylum coca* Lamk, are commonly propagated by cuttings. Rooting can be stimulated by application of growth regulators. *Bryophyllum pinnatum* (Lamk) Oken is propagated from foliar embryos. Although in vitro propagation techniques are commonly used for ornamentals, they are still rarely used for medicinal crops, though they may be very advantageous in providing homogeneous plant material.

1.8.3 Husbandry

Most medicinal crops are grown in gardens, but sometimes they are grown in pots. Certain cropping techniques can considerably influence the yield of both dry matter and pharmacologically active constituents. The quantity and quality of chemical fertilizers, for instance, may influence the content of secondary metabolites in plants. For example in *Datura stramonium* L., where the alkaloid biosynthesis is increased by replacing part of the NO_3^- in fertilizer by NH_4^+ (Demeyer & Dejaegere, 1993).

Fertilizers and pesticides may contaminate crops. Therefore, manure should preferably be applied before planting short-duration crops, because harvested plant material may be contaminated with bacteria if it is applied later. Chemical fertilizers are usually not used when growing medicinal crops, because plants usually take up too much sodium and potassium, resulting in excessive concentrations of these elements in decoctions. Very often, compost is used. Biological pest control by companion planting (e.g. with *Tagetes*) is often practised.

1.9 Harvesting and handling after harvest

1.9.1 Harvesting

Medicinal plants, especially those growing in the wild, are often harvested by hand. Even when cultivated, manual harvesting is often more practical, e.g. for harvesting bark and fruits that do not mature simultaneously (e.g. *Senna* spp.). Leafy plant material is often labour-intensive to harvest; it is easier to harvest it from cultivated plants, as the individual plants are in approximately the same stage of development and grow close together in smaller areas.
The amount of a constituent is usually not constant throughout the life cycle of a plant. Therefore, the stage at which a plant is harvested is very important for the yield of the desired constituent. There may be seasonal variations, but in perennial plants the age may also be important. It is generally assumed that the best time for harvesting is when the organ in question has reached its optimal state of development. Roots and rhizomes are usually collected at the end of the growing period, bark often at the beginning of the growing season, when it is easier to strip because of the abundance of soft cells near the cambium, leaves before flowering, flowers at anthesis, and fruits and seeds when fully ripe.
Uncontrolled stripping of bark will easily destroy trees, and in several cases has seriously threatened the diversity and abundance of species. It is therefore important, but not easy, to harvest bark in a sustainable non-destructive fashion.

1.9.2 Drying and cleaning

After harvest and cleaning, usually by washing, some plant materials have to be dried in the sun, others in the shade. Flowers are usually dried immediately after picking, in the shade; they are regularly turned over to prevent browning. Drying is the most common method of preserving plant material. Rapid removal of moisture largely prevents degradation of the constituents, since enzymatic processes require the presence of water. Drying also lessens the risk of external attack, e.g. by moulds (Samuelsson, 1992). In some extreme cases, soaking in ethanol is required to deactivate the enzyme. The desired constituents are often damaged by heat, so it is often advantageous to dry at moderate temperatures (45–50°C). The best method of drying depends on the plant material, and uncontrolled drying may cause severe loss of quality. Irradiation is sometimes practised in manufacturing to avoid contamination by bacteria and fungi. The most efficient drying is achieved in large driers of the tunnel

type. The material is spread out on trays placed on mobile racks and transported into a tunnel where they meet a stream of air. However, most often plant material is simply dried in the open. Mechanical driers are used for bulk operation. Sizeable losses still occur in drying and subsequent post-harvest handling.
Most materials have to be crushed or ground, coarsely or finely, before they can be loaded into an extractor or distillation vessel. Most extracts will be dried by distillation under vacuum or spray drying. Freeze-drying (lyophilization) is an adequate method for drying water extracts containing heat-sensitive substances such as antibiotics and proteins, but it requires relatively complicated and expensive apparatus.

1.9.3 Storage conditions

Raw material in the form of dried plant material can be stored only for a limited period of time and provided certain requirements are met. Storage time can be minimized when the processing is planned in such a way that the harvested raw material is used as soon as possible. Preparation of material for distillation varies with the properties of the material. Some materials like flowers should be distilled immediately after harvesting, whereas others such as foliage parts are best stored for some days before distilling. Some materials can be stored indefinitely before distillation.
There are great differences in the stability of crude drugs. Drugs containing glycosides, esters and essential oils are usually less stable than those containing alkaloids and tannins (Samuelsson, 1992). Optimal storage conditions must be employed to prevent deterioration. The enzymes able to break down constituents are rendered inactive in properly dried plant material, but they may become active again if not well protected from moisture during storage. Humidity should therefore be controlled, and wilted leafy plant material should be kept dry and cool to prevent fermentation or mould growth. A concrete floor under shade is often used. The moisture content of the material should stay under 10%. To avoid insect and fungal attacks, the material is often redried in the sun. In order to reduce undesirable microbial contamination and to prevent the development of other organisms, some plant materials are sterilized before storage. Ethylene oxide or methyl chloride may be used, and drugs so treated should comply with an acceptable limit for toxic residues.
The storage of end products such as extracts, also requires care. Storage vessels should be well cleaned prior to being filled. Sometimes it is necessary to fill the vessel to capacity to prevent oxidation, and to run an inert gas over the top to eliminate traces of oxygen. Post-processing oxidation of essential oils is a common problem to be avoided by exclusion of air, trace metals and sunlight. Light-sensitive products such as essential oils are stored in vessels in the dark. Under suitable conditions, however, most essential oils can be stored for long periods. Larger quantities are stored in metal drums lined with polyethylene. It is important that the essential oil is not in contact with rubber or plastic because chemical contamination may occur.

1.10 Processing, utilization and quality control

1.10.1 Extraction methods

Active constituents can be extracted from the plant material by maceration, percolation or continuous extraction. Extraction is the first step in isolating the desired constituents from plant material, using a solvent. Sometimes it is sufficient to achieve an equilibrium of concentration between drug components and the solution within set limits, as in the case of tinctures, tisanes, decoctions and teas. In other cases the drug is extracted to exhaustion, i.e. until all solvent extractables are removed by the solvent. The latter method is mostly used in industry.

In all industrial procedures the raw material is pretreated with solvent outside the extractor, preventing sudden changes in bulk and accelerating the penetration of the solvent through the cell walls to release the extractables. To facilitate extraction, the solvent should diffuse inside the cell and the desired substance must be sufficiently soluble in the solvent. The ideal solvent for extraction is one in which the extractive is most soluble and selective, so that the desired constituent will be extracted with minimum impurities. Alcohol is often used, but because of its great extractive power it is often the least selective in that it extracts all soluble constituents. The ratio of alcohol and water used varies, depending on the polarity of the active compounds.

Most alkaloids can easily be extracted with organic solvent after the powdered drug has been mixed with water and alkali. The alkali will liberate the alkaloid from its salts. However, some volatile alkaloids, protoalkaloids and quaternary ammonium alkaloids should not be extracted by this method. Even though the alkaloids are soluble in acids, the use of acids is not appropriate for industry because of the large volumes required for exhaustive extraction. Some herbs are extracted with volatile organic solvents to produce oleoresins.

The equipment used for extraction with solvents comprises the following components (Wijesekera in Chomchalow & Henle, 1993):

- An extraction vessel with a heating jacket for steam heating or fitted with electrical devices.
- A condenser in a reflux position.
- A solvent reservoir.
- A facility to convert to reboiler position or a separate reboiler.
- A short column for solvent recovery.

There are 3 basic types of essential oil distillation:

- Water distillation (hydrodistillation).
- Wet steam (water and steam) distillation.
- Dry steam (steam) distillation.

Stills of the first type are the simplest and are used by small producers. The plant material is immersed in boiling water. Steam distillation is an improved method to avoid prolonged contact of the material with heat. The still contains a grid which keeps the plant material above the water level (wet steam distillation) or steam is provided from a separate boiler (dry steam distillation). Stills should be insulated to reduce heat losses.

The passage of steam through plant material causes volatile oil to distil over with the steam. The compounds can be distilled out of the plant material at

around 100°C. When the condensate cools through a condenser, the oil, dispersed in water, separates from the aqueous phase, forming two layers which can then be separated easily. It is important that the separator has a large volume to minimize turbulence, because significant amounts of oil can be lost with the distillate water if the oil is not allowed to separate completely. The best material for stills, condensers and separators is stainless steel. The method of distillation chosen must be suited to the particular essential oil, and has to be determined experimentally.
Hydrodiffusion is another, more recent process in which low-temperature, low-pressure steam is used to extract the essential oils. Essential oils from the more fragile flower material can be obtained by enfleurage, a process in which successive batches of freshly picked flowers are exposed to layers of grease coated on stacked glass plates, and finally the resulting pomade is extracted, usually with alcohol, to obtain absolute. This is an almost superseded method practised in the perfume industry, for flowers that continue to produce aroma compounds for several days after they have been picked. At present it is only used for the most expensive perfumes. See Prosea 19: 'Essential-oil plants' for more detailed information on essential oil distillation.

1.10.2 New industrial standards

The practice in industry is to judge plants according to their content of important constituents, but the extent to which the desired secondary metabolites are technically and biologically exploitable is also a governing consideration. Tissue culture techniques have much to offer. They can produce more homogeneous plant material and are also of interest for the industrial production of plant-derived natural substances, including drugs. The main reason why plant tissue and cell cultures have not yet become important for the production of pharmacologically active natural products is the high cost of producing the desired substances by this method. The breakthrough will depend on basic research in molecular biology to clarify how the plants regulate the formation of secondary metabolites and how this is connected with the development of organs (Samuelsson, 1992). Often, high-yielding cell lines are selected, taking advantage of the somaclonal variation. This requires rapid and sensitive methods for analysing the desired metabolites.
Standards are available for several herbal products and guidelines specifying the requirements have been formulated by individual countries, the World Health Organization (WHO) and United Nations Industrial Development Organization (UNIDO). One of the key points on which the medicinal plant-based industry differs from any other agro-industry is the requirement of sophisticated facilities for chemical analyses at all stages. Quality control and assessment are needed, and analytical research has to go hand in hand with plant breeding. A range of quick, reliable and acceptable methods is available, and the institutions dealing with medicinal plants need to have a well-equipped laboratory.
For the quality control of crude drugs the identity of the crude drug must be known, and also the content of active constituents and impurities. Descriptions of the macro- and micromorphology of crude drugs are given in pharmacopoeias and handbooks. A laboratory carrying out the quality assurance of crude drugs should have a well-documented collection of reference materials.

1.10.3 Household preparation

In some countries of South-East Asia, standard pharmaceutical methods have been modified to enable herbal medicines to be made without sophisticated and expensive laboratory equipment. The materials employed in the procedures are those found in rural kitchens. In the Philippines, for instance, these methods of preparation, referred to as 'kitchen technologies', are being taught nationwide and are part of the health care system. The most common preparations made are infusions or teas, decoctions, syrups, liniments, ointments, pills, herbal soaps and lozenges.

The following general guidelines are given for household preparations of medicinal plants in the Philippines:

- Be sure of the identity of the plant.
- Use only one plant drug at a time.
- Use only the recommended plant parts.
- Collect only those plant parts that look healthy: no insect damage, discolouration or other signs of abnormality.
- Follow the recommended methods of preparation.
- When using dried drugs, use only half the amount prescribed for fresh plant drugs.
- Infusions and decoctions should be freshly prepared. A dose for one day may be prepared and kept in a thermos flask.
- Use containers made of inert materials; for cooking: earthenware pots, enamel-lined, pyrex, not metallic utensils.
- Sterilization of medicine bottles is very important. This may be done by heating the bottles, caps or bottled products in a double boiler for at least 20 minutes.
- Observe care and cleanliness at all times.

An example of 'kitchen technology' as described in the Philippines is a sweetened preparation from the leaves of *Vitex negundo* L. called lagundi syrup, and is indicated below:

- Materials: cooking pot, ladle, cup, stove, strainer, medicine bottles, labels, lagundi leaves, sugar/honey, water.
- Proportion: 1 cup chopped lagundi leaves to 2 cups water.
- Procedure: (1) Prepare a decoction by boiling the leaves in water in an uncovered pot for 20 minutes or until the water has decreased to half of the original volume. (2) Cool and strain. (3) Measure the amount of decoction produced. One-third of this volume is the amount of sugar/honey to be added. (4) Add the sweetener, stirring gently. The mixture can be put back on the stove, on low heat, until all the sweetener is dissolved/blended with the mixture. This is the syrup. (5) Transfer the syrup to the sterilized medicine bottles. Seal and label properly. (6) Store the bottled syrup in a clean, cool, dry place away from light.

1.11 Genetic resources and breeding

The need for a comprehensive inventory of medicinal plants is felt in countries where such plants are starting to play a role in the primary health care system. In most countries in South-East Asia the extent of genetic erosion is being inventoried, but this is not being done as well as it should be, because of the huge cost involved.

1.11.1 Plant diversity and conservation

Several species occurring in primary forest are rare and endangered because of large-scale forest destruction and/or over-collecting. Forest destruction may easily endanger species with a narrow area of distribution and may result in genetic erosion. The discovery and use of plants by the herbal and pharmaceutical industries often lead to degradation of the resources. Often both habitat loss and over-harvesting reinforce each other as synergetic factors contributing to the species's overall endangered status. However, in only a few cases is it known whether certain medicinal plants are already or potentially endangered (Lange & Schippmann, 1997). It has been necessary to protect some species, e.g. *Rauvolfia serpentina* (L.) Benth. ex Kurz and *Aloe* spp., by including them in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Several species with a large area of distribution (e.g. *Acorus calamus* L.) need not be considered as at risk from genetic erosion; others have a remarkable capacity to regenerate.
Although medicinal plants have been cultivated for centuries, their germplasm collection has been very limited. There are no germplasm collections for most species and very little effort has been made towards conserving the genetic variation. Gene banks are a way of conserving genetic diversity, but they generally cover major food crops and include hardly any medicinal plants. Gene banks of medicinal and poisonous plants with limited collections (up to 500 accessions) are listed for most of the countries in the region, but the coverage of the geographical and botanical diversity is far from complete. In situ conservation of valuable species in natural parks and reserves and in botanical gardens is too little focused on medicinal plants. In the few important medicinal plant gardens in South-East Asia, the diversity of species has mostly decreased in the last 30 years.

1.11.2 Breeding

Unlike other commercial crops, medicinal crops continue to be cultivated in the same way as they were hundreds or sometimes thousands of years ago, with few exceptions. Very little has been done to genetically improve these crops, despite their long history of domestication. There seems to be great potential for improving the yield and quality of medicinal crops. Breeding work on medicinal crops whose wild forms have great genetic variability often leads to spectacular successes, even in the first few cycles of selection. Therapeutic value and yield are important criteria for selection and breeding. For industrial-scale production of raw material it is vital to select cultivars with the required characteristics.
Research on breeding of medicinal crops thus lags far behind that of food crops and other commodities. The objectives of breeding in medicinal crops are to obtain a high yield of active constituents, to improve adaptability and quality, and also to obtain resistance to diseases and pests and stress tolerance. The trend in several countries towards using plants in primary health care in-

creases the need for improvement of crops through breeding. However, for many species there is still no information available.
Examples of existing breeding programmes include:
- The development of genotypes of *Rauvolfia* with a short maturation period and a high root yield for the production of reserpine and ajmalicine.
- The development of genotypes of *Catharanthus roseus* (L.) G. Don with a high root yield and total alkaloid content.

Biotechnology, plant cell culture and molecular techniques are important for the improvement of medicinal plants. For many medicinal species, complete plants have been regenerated from callus cultures, excised plant organs and isolated protoplasts, whereas selections have been made for cell lines with high alkaloid content. Natural or artificially induced mutations have been used to develop plants that produce desired types of alkaloids (e.g. in *Datura* and *Papaver*). Sophisticated hybridization techniques have been applied to several plants of pharmaceutical interest, for the purpose of combining certain desirable characteristics or for producing entirely new characteristics not found in either parent. Gene transfer is possible from related wild species to cultivated plants.
The most profitable system for the synthesis of secondary metabolites is plant cell suspension culture, but the yields of medicinally important alkaloids are lower than in whole plants grown in the field. Hairy root cultures are promising, but quite expensive. Genetic transformation may lead to better in vitro production of secondary metabolites.

1.12 Research and development

1.12.1 Main research topics

Research priorities in South-East Asia for medicinal and poisonous plants are:
- Ethnobotanical research on traditionally used plants.
- Agronomy and commercialization of traditional medicinal plants.
- Medical, biological, microbiological and biochemical screening and standardization.
- Issues related to the use, conservation and socio-economic aspects of traditionally used medicinal plants.
- Legislation and management locally, regionally, nationally and internationally.

1.12.2 Main institutions

The main institutes and universities conducting research on medicinal and poisonous plants in the respective countries in South-East Asia are:

Indonesia

- Agency for Development and Application of Technology (Badan Pengkajian dan Penerapan Teknologi), Serpong
- Central Institute for Research and Development of Agrobased Industry (Balai Besar Penelitian dan Pengembangan Industri Hasil Pertanian), Bogor

- Research and Development Centre for Biology (Pusat Penelitian dan Pengembangan Biologi), Bogor
- Research and Development Centre for Industrial Crops (Pusat Penelitian dan Pengembangan Tanaman Industri), Bogor
- Research and Development Centre for Pharmacy (Pusat Penelitian dan Pengembangan Farmasi), Jakarta
- Research Institute for Spices and Medicinal Crops (RISMRC), Bogor (including 14 experimental gardens)
- Research Institute for Veterinary Medicine, Bogor
- Tawangmangu Research Institute for Medicinal Crops (Balai Penelitian Tanaman Obat Tawangmanggu), Surakarta
- various academic institutions throughout Indonesia including Institut Teknologi Bandung, Universitas Airlangga (Surabaya), Universitas Gadjah Mada (Yogyakarta), Universitas Jenderal Sudirman (Purwokerto), Universitas Udayana (Denpasar).

Malaysia

- Forest Research Institute Malaysia (FRIM), Kepong
- Malaysian Agricultural Research and Development Institute (MARDI), Serdang
- Universiti Putra Malaysia (UPM), Serdang
- University of Malaya (UM), Kuala Lumpur
- Universiti Kebangsaan Malaysia (UKM), Bangi
- Universiti Sains Malaysia (USM), Penang

Papua New Guinea

- Wau Ecology Institite, Wau
- University of Papua New Guinea, Port Moresby

The Philippines

- University of the Philippines System: various institutes, colleges and departments at UP Los Baños, UP Manila and UP Diliman, Quezon City
- Department of Science and Technology: Philippine Council for Health Research and Development (PCHRD), Philippine Council on Agriculture and Foresty Resources Research and Development (PCARRD), Integrated Technology Development Institute (ITDI), Forest Products Research and Development Institute (FPRDI), Food and Nutrition Research Institute (FNRI), National Research Council of the Philippines (NRCP)
- Department of Health: Traditional Medicine Unit (TRADMED), Philippine Institute for Traditional and Alternative Health Care (PITAHC), Bureau of Food and Drugs (BFAD), Institute of Tropical Health (ITM)
- various academic institutions including University of Santo Tomas and De la Salle University in Manila, Philippine Institute for Pure and Applied Chemistry and Ateneo de Manila University in Quezon City

Thailand

- Department of Agriculture: research stations at Chiang Rai, Chiang Mai, Chanthaburi, Chumphon, Ubon Ratchathani, Chai Nat, Suphan Buri
- Department of Medical Sciences: botanical garden at Chanthaburi
- Royal Forestry Department: Phu Khae Botanic Gardens and various National Parks
- Thailand Institute of Scientific and Technological Research (TISTR), Bangkok
- various academic institutions, in particular Mahidol University, Faculty of Pharmacy, Bangkok

Vietnam

- Institute Materia Medica, Hanoi
- Institute of Natural Products Chemistry, Hanoi
- Institute of Chemistry, Ho Chi Minh City
- Ministry of Health, Hanoi
- Science Production Centre of Vietnamese Ginseng, Ho Chi Minh City
- Institute of Tropical Biology, Ho Chi Minh City

1.13 From plant to drug

Since the 1950s, the pharmaceutical industry has relied primarily on new synthesized compounds, with the exception of most antibiotics which are derived from micro-organisms. There was almost no interest in using plants for drug development, but in the last few years that situation has changed slowly.
Plants are still an overwhelming source of novel chemical structures, and substances within plants widely used by humans are less likely to be seriously toxic than synthetic chemical compounds. There is renewed recognition that traditional systems of medicine are appropriate starting points for the development of modern medicines. Another reason for a shift from synthetics to plant-derived products is the increased interest of the public in using medicines from plant sources.
When one or more active constituents have been isolated, studies are performed in animal species (rodents, other mammals) to investigate the mechanism of action. Acute and chronic toxicity studies are required, to ensure the safety of the drug. The most suitable preparation must be determined, i.e. one that provides the proper dose of the drug and is stable enough to be launched on the market. Then clinical studies are carried out. The first clinical phase deals with a small group of healthy subjects, to observe the efficacy and possible side-effects. In the second clinical phase the drug is tested on a small group of patients, and finally a complete clinical study is carried out. All this involves much time and money.
Drug discovery programmes have become less efficient, and the costs involved in developing a drug have escalated rapidly with the increasing requirements associated with the demonstration of the safety and efficacy of a compound. The minimum costs are US$ 100 million (Horrobin & Lapinskas in Prendergast et al., 1998), but may amount to US$ 2000 million. The high costs discour-

age companies from entering a drug development programme unless there is a fair chance that the returns will eventually be much higher and there is protection of intellectual property.
Although the patenting of new pharmaceutical uses of known compounds is now possible in many countries, new plant-source drugs often cannot be patent-protected. They may arise from traditional sources or from scientific publications, and in such cases marketing protection may be necessary to make the necessary investment attractive for companies to take the drug through the approval process. This is often in the form of a market monopoly for a period up to 10 years.
Important issues to be addressed to develop a plant source successfully as a pharmaceutical are:
- A chemical substance must be shown to be safe and to have a reasonable prospect of being effective. A problem arises because in many cases, the activity of isolated compounds is equated with the efficacy of the preparation without considering the possibly important modifying action of other drug constituents.
- A financial assessment should be made to compare the costs for developing the drug with the revenue expected from sale of the product.
- Where possible, it is usually preferable to prepare the compound concerned at reasonable cost synthetically. Where this is not possible, plants should be comparatively easy to cultivate and the plant should contain a reasonable amount of the compound, preferably in easily harvested parts such as leaves or seeds.

1.14 Prospects

The South-East Asian region abounds with medicinal and poisonous plants, many providing drugs for various therapeutic categories and having revolutionized medical science over the years. Accounts of positive effects of herbal preparations are no longer just folklore; they are backed by extensive scientific research, and many modern-day medicines have been derived from medicinal plants. More significant cures for major health problems remain to be discovered.
The sharing of benefits is at present a sensitive issue for the cooperation between drug-resource countries and drug-producing countries. Standard regulations should be set up by resource countries to gain benefit from commercial production of drugs from plant resources.
To harness the full potentials of medicinal plants research should focus not only on the validation of safety and efficacy, combined with development and conservation efforts, but also on chemistry, biological activity, formulation of drugs, clinical trials and cultivation technology. The need for state-of-the-art facilities, adequate funding for research and training of medical researchers are issues to be addressed. Concerted efforts along these lines are critical if long-term objectives are to improve the health of man and provide good health care to all.
There is worldwide concern about the side-effects produced by purified compounds and synthetic drugs. Dangerous side-effects of medicinal plants tend to be limited, but are often concentration-dependent. The long-continued use of

numerous medicinal plants with apparent positive effects and no evidence of detrimental side-effects validates their safety and efficacy and supports their position in the medical practice today. Furthermore, some optically active asymmetrical compounds cannot be synthesized chemically. Many plants are used as pesticides in farms, gardens and homes. People concerned with maintaining ecological balances prefer pesticides from plant products over synthetic formulations.

This implies that the prospects for medicinal and poisonous plants are promising. In fact, there is already a trend in South-East Asia towards a revaluation of the use of medicinal plants in primary health care. In some countries, there are already initiatives to promote their use and to disseminate information on proper applications. In other countries, the recent economic crisis is forcing governments to seriously consider the use of medicinal plants. Sometimes regulations have to be modified to make it easier to register locally produced herbal drugs. At the same time, appropriate manufacturing practices should be introduced to assure the quality of such drugs.

It is envisaged that certain medicinal plants may become commercial crops. However, the demand for medicinal plant products is often not as large as expected and can change rapidly. Oversupply must be avoided by attuning supply to demand in and between countries.

It has been estimated that the higher plants in the world's tropical forests contain about 375 potential pharmaceuticals of which about 50 have already been discovered. It has been suggested that the complete collection and screening of all tropical forest species may cost about US$ 3–4 billion to a private pharmaceutical company, and as much as US$ 147 billion to society as a whole (Mendelsohn & Balick, 1995). The potential value of undiscovered drugs is an additional incentive to conserve species-rich tropical forests.

L.S. de Padua, N. Bunyapraphatsara & R.H.M.J. Lemmens

with contributions from D.K. Holdsworth (traditional and modern medicine in South-East Asia: Borneo, New Guinea), R.P. Labadie (phytochemistry (introductory part), biological and pharmacological activity and therapeutic applications), Nguyen Tien Ban (traditional and modern medicine in South-East Asia: Vietnam), N. Wulijarni-Soetjipto (traditional and modern medicine in South-East Asia: Indonesia) & J.L.C.H. van Valkenburg (definitions, botany, research and development)

2 Alphabetical treatment of genera and species

Abrus Adanson

Fam. pl. 2: 327, 511 (1763).
LEGUMINOSAE
$x = 10, 11, 12$; *A. fruticulosus*: $n = 12, 24, 2n = 22$, *A. precatorius*: $n = 11, 2n = 22$

Major species *Abrus fruticulosus* Wight & Arn., *A. precatorius* L.

Vernacular names Indonesia, Malaysia, the Philippines: saga.

Origin and geographic distribution There are 4–20 species in *Abrus*, the number depending on how a species is defined. The genus is distributed pantropically, with 2 species in South-East Asia including the whole of Malesia.

Uses An extract of roots and leaves is used in traditional medicine to treat cough, hoarseness, digestive disorders such as gastralgia, and aphtha; it is also used as a diuretic. The seeds of *A. precatorius* have also played an important role in the treatment of conjunctivitis in various parts of the world. Macerating 3–5 seeds in 1 l water and applying drops of the liquid to the eye produces an inflammation of the conjunctiva, which used to be considered a cure for granular conjunctivitis. This practice has been abandoned because it appeared to be dangerous and uncontrollable. Although extremely toxic, the seeds have been used against malaria and dysentery, in conjunction with other drugs. In India, *A. precatorius* has a considerable reputation in the Ayurvedic, homeopathic, Unani and allopathic systems of medicine. The seed is one of the components of an oil applied to expel worms and against itching and skin diseases. It is also used to prepare an aphrodisiac and for a paste to remove piles, as an antidote when poisoned, and to treat glandular swellings and ulcers. It is used to induce abortion. Extracts from the seeds are used in Africa for the treatment of urinary schistosomiasis.

Leaves and roots have been used in various countries to sweeten foods. The leaves of *A. fruticulosus* are employed to sweeten traditional medicines used in central Thailand. The attractively coloured seeds of *A. precatorius* are often used as objects of art, ornaments or mascots; they are used as beads in rosaries and necklaces. They have also been used in soldering jewellery; when macerated in water they become mucous, and this sticky substance was mixed with solder to distribute it evenly and as a temporary cement prior to heating. In the Philippines, powdered seeds made into a paste have been used to poison darts and arrows. The stems have been used to tie together materials in harbour works. *A. precatorius* is often cultivated in Java as an ornamental.

Production and international trade Although *A. precatorius* is sometimes cultivated for its medicinal uses or for the sweetening properties of the leaves, there are no statistics on production.

Properties *A. precatorius* seeds are extremely poisonous. They contain a toxic lectin fraction, usually called abrin, which is a complex mixture of toxic abrins and relatively non-toxic *Abrus* agglutinins. There are several methods for isolating the different toxins and agglutinins. However, there are so many isomorphs of the toxins (glycoproteins) that a number of subfractions (e.g. abrins A, B, C, D or abrins a, b or abrins I, II, III – all with slightly different characteristics) can be isolated, depending on the procedure used. Very little information is available on relations between the toxins isolated by the different methods; a gross relationship has been established on the basis of subunit compositions and sepharose 4B binding. From this, it can be concluded that abrin III probably corresponds to abrin C, and abrin I might resemble abrin A.

Typically, 100 g of seed kernels yield approximately 120 mg of abrin I, 150 mg of abrin II and 240 mg of abrin III. All abrins are glycoproteins (M_r 63 000–67 000), composed of 2 polypeptide chains (A and B chains) linked through a single disulphide bond. The smaller A chain inhibits protein synthesis at nanomolar concentrations, and causes cell death. It is an N-glycosidase which inactivates eucaryotic ribosomes by cleaving the N-glycoside link of the residue at A^{4324} of 28S-rRNA. It does not directly affect protein synthesis under the same conditions. Because of its ribosome-inactivating properties, studies of its biological activity have mainly focused on its potential as an immunotoxin in cancer therapy. It has been shown to be more toxic to tumour cells than to normal cells, and to provide therapeutic protection against Ehrlich ascites tumour and fibrosarcoma in mice and Yoshida sarcoma in rats, and to have an inhibitory effect in mice with solid human tumours. The larger B chain of the abrins is a galactose-specific lectin that binds to galactose-containing receptors on the cell plasma membrane. *Abrus* agglutinin is a tetramer with M_r 134 900. It can be separated on DEAE-Sephacel into 2 fractions (APA-I, -II) that have several isomorphs. It is non-toxic to animal cells, but it is a potent haemagglutinator. When tested on mouse spleen cells, abrin was demonstrated to be a potent lymphocyte mitogen. Fresh preparations from the seeds of *A. pre-*

catorius are extraordinarily toxic, but are not mitogenic. However, after being stored for several months at 4°C it seems that such preparations are relatively non-toxic and are effective mitogens. The lectins from the seeds have blastogenic properties on human blood lymphocytes in vitro.

Abrin is one of the two most toxic substances of plant origin known (the other being ricin from the seeds of *Ricinus communis* L.). The LD_{50} value of abrin in mice is as low as 20 μg/kg (intra peritoneal) for the purified substance, and goats fed with a daily amount of 1 g/kg body weight of the seeds die within a few days. The symptoms are loss of appetite, bloody diarrhoea, dyspnoea, dehydration, loss of condition and recumbency caused by fatty change and necrosis of hepatocytes and renal convoluted tubules, pulmonary haemorrhage, oedema and emphysema, and erosions of the abomasal and intestinal epithelium. Intoxication of dogs resulted in death after 15–40 hours. When non-lethal doses of abrin were given to mice and dogs, the symptoms were reversible. The animals recovered, apparently completely, in 1–3 weeks. In addition to its toxic effect, the aqueous seed extract also has antigenic, abortive and teratogenic properties. Human poisoning is characterized by a latent period of several hours to days, followed by severe gastro-enteritis with erosion, necrosis of the liver, kidneys, spleen and lymphatic tract. After ingestion of seeds, for instance by children, immediate emesis is essential; less than one seed can be fatal when it is thoroughly masticated and the tough seed-coat has been damaged. Seeds swallowed whole with intact testa remain innocuous. The toxins are heat-stable to incubation at 60°C for 30 minutes; at 80°C, however, most of the toxicity is lost within 30 minutes.

Abrus seeds are also a rich source of alkaloids, among which abrin (N-methyl-L-tryptophan), hypaphorine, N,N-dimethyl tryptophan methylester, precatorine, choline and trigonelline. The insecticidal properties of seed extracts are attributed to the alkaloids (rotenoids), with hypaphorine being the most effective. The alkaloids reduce the fecundity of female mites and also deter feeding. The seeds contain an indole fraction that inhibits the growth of several plant species, e.g. of germinating lettuce. The active component of this fraction differs from the indole alkaloids abrine and hypaphorine, and has been determined as N,N-dimethyl tryptophan.

A methanol extract of the seeds furthermore showed a concentration-related inhibitory effect on the motility of human spermatozoa, and reduced sperm viability; this offers prospects for application as a human contraceptive. Seed extracts also fully inhibit germination of spores of the fungi *Botrytis cinerea* and *Colletotrichum gloeosporioides*. An almost 100% inhibition of tobacco mosaic virus was found on *Capsicum* pepper plants in vitro.

The roots and leaves of *A. precatorius* are known to contain constituents that have anti-inflammatory, anti-tumour, antitoxic, antitussive, antithrombotic and antibiotic properties. Phytochemical investigations of the herb and roots have revealed the presence of a series of isoflavanquinones: abruquinones A, B and C from the herb, and abruquinones A, B, D, E and F from the roots. Abruquinones A, B and D were found to exhibit remarkable inhibitory effects on platelet aggregation. The IC_{50} of abruquinones A and B for the inhibition of the platelet aggregation induced by arachidonic acid and collagen were less than 5μg/ml, whereas that of abruquinone D was less then 10μg/ml for the aggregation induced by arachidonic acid. Abruquinones A, B, D and F also showed strong anti-inflammatory and anti-allergic effects: superoxide formation was inhibited at a dose of less than 0.3 μg/ml, and the release of both β-glucuronidase and lysozyme from rat neutrophils and of both β-glucuronidase and histamine from mast cells were inhibited at a dose of less than 1 μg/ml. All these effects were measured in vitro.

The roots are also known to have antioestrogenic activity. Tests with laboratory animals (hamsters) infected with *Schistosoma haematobium* seemed to confirm the activity against urinary schistosomiasis. After oral application of a root extract of *A. precatorius* both the egg count and worm load were significantly reduced when compared to the controls.

The powdered drug from the leaves of *A. fruticulosus* used in Thailand is pale green and has a sweet taste. The sweet constituents of the leaves (of *A. precatorius* and *A. fruticulosus*) have been characterized as the cycloartane glycosides abrusosides A, B, C and D. Their aglucone, obtained by acid hydrolysis has been identified as abrusogenin. Abrusosides exhibit sweetness potencies in the range of 3–100 times greater than sugar (2% sucrose solution). In preliminary safety tests they were found to be non-toxic for rodents and were non-mutagenic. The yield of abrusosides A–D from *A. fruticulosus* leaves (0.33%) is slightly lower than from *A. precatorius* leaves (0.39%), but the concentration of abrusoside B, the sweetest compound, is higher in *A. fruticulosus* (0.08% versus 0.03% in *A. precatorius*).

The ethanol extract of the leaves has been found to inhibit acetylcholine-induced contractions of preparations of toad rectus abdominis and rat phrenic nerve-diaphragm muscle. The effects were concentration-dependent and reversible. Furthermore there were no effects on direct electrical stimulation of the rat diaphragm. Thus the ethanol extract is similar to d-tubocurarine with respect to its pattern of neuromuscular blockade. Leaves and roots have been reported to contain some abrin.

Adulterations and substitutes As already mentioned, the toxicity of abrin is parallelled by ricin from *Ricinus communis*, which has similar properties. Other vegetable proteins with pharmacological potential that are broadly comparable with abrin are found in the *Cucurbitaceae* genera *Luffa*, *Momordica* and *Trichosanthes*. They also have abortifacient and antitumour properties.

The roots of true liquorice (*Glycyrrhiza glabra* L.) contain the sweetener glycyrrhizine, which is used worldwide on a much larger scale than the sweetening substances in *Abrus* leaves or roots. It has similar medicinal properties to the abrusosides (e.g. anti-inflammatory and antitussive properties) and is used to cure coughs, bronchitis and gastralgia.

Description Woody subshrubs or lianas up to 6(–9) m long, stems often reaching 1.5 cm in diameter, often slender-branched. Leaves alternate, paripinnate with opposite leaflets, the rachis projecting beyond the last pair of leaflets; stipules small, usually persistent. Inflorescence axillary or terminal, pseudoracemose with the flowers in clusters on short reduced wart-like branchlets often arranged unilaterally on the rachis. Flowers sessile or subsessile, bisexual, 5-merous; calyx tube almost toothless or with 5 short teeth, the upper pair partly joined; corolla papilionaceous, much longer than the calyx, white, yellow, pink to dark purple, standard ovate-orbicular with a short claw and notched at the apex, wings oblong-falcate with long claws, keel longer than wings; stamens 9, filaments joined into a tube but free in upper part, staminal tube at the base adnate to the standard; ovary superior, subsessile, pubescent, 1-loculate, with numerous ovules, style curved, usually persistent, stigma capitate. Fruit an oblong to linear pod, flattened or inflated, beaked, pubescent, dehiscent, (1–)3–12-seeded, more or less septate between the seeds. Seeds subglobose, ovoid to ellipsoid, sometimes compressed, usually shiny. Seedling with epigeal germination; hypocotyl elongated.

Growth and development The swollen wart-like branchlets of the inflorescence of *A. precatorius* are visited by ants.

Other botanical information *Abrus* is usually considered to have an isolated position within the subfamily *Papilionoideae* and placed in a separate tribe *Abreae*. It is characterized by the combination of woody stems with a tendency to twine, paripinnate leaves, pseudoracemes and 9 stamens. Some taxonomists adhere to a wide species concept, resulting in the acceptance of only 4 species worldwide. Others prefer a more narrow species concept and accept up to 20 species. *A. fruticulosus* is an extremely polymorphic and widely distributed species, which is sometimes considered as a complex of several separate species.

Ecology *Abrus* occurs rather frequently in grasslands, cropped land (also as a weed), thickets, edges of rain forest and gallery forest, up to 1500 m altitude.

Propagation and planting The seed weight of *A. precatorius* averages 150–410 mg. When untreated, the germination rate is about 40% in 18 days. After seeds have been soaked in concentrated H_2SO_4 for 3 hours at 30°C the germination is about 85% in 10 days. Mechanical scarification results in a germination rate of 97%. Seed can be sown directly in the field or in a nursery. When sown directly in the field, 40 kg/ha is needed to obtain 40 000–50 000 plants. 2–3 seeds are planted per hole. Plants from seed sown in a nursery are planted into the field at 25 cm × 60 cm when 3–4 months old. Young plants should preferably be shaded by trees. In Indonesia, *Gliricidia sepium* (Jacq.) Kunth ex Walp. and *Leucaena leucocephala* (Lamk) de Wit are commonly used as shade trees. Propagation by cuttings is easy. *A. precatorius* can be raised in sole cropping or as a cover crop e.g. in rubber plantations in Peninsular Malaysia.

In vitro production of active compounds Ribosome-inactivating proteins and agglutinins have been isolated from callus and cell suspension cultures established from seed explants of *A. precatorius*. Biosynthesis of these lectins is positively correlated with the growth of the cultures. The lectins can be purified from the culture, and their electrophoretic mobility and biological activity are comparable with those of the lectins purified from the seeds. The cultures can be maintained on revised Murashige and Skoog medium. The rotenoid content of leaves, stems and seeds is, however, greater than in tissue cultures. Small amounts of tephrosin and deguelin can be found in the tissue culture.

Husbandry Farmyard manure can be given early at 10–15 t/ha. Plants 2–3 months old can be fertilized with 150 kg urea + 150 kg triplesuperphosphate + 50–100 kg KCl per ha. Experiments with planting *A. precatorius* without support gave a higher yield of leaves (14.5%) and facilitated harvesting.

Diseases and pests The most serious disease of *A. precatorius* in Indonesia is *Rhizoctonia solani*, a fungus that causes stem rot. Witches broom disease caused by a mycoplasma-like organism has been reported on *A. precatorius* in Taiwan.

Harvesting The first harvest can be obtained when *A. precatorius* plants are 6–8 months old. Plants are cut 25–30 cm above the ground; 4–6 harvests per year can be expected.

Yield When harvested 4–6 times per year, a total of 4.7 t/ha of fresh leaves and twigs per year is obtained, which is equivalent to 0.6–1 t of dry leaves. Roots are harvested when plants are 30–36 months old, yielding 2.5–3.5 t of fresh roots per ha.

Genetic resources and breeding Both Malesian *Abrus* species have large areas of distribution and often inhabit anthropogenic localities. They do not seem to be at risk of genetic erosion. In India, the populations of *A. precatorius* have been gradually depleted because of the extensive use in local medicine. No germplasm collections are known to exist, except in botanical gardens. In Indonesia, living plant material is available at the Research Institute for Spices and Medicinal Plants, Bogor and the Research Institute for Medicinal Plants at Tawangmangu.

Prospects Extensive research has been carried out on *A. precatorius* to elucidate the chemical composition, structure and properties of the seed constituents and to a lesser extent of those in the leaves and roots. It appears that certain constituents exhibit anti-cancer and anti-leukaemia effects. Moreover, they may influence fertility as well, whereas the toxic properties may be applicable as effective insecticide. In short, *Abrus* shows promise.

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Selection of species

Abrus fruticulosus Wight & Arn.

Prod. Fl. Penins. Ind. Or. 1: 236 (1834).

Synonyms *Abrus melanospermus* Hassk. (1844), *Abrus pulchellus* Wallich ex Thwaites (1859).

Vernacular names Indonesia: saga areuy, areuy si hayam (Sundanese), daun sambang (Javanese). Malaysia: saga negri, akar kachang inai (Peninsular). Thailand: ma klam phueak (Chiang Mai), kho kiu (Chanthaburi), ma khaam yaan (Trang). Vietnam: k[ee] c[oos]t th[ar]o.

Distribution Africa, India, Sri Lanka, Burma (Myanmar), Indo-China, China, Thailand and Malesia (with certainty in Peninsular Malaysia, Java, Borneo, the Philippines, Sulawesi and New Guinea).

Uses The roots are used to treat digestive disorders. The leaves are employed to sweeten traditional medicines used in the central regions of

Thailand. The stems have been used to tie together materials in harbour works.

Observations A prostrate subshrub or woody climber up to 6 m long; leaves with (10–)12–34 oblong, obovate-oblong or ovate leaflets, truncate to broadly rounded and mucronulate at apex; inflorescence comparatively slender, usually straight, flowers in clusters on cushion-like reduced branchlets; fruit oblong to linear-oblong, compressed, 4–12-seeded; seeds usually strongly compressed, greyish-brown to reddish-brown, sometimes speckled. *A. fruticulosus* is extremely polymorphic and often subdivided into several separate species and subspecies. It occurs in roadsides, along streams, in thickets and edges of lowland rain forest up to 1000 m altitude.

Selected sources 202, 262, 451, 580, 1519, 1520.

Abrus precatorius L.

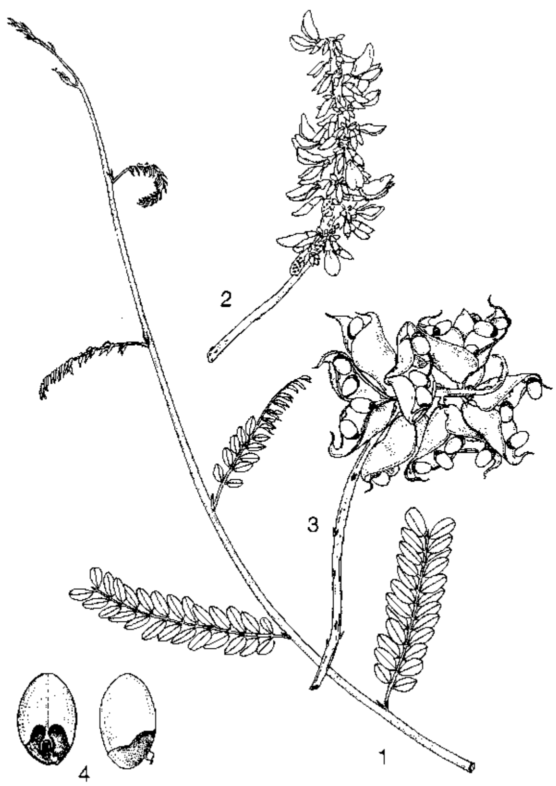
Syst. nat. ed. 12: 472 (1767).

Vernacular names Indian liquorice, jequirity bean, crab's eye (En). Jéquirity, liane reglisse (Fr). Indonesia: saga, saga manis (general), saga telik (Javanese). Malaysia: akar saga. Philippines: saga, kansasaga, bangati (general). Burma (Myanmar): ywe-nge. Cambodia: ângkreem, kre:m krâ:m (Kompong Thom). Laos: khua sa em, makam. Thailand: ma klam taanuu (Bangkok), klam khruea (Chiang Mai), ma khaam thao (Trang). Vietnam: d[aa]y c[uw][owf]m th[ar]o, cam th[ar]o d[aa]y, d[aa]y t[uw][ow]ng t[uw].

Distribution Africa, tropical and subtropical America (introduced), tropical Asia, Australia and the Pacific Islands; throughout South-East Asia.

Uses The seeds have played an important role in the treatment of conjuctivitis in various parts of the world. An extract of roots and leaves is a traditional cure for aphtha. In coastal areas of Papua New Guinea, leaves are chewed for a week as a traditional treatment for asthma. The leaves are also used in the same way as liquorice. The seeds are used in ornaments.

Observations A woody climber up to 6(–9) m long, stems often attaining 1.5 cm in diameter; leaves with 16–34 oblong, obovate-oblong or ovate leaflets, obtuse to acuminate at apex; inflorescence thick and robust, usually curved, flowers in dense clusters on cushion-like nodes; fruit oblong, inflated, 1–7-seeded; seeds ovoid, scarlet with area around the hilum black, rarely entirely black, whitish or yellowish. The African material has been separated as subsp. *africanus* Verdc., based on minor differences in pod characteristics from



Abrus precatorius L. – 1, young shoot; 2, inflorescence; 3, infructescence; 4, seeds.

the Asian subsp. *precatorius*. *A. precatorius* occurs in grasslands, cropped land (also as a weed), thickets, edges of monsoon rain forest and gallery forest up to 1500 m altitude.

Selected sources 65, 130, 190, 193, 196, 202, 255, 268, 350, 353, 301, 363, 398, 417, 557, 568, 580, 597, 633, 696, 706, 711, 712, 714, 736, 738, 811, 896, 948, 1015, 1035, 1059, 1060, 1170, 1178, 1206, 1328, 1519, 1520, 1541, 1563, 1612.

R.H.M.J. Lemmens & F.J. Breteler

Achillea millefolium L.

Sp. pl. 2: 899 (1753).

COMPOSITAE

$2n = 18, 36, 54, 72$

Vernacular names Yarrow, milfoil, thousand weed (En). Achillée millefeuille (Fr). Vietnam: d[uw] [ow]ng k[yf] th[ar]o.

Origin and geographic distribution *A. millefolium* is considered as a complex of difficult-to-separate taxa found primarily throughout the temperate and boreal zones of the Northern Hemisphere and, to a lesser extent, the Southern Hemisphere. It is cultivated, usually as an ornamental, in mountainous areas of some parts of Malesia (e.g. locally in the Philippines and in Java), and is locally naturalized there. It grows wild or is naturalized in Indo-China.

Uses The flowering tops of yarrow (and the herb) are listed in many Western pharmacopoeias. In traditional medicine they are considered to possess antiphlogistic, spasmolytic, stomachic, carminative and choleretic properties. Yarrow is used internally for the treatment of gastro-intestinal complaints (inflammation, diarrhoea, flatulence, cramps, poor digestion), as a bitter aromatic (to counter loss of appetite), to stimulate the secretion of bile (choleretic activity) and to enhance the renal elimination function. In the Unani system of medicine, the flowers are used as abortifacient and emmenagogue. Externally the herb is used in poultices or preparations with alcohol (percolates, fluid extracts) in the treatment of inflammation of the skin and mucous membranes, as well as for healing wounds and relief of itches. In folk medicine, the drug is often employed as a haemostyptic, e.g. in bleeding from haemorrhoids and in menstrual disorders.

The etherial luteolin oil has found widespread use in cosmetic and dermatological preparations. It is also used as a rinse to strengthen the hair, and as a shampoo to prevent baldness. In the form of a bath, yarrow or its oil are applied to remove perspiration.

Yarrow has been reported to be used medicinally in Java, usually as a decoction of fresh flower heads and leaves in water, internally and externally, for the same purposes as in traditional medicine in Europe. Yarrow is often one of the ingredients in herbal mixtures. In India, it is used in a powdered mixture of 18 medicinal plants, which has shown anti-viral activity in mice experimentally infected with encephalitis virus.

Besides its numerous medicinal uses, yarrow has been used as a ceremonial smoke, snuff and beverage by North American Indians, as an occasional substitute for cinnamon or nutmeg, and as a substitute for hops in the brewing of beer. It is a common ingredient of herbal candies. Yarrow is commonly planted as an ornamental, particularly the forms with reddish flowering heads.

Production and international trade Yarrow is grown commercially in Albania (700 kg/year) and Hungary (100 kg/year) and in small quantities in the northern United States and Canada. The quantity of oil produced annually is less than 1000 kg worldwide.

Properties Approximately 150 different compounds have been isolated and identified from yarrow. The essential oil (content 0.2% to more than 1%) has been much investigated chemically because of its pharmacological properties. The essential oil is found in different concentrations in all aboveground parts of the plant: the leaves, however, contain less than the flower-heads. It contains sesquiterpene lactones which are precursors of azulenes (proazulenes, e.g. achillicin); upon steam distillation, they yield azulene and chamazulene. Oils rich in azulene and chamazulene (up to 51% of the oil) have a characteristic deep blue colour. Other sesquiterpenes include achillin, achillifolin, matricarin, millefin, dihydroparthenolide, germacrene D (up to 54%), β-caryophyllene (up to 8%), balchanolide, and farnesol. The monoterpenes present in the oil include, depending on the origin of the oil: terpinen-4-ol, terpineol, α-pinene (up to 2% of the oil), β-pinene (up to 10%), 1,8-cineole (up to 6%), sabinene (up to 17%), myrcene (up to 15%), camphor (up to 7%), linalool (up to 26%), β-thujone (up to 14%), α-thujone (up to 20%), α-phellandrene (up to 12%) and limonene (up to 3%).

Several monoterpenes and sesquiterpenes have been identified in the essential oil from plants from Greece, with ascaridole as the main component (47%) and lesser amounts of 1,8-cineole (10%), p-cymene (7%), α-terpinene (7%) and camphor (8%); other populations from Greece had camphor as the main constituent (22%), with smaller amounts of 1,8-cineole (12%), lavandulol (7%) and borneol (8%), and small amounts of another 80 compounds.

The flavonoids have also received considerable attention. Yarrow contains flavonoids (apigenin and luteolin-7-O-glucoside), glycosylflavones (especially swertisin, vicenin-2 and -3, schaftoside and isoschaftoside) and 6-methoxylated or di- and tri-methylated flavonols (such as pectolinarigin, 3-methylbetuletol and 3,6,4'-methylquercetagetin).

ascaridole

The roots of *A. millefolium* are reported to contain polyynes (e.g. pontica epoxide) and alkylamides (e.g. undeca-2E,4E-diene-8,10-diynoic acid isobutylamide). Other nitrogen-containing compounds isolated from the herb include betaine (0.05%), betonicine (= achilleine ≈ L-(–)-hydroxystachydrine, a compound with reported haemostatic activity) and L-(–)-stachydrine. Triterpenes, saponins, coumarins (0.35%) and tannins (3–4%) have also been reported.

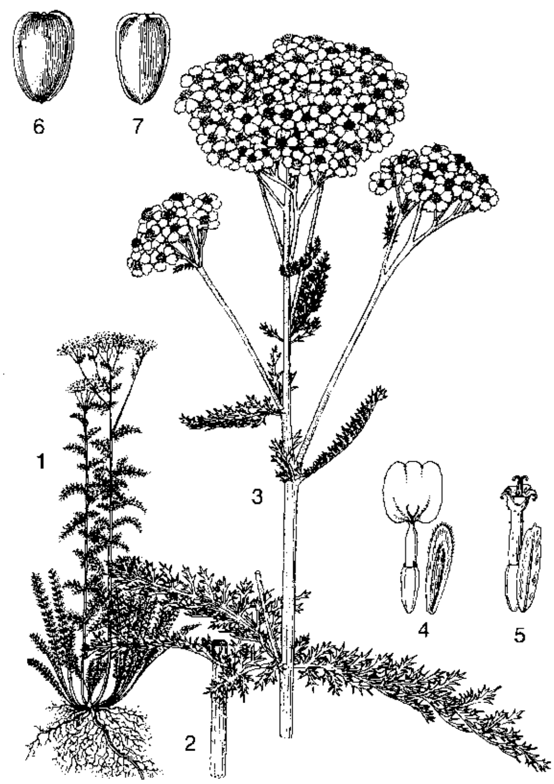
The anti-inflammatory and antispasmodic effects have been confirmed in respectively a mouse-footpad oedema model and an isolated rabbit-ileum model. These properties are tentatively attributed to the flavonoids, which are known to have such activity, but azulene and related compounds have also been claimed to possess anti-inflammatory together with antipyretic activity. The mechanism of anti-inflammatory activity has been suggested by the synthesis of anti-prostaglandin. Sesquiterpene lactones exhibit interesting biological effects, including antimicrobial and cytotoxic and anticancer activity. The methyl esters of the sesquiterpenes achimillic acid A, B and C (isolated from *A. millefolium* flowers) were found to be active against mouse P-388 leukaemia cells in vivo.

Ascaridole (a monoterpene-peroxide) and α-peroxyachifolide (a sesquiterpene-peroxide) both showed in vitro activity against malaria parasites (*Plasmodium falciparum*). The activity of ascaridole is about the same as for artemisinin from *Artemisia annua* L. The activity of α-peroxyachifolide is much less than that of the latter compound (EC_{50} 1 μg/ml and 0.01 μg/ml, respectively). Besides the anti-protozoal effects, ascaridole also has anthelmintic activity against *Ankylostoma*, *Ascaris*, *Necator* and *Trichuris* worms. Thujone is known to possess abortifacient activity.

Yarrow has been reported to contain substances that inhibit seed germination, are antibacterial and act as a mosquito larvicide, and a volatile oil that evokes sex pheromone-like responses in male cockroaches. An ethanol extract of plants from Sweden showed repelling properties against the mosquito *Aedes aegypti*. The most active compounds were identified as stachydrine, caffeic, chlorogenic and salicylic acids, and the phenolic compound pyrocatechol. These substances seem to be fairly safe for cutaneous application, but more toxicity studies are desirable. Yarrow may induce allergic dermatitis, which is usually attributed to the sesquiterpene lactones such as guaianolide peroxides. Furanocoumarins might be the cause of phytophotodermatitis.

Adulterations and substitutes Matricaria or German chamomile, *Matricaria recutita* L. (synonyms: *Chamomilla recutita* (L.) Rauschert, *Matricaria chamomilla* auct. non L.) is another plant species with an essential oil containing a sesquiterpenoid lactone, i.e. matricin, which may decompose to chamazulene. Wormseed (*Chenopodium ambrosioides* L.) also contains ascaridole in larger amounts.

Description A perennial herb, (8–)30–90 cm tall, with aromatic odour and greyish-green colour from the numerous small hairs; stem angular. Leaves alternate, clustered at the base of the stem and with smaller leaves upwards, highly dissected, up to 3-pinnatifid, lanceolate to linear in outline, up to 20 cm × 6 cm. Flowering heads (capitula) in a flat-topped corymb, small, pedunculate, varying in colour from white to pink, magenta and red; involucral bracts in few rows, the outer somewhat shorter than the inner, with a scarious mar-



Achillea millefolium L. – 1, plant habit; 2, middle part of stem with leaf; 3, upper part of flowering stem; 4, ray flower and involucral bract; 5, disk flower and receptacle scale; 6, achene from disk flower; 7, achene from ray flower.

gin. Outer florets in each capitulum usually 5, female, ligulate with more or less 3-dentate, patent ligules; inner florets hermaphrodite, 5-lobed, with compressed corolla tube and a receptacle scale at the base. Fruit a compressed achene, oblong or obovate, without pappus.

Growth and development Plants of yarrow reproduce by suckers and consequently usually grow in groups. The suckers develop into rhizomes. Yarrow is an obligate cross-pollinator, and is pollinated by insects. The fruits are distributed by wind.

Other botanical information In the literature the name *A. millefolium* may refer to several species of the complex. In West European literature it usually means *A. millefolium* sensu stricto; in Eastern Europe it is mainly *A. millefolium* s.s. and *A. collina* J. Becker ex Reichenb.; in North America usually *A. lanulosa* Nutt and, to a lesser extent, *A. millefolium* s.s. is meant.

A. collina (also described as *A. millefolium* subsp. *collina* (J. Becker ex Reichenb.) Weiss) is tetraploid and *A. millefolium* s.s. is hexaploid, but they cannot be clearly distinguished by morphological characteristics. Diploid, tetraploid, hexaploid and octoploid taxa have been reported within the complex *A. millefolium*. The most common form in Western Europe is the hexaploid with white flowers.

Ecology *A. millefolium* generally grows in open, unshaded areas ranging from cliffs and alpine pastures to lowland meadows, lawns, roadsides and waste ground. The stems and rhizomes are tough and withstand trampling well; yarrow often grows close to paths and roads. In closed grassland it is usually suppressed by the grasses. Tetraploid populations containing proazulenes have only been found in meadow habitats and not in roadside vegetations and pioneer habitats, where the hexaploid type occurs with little or no proazulenes. Shoot height and aboveground fresh matter decrease sharply on acid soils.

In South-East Asia, yarrow is locally naturalized in grassy habitats, such as roadsides and lawns, and in mountainous areas.

Propagation and planting Yarrow can easily be grown from seed. Vegetative propagation from suckers is also possible.

In vitro production of active compounds Friable calli were obtained from hypocotyls of yarrow in Gamborg B5 medium. They were used for the production of cell suspension cultures in the same liquid in the dark supplemented with 1.5 mg/l dichlorophenoxyacetic acid, 0.1 mg/l kinetin and 2% sucrose. Cultures grown as such had a doubling time of 35–40 hours. Analysis of the volatile component produced by yarrow cell suspension cultures showed the presence of monoterpenes and sesquiterpenes, some of them not present in plant extracts.

Husbandry Presumably, yarrow plants with reddish flowering heads were favoured for cultivation as medicinal plant. Where yarrow is cultivated, seeds are planted in early spring, and the crop is grown as an annual.

Harvesting Planted yarrow is usually harvested late summer when in full bloom.

Yield There is a considerable variation in the contents of oil and azulene in yarrow, due to provenance of the material, the plant part used, its age, season of collection, climatic and soil conditions, and the inverse relationship between the amounts of oil and azulene produced. In the Ukraine, *A. collina* cultivated experimentally showed very promising results: 6.3 t/ha of fresh matter, 0.2% essential oil of which 42% azulene. In experiments with yarrow in Brazil, manuring resulted in an average increase of biomass production from 47 to 134 g/plant, and of essential oil yield from 0.04 to 0.15 ml/100 g of fresh flower heads.

Handling after harvest After harvesting, yarrow should be wilted for 24–48 hours but kept dry to prevent fermentation. Whole plants are distilled by steam distillation, which takes 6–10 hours. Cohobation is recommended. The oil should be stored in dark containers under cool conditions.

Genetic resources and breeding Tetraploid yarrow in the *A. millefolium* complex contains fair amounts of proazulenes, yielding azulenes upon steam distillation. Except for a few hexaploid populations the essential oil of hexaploids contains no more than traces of proazulenes. Diploid yarrow is reported to lack flavones and flavonols. The widely varying medicinal properties and uses of yarrow in different regions is the result of the occurrence of several genotypes in the *A. millefolium* complex with different chemical composition.

Prospects Western pharmacopoeias prescribe determining the essential oil content (>0.3%) for yarrow and characterizing azulenes in the drug. Only certain taxa and populations within the *A. millefolium* complex can meet these requirements. The relation between chemical composition, ploidy level and ecological conditions is very complicated and makes standardization extremely difficult. Moreover, unambiguous identification is hampered by the frequent occurrence of hybridization and aneuploids. Yarrow and its properties are poorly known in South-East Asia. Information on the chemical composition is urgently needed. Yarrow is easy to propagate and grow and might be well cultivated in home gardens at higher altitudes in Malesia.

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Other selected sources 139, 197, 240, 549, 580, 589, 750, 1035, 1149, 1178, 1262, 1474, 1566.

R.H.M.J. Lemmens & N. Bunyapraphatsara

Acorus calamus L.

Sp. pl. 1: 324 (1753).

ACORACEAE

$2n = 24, 36, 48$

Synonyms *Acorus terrestris* Spreng. (1825), *Acorus asiaticus* Nakai (1936).

Vernacular names Sweet flag, sweet root, calamus (En). Calamus, acore odorant, acore vrai (Fr). Indonesia: daringo (Sundanese), dringo (Javanese), jerango (Sumatra). Malaysia: jerangau, deringu, jerangoh (Peninsular). Papua New Guinea: lepe (Angi, Enga), eseue (Mendi, Southern Highlands), wamala (Aroma, Central Province). Philippines: lubigan (Tagalog, Bisaya), acoro (Spanish), daraw (Iloko). Laos: hang khao nam. Thailand: kha chiang chee (northern), wan nam (central), haang khaao phaa (Chiang Mai). Vietnam: th[ur]y x[uw][ow]ng b[oof], x[uw][ow]ng b[oof], b[oof] b[oof] n[ees]p.

Origin and geographic distribution Sweet flag is probably a native of China and India. Its use as a medicinal plant dates back to Egypt, Greek and Roman times. Sweet flag was distributed from its native range by rhizomes through trade and commerce, and arrived in Europe in the 16th Century. In the Malesian region, it is considered as naturalized and not truly wild. It is found in many parts of Indonesia, Malaysia, and Papua New Guinea and locally in the Philippines (Bontoc and Benguet Provinces), and outside Malesia in Indo-China and Thailand. It is also cultivated here and there.

Uses The rhizomes of sweet flag have been used extensively in traditional medicine by Chinese, Indians, American Indians and others, and are still used in many regions. In Roman and Arabic civilizations aphrodisiac properties were attributed to the rhizome and it was used in North America and Europe as a panacea; in India, sweet flag has, for centuries, been an important medicinal aid for stomach complaints and colic in children. Since ancient times it has been reputed for its stimulant digestive virtues. In India, the rhizomes are traditionally used in an infusion to treat diarrhoea, dysentery, atonic dyspepsia and asthma, and for their carminative, expectorant, nauseant, antispasmodic, stomachic, vermifuge, sedative and emetic properties. In Vietnam, sweet flag is used to treat respiratory disorders (asthma, inflammation), rheumatism, remittent fevers, snake bites and as sedative. In Indonesia and Malaysia, the rhizomes are usually used externally to treat inflammation, rheumatism, lumbago and skin diseases, and internally after childbirth. In Java, sweet flag is an ingredient of certain 'jamus', and in the Philippines it is used as a masticatory against toothache and as a stimulant, carminative and antirheumatic. In Papua New Guinea, the leaves of sweet flag are taken as a tonic, and chewed to relieve tootache. The crushed rhizome is rubbed into the hair to kill lice. In Brunei, sweet flag is used to treat gastritis and diarrhoea and also as a poison antidote. In Thailand, the rhizomes are used as carminative, analgesic, anthelmintic, and to treat diarrhoea and dysentery. In Japan, *Acorus* oil is used as bathing agent, considered to be effective against skin diseases and to improve blood circulation. In the Unani (Greco-Arab) system of medicine, sweet flag is used to treat cardiovascular diseases. In Vietnam, a dose of 2–5 g/day is administered in decoction. In modern phytotherapy, sweet flag rhizomes ('calami rhizoma') can, on the basis of their constituents, be called a bitter aromatic. This is principally used as a stomachic and carminative (internally) and externally as a rubefacient and in the treatment of seborrhoea (as a bath).

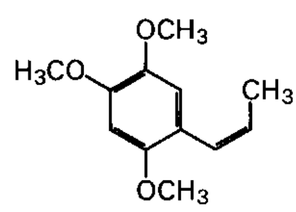
The fragrant oil obtained from the rhizome is not only used medicinally, but also for flavouring alcoholic beverages (e.g. vermouths), fish, sweets and cakes, in perfumes and sacred oils and as an insecticide. As an insecticide, it is often used as emulsified foliage spray. The use of rhizome powder in warehouses and on the farm to protect stored grain, rice and pulses from insect pests has proved fairly effective and economical; powdered rhizomes may also reduce the extent of fungal and bacterial contamination. The hydroalcoholic extract is important in food technology, whereas the essential oil is important in perfumery. The extract is also useful as an antibacterial and antifungal agent. In ancient times the fragrant leaves were used as a strewing herb to remove disagreeable odours and to deter pests. The candied rhizome was a confection in Europe and America. Sweet flag is used in magic rituals in New Guinea and it was also used in snuff rituals by American Indians.

Production and international trade The dried rhizomes of sweet flag are traded locally on markets. Nowadays this trade is not very important, but the extremely large area of distribution resulting from former cultivation indicates that it must have been considerable in the past. The oil is traded in somewhat larger amounts in Europe, mainly for flavouring alcoholic drinks. It is reported that annually about 200 t of rhizomes are used for manufacturing medicines in the Ukraine, and about 20 t in Germany. Almost 30 medicinal preparations which contain sweet flag are available in Europe.

Properties The rhizome of sweet flag is aromatic, smelling of citrus, with a bitter spicy taste. The rhizome contains 2–6(–9)% of a pale yellow to pale brown essential oil with a woody spicy odour with increasingly sweet afternotes and great tenacity. It is normally obtained by steam distillation of fresh or dried unpeeled rhizomes.

Thanks to the great amount of research done on the chemical compounds in the rhizome it is known that sweet flag oil is a source of oxygenated sesquiterpenes of great structural variety. The major chemical constituents of the essential oil are phenylpropanes, monoterpenes and thermolabile sesquiterpenoids. As many as 250 or so volatile components have been detected in the oil of the triploid European var. *calamus*, and about 100 in the tetraploid var. *angustatus*. The major constituents include β-asarone (cis-isoasarone), methyleugenol, cis-methylisoeugenol, geranylacetate, β-farnesene, shyobunone, epishyobunone, isoshyobunone, calamusenone and acorenone. The proportion of each chemical component in the oil varies among the varieties, depending on the degree of polyploidy. The concentration of β-asarone varies markedly; it may form as much as 4–8% of the rhizome and up to 96% of the essential oil in tetraploid Asiatic plants, but only about 0.3% of the rhizome and up to 5% of the oil in triploid European plants, but is absent (or undetectable) in diploid North American plants. The asarone is odourless, so the minor components are decisive in the fragrance of the oil.

The 2 stereoisomers α-asarone (trans-isoasarone) and β-asarone (cis-isoasarone) are reported to have psychoactive effects. This has been attrib-



β-asarone (cis-isoasarone)

uted to the structure, which is similar to that of amphetamines and of the hallucinogenic compound mescaline. Asarone has a relaxing effect on smooth muscle tissue, and the oil has been found to induce spasmolytic activity in rabbit intestines, aortae and uteri. Experiments with guinea-pig ilia have demonstrated that the cortex of the rhizome acts as an antispasmodic agent. In tests on laboratory animals it also showed antihistamine, anticonvulsant and antipyretic activity. It has also been found to act as neuroleptic enhancer, central nervous system depressant, carcinogen, hypothermic, hypotensive, analgesic, anti-inflammatory, bronchodilator, respiration inhibitor, hepatotoxin and antifibrillatory. However, other tests have shown negative results for many of these activities. Although β-asarone is reported to relax smooth muscle tissue, the American drug that does not contain this component has also been shown to be spasmolytically active. These results suggest that β-asarone cannot be solely responsible for the effect and that other antispasmodic compounds must also be present.

The oil is reported effective for hypotensive relief in cats and as an anticonvulsant in pregnant mice. An oral dose of 500 mg/kg of the ethanolic extract showed significant anti-secretory and anti-ulcerogenic activity in rats subjected to pyloric ligation, reserpine and cysteamine administration, and had a highly significant protective effect against cytodestructive agents; these results support the use of sweet flag for the treatment of gastropathy in traditional medicine. Extracts have shown effective antifungal and antibacterial activity, and are reported to be effective against leeches. The rhizome has shown insecticidal activity against a wide range of insect species. Both antifeedant activity and contact toxicity have been reported, and the oil can cause sterility in some insects.

The oil has shown anti-amoebic activity against *Paramecium caudatum* and nematicidal activity against *Ascaris lumbricoides*, *Toxocara canis* and *Meloidogyne incognita*, as well as acaricidal properties against the tick *Boophilus microplus*. It has also been found to inhibit the germination of weeds in cotton. Tests with ground rhizomes mixed with cotton seeds showed promising results for the use as seed protectant against the fungus *Sclerotium rolfsii* that causes damping-off disease. The active compound seems to be β-asarone which has toxic and sterilizing effects. Since the amount of β-asarone is highly dependent on the source of the plant material, care should be taken to carefully record this source. Dried rhizomes have been found to exhibit no antiviral and antitumour activity.

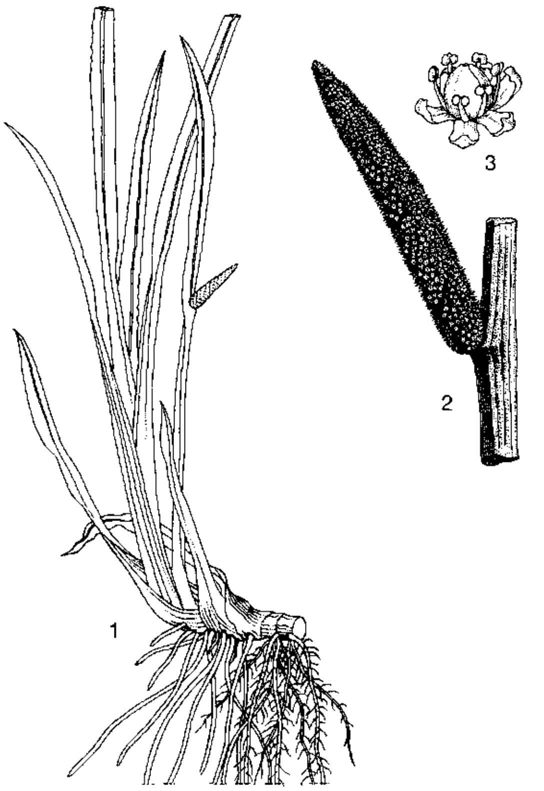
Tannins, starches, mucin, soft gums and resins are also present. Rhizomes contain approximately 10% moisture, 8% sugar, 16% protein, 2% nitrogen, 6.5% ash and 28% ethanol-soluble extractive. Under certain conditions sweet flag is poisonous, causing disturbed digestion, gastro-enteritis and persistent constipation, followed by diarrhoea and passage of blood into the faeces. The use of sweet flag is prohibited in the United States and Canada, because cancerous tumours were found in laboratory animals treated with sweet flag for long periods. The carcinogenic agent seems to be β-asarone, from which mutagenic (demonstrated on *Salmonella typhimurium*) and chromosome damaging properties have also been reported. In general the diploid (North American) variety void of β-asarone should be used for pharmaceutical applications. However, triploid European forms poor in β-asarone (< 0.5%) are acceptable, providing they are not used for prolonged periods. The recommended limit in Europe for flavouring is 0.1 mg/kg in foods and 1 mg/kg in alcoholic beverages and spice mixtures. A rapid and reliable thin-layer chromatographic method, allowing determination down to 0.01 mg/l is available. In some cases, the oil has been known to cause dermatitis when in contact with the skin.

The properties of the mainland Asiatic *A. gramineus* have been studied much less than those of *A. calamus*. It seems to contain less essential oil, but this oil has a high concentration of β-asarone (63–81%), whereas α-asarone has also been reported as one of the important principles of the dry rhizome. The hexane fraction from methanolic extracts revealed potent inhibitory activity against the resistance of multi-drug resistant *Staphylococcus aureus*; benzoic acid phenylmethyl ster (benzyl benzoate) has been identified as active principle. A water extract of the dry rhizome decreased the locomotor activity of mice and increased the pentobarbital-induced sleeping time, in a dose dependent way.

Adulterations and substitutes In India, the rhizomes of *Alpinia galanga* (L.) Willd. and *A. officinarum* Hance are commonly used as adulterant for medicinal purposes. Neem seed oil (from *Azadirachta indica* A.H.L. Juss.) has similar insecticidal properties, as do extracts from leaves and fruits of *Melia azedarach* L., from the rhizome of turmeric (*Curcuma longa* L.) and from garlic (*Allium sativum* L.), and the oils from basil (*Ocimum* spp.), star anise (*Illicium verum* Hook.f.)

and nutmeg (*Myristica fragrans* Houtt.).

Description A perennial glabrous herb up to 150 cm tall; rhizome creeping, extensively branched, up to 3 cm in diameter, pale yellowish to pinkish-brown outside, whitish, sometimes slightly pinkish inside, upper surface marked with large V-shaped leaf-scars, longitudinally furrowed, under surface with circular pitted scars of rootlets arranged in irregular lines. Leaves erect, linear-ensiform, with obliquely acuminate apex, often characteristically corrugated at one side in the upper part, with distinct midrib and numerous thin parallel veins, glossy green but often reddish towards base, aromatic. Inflorescence arising from the rhizome, erect, with a cylindrical, straight or slightly curved spadix up to 10 cm long and produced from about the middle of an apparent leaf consisting of the compressed trigonous leaf-like peduncle and the leaf-like spathe forming a continuation of the peduncle. Flowers densely arranged on the spadix, bisexual, 3-merous; tepals 6, in 2 whorls, free, narrowly oblong, 2–3 mm long;



Acorus calamus L. – 1, plant habit; 2, inflorescence; 3, flower.

stamens 6, free, about 3 mm long, with strap-shaped filaments and orbicular-elliptical anthers dehiscent by a longitudinal slit; ovary superior, subquadrangular, 2–3-celled, stigma sessile, subconical. Fruit a 2–3-celled berry, turbinate and prismatic with pyramidal top, few-seeded, reddish. Seeds ellipsoid.

Growth and development Rhizomes of sweet flag can rapidly develop leaves and inflorescences under favourable conditions, e.g. in spring in temperate climates. Rhizomes show a remarkable tolerance of anaerobic conditions. Plants are usually exposed to periods of flooding and consequently to anaerobic conditions, and can survive for about 2 months in the complete absence of oxygen. The physiology of the plant is adapted to these conditions: the expression of genes enclosing glycolytic enzymes is induced during periods of submergence.
In certain populations plants often do not flower for years. In Malesia, sweet flag is even reported to flower rarely. In many areas the plant does not develop fruits. In Java, the tetraploid plants do fruit sometimes.

Other botanical information *Acorus* has traditionally been placed in the family *Araceae*, where it is included in the subfamily *Pothoideae* together with e.g. *Pothos* and *Anthurium* and forms the tribe *Acoreae*. However, recent taxonomic studies suggest that on the basis of morphological, anatomical, developmental and molecular evidence the genus should be placed in the monotypic family *Acoraceae*. The recent suggestion that *Acorus* is a member of the oldest extant lineage of monocotyledons is based on phylogenetic analysis from DNA sequences; there is supporting morphological, anatomical and embryological evidence. *Acorus* is generally considered to consist of 2 species, but a third species has been distinguished in China.
A. calamus is highly variable in many respects. The size and shape of rhizomes, leaves and spadices are greatly affected by growth conditions. The species has been subdivided primarily on the basis of genome differences. Var. *americanus* (Raf.) Wulff is diploid and fertile and occurs from North America to Siberia, var. *calamus* is triploid and sterile and occurs in Europe, the Himalayas and temperate India and certain parts of the United States of America, and var. *angustatus* Bess. is tetraploid and partly fertile and occurs in eastern and southern Asia from Japan and China to the Malesian region. The tropical ecotype of this last variety is sometimes called var. *verus* L.

Another polytypic species, *A. gramineus* Soland. ex Aiton, is diploid. It differs from *A. calamus* in its usually very narrow worm-like spadix, leaves without distinct midrib but with ribs on the margins, and tougher rhizomes and leaves. It is native to mainland south-eastern Asia (from India, Thailand and Indo-China to China) and Japan, and is used there for similar purposes as *A. calamus*.

Ecology Sweet flag is a component of semi-aquatic habitats, usually in eutrophic locations. It can be a vigorous invader of new sites. In Malesia, it is found along ditches, pools, fish-ponds and marshes, and is sometimes cultivated. In Java, it is found up to 2100 m altitude. Sweet flag can be planted on clayey loams and light alluvial soils.

Propagation and planting Sweet flag can be propagated easily from pieces of rhizome. The field is ploughed and watered prior to planting, and sometimes green manure is incorporated. The rhizome pieces to be planted are generally 6 cm long and have growing tops. They are planted at 20 cm × 20 cm. Roots start to develop 10–15 days after planting, and are soon followed by leaves. In India, sweet flag has been successfully intercropped with poplar (*Populus* sp.).

Harvesting Sweet flag can be harvested within one year after planting. The timing strongly affects the yield of essential oil. In temperate climates, the best period for harvesting is autumn, and the least suitable period is spring.

Yield In India, the average weight of individual green rhizomes harvested 10 months after planting was 175 g (95 g after drying). They contained 1.4% essential oil on average, and the highest yield was 10.4 kg/ha.

Handling after harvest After harvesting, the rhizomes are freed from leaves and roots and washed; they are dried unpeeled, cut in pieces and sold on the market. Storing powdered rhizomes for 2 months at 29°C and 65–75% relative humidity did not reduce their effectiveness as an insecticide.

Genetic resources and breeding Sweet flag has a very large area of distribution and is common in many parts of the world in habitats which are not at risk of destruction. However, locally (e.g. in certain parts of India) it is endangered or even on the verge of extinction. The great genetic variability which is correlated with differences in chemical composition should be taken into account when making germplasm collections and when breeding for special purposes.

Prospects Research findings suggest that sweet flag may have applications for several ailments for which it has a historical record of use. It may still have beneficial applications in modern medicine. Its use in perfumes, foods and beverages is limited because of the carcinogenic phenylpropane derivative β-asarone present in the extract, but the presence of diploid populations which seem to be free from this component offers new opportunities for more extensive use in the future after selection. Sweet flag might have good prospects for commercial exploitation as a pesticide of plant origin.

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Other selected sources 97, 190, 194, 202, 297, 332, 348, 350, 386, 580, 597, 964, 1035, 1178, 1312, 1566.

Nguyen Van Dzu

Aerva Forssk.

Fl. aegypt.-arab.: 170, cxxii (1775).
AMARANTHACEAE
x = unknown; *A. lanata*: $2n = 16$, *A. sanguinolenta*: $2n = 36, 42, 44, 52$

Major species *Aerva lanata* (L.) A.L. Juss. ex Schultes, *A. sanguinolenta* (L.) Blume.

Origin and geographic distribution *Aerva* consists of approximately 10 species and occurs in tropical and subtropical regions of Africa and Asia. Africa is considered the centre of diversity. Two species occur within the Malesian region, especially in regions with a monsoon climate.

Uses Common medicinal uses of *Aerva* include applications as diuretic (valued in cases of lithiasis and catarrh of the bladder, and for prostatic ailments) and as vermifuge. In India the dried plants are used against diabetes and malaria. The seeds are used against bronchitis. In Sri Lanka small clumps of *A. lanata* are frequently grown in gardens to make a medicinal tea. The use of cultivated reddish forms of *A. sanguinolenta* to treat haematuria and menstruation problems has been considered as doctrine of the signature. In India the leaves are made into a paste and applied for the treatment of wounds. *A. sanguinolenta* is also cultivated as an ornamental.

Production and international trade *Aerva* is usually cultivated in home gardens for use in local medicine and as an ornamental, and the plants do not enter the international trade.

Properties Several alkaloids have been isolated, including aervine, methylaervine, aervoside, aervolanine, canthine-6-one and β-carboline-1-propionic acid in *A. lanata*. Several flavonoid glycosides have also been isolated and identified from this species, e.g. narcissin, aervitrin and 4 flavonoid β-coumaroylglycosides, together with 2 feruloylamides and other phenolic compounds. The compounds β-sitosterol, campesterol and chrysin have been isolated from *A. lanata* plants cultivated in Egypt and β-sitosterol, daucosterol, syringic acid, vanillic acid, feruloyltyramine and feruloylhomovanillylamine have been isolated from plants cultivated in Russia. Glucose, galactose and xylose were the predominant carbohydrates in hydrolysates from leaves and flowers.

Preliminary tests in India on rats to study the effects of fresh juice and aqueous extracts of *A. lanata* on the chemically induced nephrotic syndrome, and as anti-inflammatory, diuretic and steroidal agent showed positive results. An ethylacetate extract of the dried whole plant exhibited antimalarial activity. The diuretic effect has also been studied in humans. An extract (200 ml of a 50 g/l infusion) was reported to induce diuresis; the urine output was significantly elevated with extract from fresh plants, when compared with the control group which received the same quantities of water or isotonic saline. Furthermore, of the different parts of the plants tested, the flowers were found to be most effective in inducing diuresis. However, the nature of the diuresis (aquaretic or saluretic) was not defined, since only the urine flow was estimated. In a more comprehensive double-blind setting with healthy volunteers these results could not be repeated: the *A. lanata* extract did not significantly increase urine flow, sodium excretion, potassium excretion, or urine and plasma osmolality as compared to water or a diluted infusion of tea prepared to resemble the *A. lanata* extract as closely as possible in colour and taste. The influence on the formation of urinary (bladder) stones was investigated in the rat. It was shown that *A. lanata* did not affect the formation or dissolution of urinary stones of the phosphate type.

Leaves of *A. sanguinolenta* contain a potent inhibitor of plant virus infection. Leaf extracts mixed with the virus inoculum of tobacco mosaic virus and sunhamp rosette virus caused almost total inhibition of virus infectivity. The resistance to virus infection induced by the extract is systemic and long lasting. Leaf extracts of *A. sanguinolenta*, applied as 4% foliar spray, delayed the appearance of disease symptoms caused by yellow mosaic virus on mung bean, but they could not be used to control the disease.

Adulterations and substitutes Java tea (*Orthosiphon aristatus* (Blume) Miq.) is another herb which is reputed for its diuretic activity, and which is prescribed to treat similar complaints and in similar preparations.

Description Perennial, erect or somewhat clambering, dioecious or polygamous herbs up to 200 cm tall, often almost woody at base, often divided from near the base into ascending or erect branches; branches often unbranched for a considerable length, terete, densely clothed with appressed or patent whitish hairs. Leaves alternate or opposite (often on a single specimen), simple and entire, densely clothed with appressed white hairs on both surfaces (but especially beneath); petiole short, stipules absent. Inflorescence an axillary and terminal spike, solitary or fascicled and sometimes forming a paniculate inflorescence. Flowers small, usually bisexual but sometimes unisexual, solitary in the axil of persistent bracts, subtended by 2 bracteoles, white or tinged with purple; tepals 5, free, hairy; stamens 5, filaments connate at base, free parts subulate, about half as long as tepals, alternating with shorter staminodes, anthers 2-celled; ovary superior, 1-celled, compressed, glabrous, style very short with 1–2 stigmas. Fruit a much compressed utricle, about 1 mm in diameter, bursting irregularly, 1-seeded. Seed reniform, shiny black.

Growth and development *A. lanata* is often reported not to flower before the second year, but flowering sometimes does occur in the first year. In India two forms have been distinguished, one reddish with a deep penetrating taproot having numerous lateral roots, short branches and leaves and comparatively long and numerous spikes, and the other green in colour with a short, thin taproot having few lateral roots, longer branches, larger leaves and comparatively short and few spikes. The first form is apparently an adaptation to drier conditions. Intermediate forms have been found.

Other botanical information Three *Aerva* species have been reported to occur in the Malesian area, but one of these (*A. curtisii* Oliv.) has been transferred to a new genus *Psilotrichopsis* together with the continental South-East Asian species *A. cochinchinensis* Gagn.

Ecology Both *Aerva* species occur especially in periodically dry areas and in dry locations. They are found in sunny or slightly shaded sites, e.g. along roadsides, in waste places, in brushwood and hedges, and are common in many regions. They can be a weed on cropped land.

Propagation and planting *A. sanguinolenta* may be propagated by stem cuttings. Plant growth regulators (e.g. ethyl hydrogen-1-propyl phosphonate) promote root formation and subsequent shoot growth.

Genetic resources and breeding *Aerva* species occur widespread in anthropogenic habitats and are not at risk from genetic erosion.

Prospects *Aerva* may have some prospects as a medicinal plant that is easy to cultivate on a small scale e.g. in home gardens. The diuretic properties that have been claimed since antiquity, however, should be clarified first to define their exact nature, before recommendations can be given for a possible application of *A. lanata* as a drug.

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Selection of species

Aerva lanata (L.) A.L. Juss. ex Schultes

Roemer & Schultes, Syst. veg. 5: 564 (1819).

Synonyms *Achyranthes lanata* L. (1753), *Illecebrum lanatum* (L.) L. (1771), *Achyranthes villosa* Forssk. (1775).

Vernacular names Indonesia: katumpangan uler, rumput upas-upasan. Philippines: tabangahas, apugapugan, pamaynap (Tagalog), karlatan (Iloko). Vietnam: mao v[ix] l[oo]ng.

Distribution Africa, Madagascar, the Seychelles and other islands in the Indian Ocean and southern Asia from Arabia to India, Sri Lanka, Indo-China and Malesia (Sumatra, Bangka, Java, the Philippines, Timor, the Aru Islands and southern and south-eastern New Guinea).

Uses In the Philippines, a decoction is consid-

Aerva lanata (L.) A.L. Juss. ex Schultes – 1, plant habit; 2, branchlet with young inflorescences; 3, flower; 4, opened staminal tube with stamens and staminodes.

ered to be an efficacious diuretic and is used against catarrh of the bladder and gonorrhoea. Leaves steeped in hot water are applied to swellings in Indonesia. In India, the roots are additionally used to treat headache, as demulcent, to cure coughs and as a vermifuge.

Observations A perennial erect herb up to 110 cm tall, main branches and upper part of the stem often unbranched for a considerable length, leafy and flowering almost throughout, internodes usually shorter than 2 cm; leaves alternate, ovate-elliptical to obovate, 0.5–5 cm × 0.3–3 cm; spikes up to 2.5 cm long, in the axil of normal leaves, never forming a loosely branched paniculate inflorescence; tepals 1–1.5 mm long, stigmas 2, spreading; fruiting spike easily breaking up. *A. lanata* is locally common along roadsides, in abandoned fields and waste places, in Java up to 100 m altitude.

Selected sources 57, 93, 96, 190, 332, 497, 580, 891, 1041, 1127, 1178, 1202, 1469, 1470, 1483, 1641, 1642, 1643, 1644.

Aerva sanguinolenta (L.) Blume

Bijdr. fl. Ned. Ind.: 547 (1826).

Synonyms *Achyranthes sanguinolenta* L. (1762), *Aerva scandens* (Roxb.) Wallich ex Moq. (1849), *Aerva timorensis* Moq. (1849).

Vernacular names Indonesia: ki sambang (Sundanese), sambang colok, gondang kasih (Javanese). Laos: do:k khaix ped (Luang Prabang). Thailand: khruea khaao tok (northern), yaa dok khaao (central), phan nguu yai (Saraburi). Vietnam: m[oo]ng g[af] (Phu Khanh), rau chua, mao v[ix] d[or].

Distribution From India, Indo-China, southern China and Taiwan to Thailand and the Malesian region (Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and the Philippines).

Uses Decoctions of young branches are used internally against haematuria and irregular or painful menstruation. *A. sanguinolenta* is cultivated as an ornamental, particularly the purplish tinged form, e.g. in Java.

Observations A perennial, erect or clambering herb up to 200 cm tall, sometimes branched, internodes often longer than 3 cm; leaves alternate or opposite, ovate-elliptical, oblong or lanceolate, 1.5–7.5 cm × 0.5–4.5 cm; spikes up to 5 cm long, partly in the axil of normal leaves, partly in the axil of bracts and often forming a loosely branched paniculate inflorescence; tepals 2–2.5 mm long, stigma 1, entire or obscurely 2-lobed; fruiting spike dense and thick, not easily breaking up. *A. sanguinolenta* is locally common in abandoned fields, brushwood and hedges, in Java up to 200 m altitude, but in Indo-China up to 2000 m.

Selected sources 93, 96, 580, 750, 816, 868, 1367, 1368, 1469, 1470, 1522.

N. Bunyapraphatsara & R.H.M.J. Lemmens

Ageratum L.

Sp. pl. 2: 839 (1753); Gen. pl. ed. 5: 363 (1754).

COMPOSITAE

$x = 10$; *A. conyzoides*: $2n = 20, 40$, *A. houstonianum*: $2n = 20$

Major species *Ageratum conyzoides* L.

Vernacular names Goatweed, billy goat weed (En).

Origin and geographic distribution *Ageratum* comprises approximately 30 species, all of which – except for *A. conyzoides* and *A. houstonianum* – are restricted to the Americas and adjacent West Indies. Goatweed is a pantropical weed which originates from South and Central Ameri-

ca. It extends about 30° north and south of the equator.
A. conyzoides was already being cultivated as an ornamental at the end of the 17th Century, in Europe. *A. houstonianum* was not cultivated before about 1820, but is now a very popular garden plant, whereas *A. conyzoides* has fallen out of favour. Both species occur as a weed in South-East Asia, but *A. conyzoides* is more widespread and common.

Uses *A. conyzoides* plays a role in traditional medicine in many parts of the world. It is widely used externally to treat skin diseases, wounds (both disinfection and haemostasis), ulcers and boils; internally as febrifuge and to treat diarrhoea and haemorrhages. Local uses reported include applications as an emetic (internally), and to treat eye diseases (externally), pneumonia (externally), sore throat (infusion as syrup), stomach-ache (internally), gonorrhoea and catarrh (internally). In Indonesia, an infusion of the roots is used against fever, and an infusion of the leaves to wash sore eyes, and to treat stomach-ache and wounds. In Malaysia, leaves are used externally to heal wounds, cuts, scratches and itches and to alleviate tooth-ache; a decoction of the root is taken for treating coughs and a decoction of the whole plant is taken against asthma. The juice of fresh leaves is widely used as a vulnerary in the Philippines, and leaves cooked in coconut oil are also applied to wounds. A decoction of the herb is used to treat stomach troubles. In Papua New Guinea, a solution of crushed leaves is taken to treat diarrhoea and juice from squeezed leaves is used to treat sore eyes; the leaves are used in New Britain internally against fever and dysentery and externally to heal wounds. In Thailand, the leaves are used for treating wounds, itching and eye inflammations. The whole plant is used as antipyretic, diuretic, carminative, anti-amoebic and emmenagogue. In Vietnam, *A. conyzoides* is reported to be effective in the treatment of allergic sinusitis and rhinitis; it is also used in hair care. Extracts may be used as insecticide.
Both *A. conyzoides* and *A. houstonianum* are sometimes grown as ground cover, e.g. in rubber plantations in Java. In China, *A. conyzoides* is used as a cover crop in citrus plantations, and is reputed to be effective in the biocontrol of mites as it hosts predacious mites. *A. houstonianum* is often cultivated as annual ornamental, in tropical as well as temperate regions.

Production and international trade Goatweed is only used locally medicinally and is not traded on the international market. It is only planted on a fairly large scale in China. Goatweed is rarely cultivated on a larger scale to obtain insecticides, since the active compounds can be synthesized.

Properties Goatweed has a disagreeable odour which has been described as the smell of a billy-goat or of salty shrimps. When dried it smells of coumarin.
Both goatweed species contain an essential oil (in *A. conyzoides* 1.6% w/v), which can be isolated from the fresh leaves and stems. This oil is characterized by the presence of volatile chromene derivatives (up to 85%) of the precocene (e.g. 7-methoxy-2,2-dimethylchromene (precocene I), and ageratochromene (precocene II)) and encecalin type. The proportions of precocene I and II differ between the species: the oil of *A. conyzoides* is rich in precocene I (about 80%) and poor in precocene II (less than 1%), and that of *A. houstonianum* contains approximately equal amounts (23–32% of precocene I and 24–44% of precocene II). The presence of terpenes as well as of chromenes has been established; β-caryophyllene is the main constituent (10% in *A. houstonianum*) after the precocenes of both oils.
Analysis of the aerial parts of *A. conyzoides* yielded 11 chromenes in total, and also the lignan (+)-sesamin and the sesquiterpene caryophyllene-epoxide (caryophyllene oxide). Another study found the largest amounts of precocenes in the leaves, followed by the flowering heads, whereas stems and roots had only minor amounts.
The genus *Ageratum* is known to be rich in flavonoids, especially of the polymethoxygenated flavone type. The following have been identified in *A. conyzoides*: 5,6,7,5'-tetramethoxy-3'4'-methylenedioxyflavone, 5,6,7,8-tetramethoxy-3'4'-methylenedioxyflavone (= linderoflavone B), 5,6,7,8,5'-pentamethoxy-3'4'-methylenedioxyflavone (= eupalestin), 5,6,7,8,3',4',5'-heptamethoxyflavone (= 5'-methoxynobiletin), 5,6,7,8,3',4'-hexamethoxyflavone (= nobiletin), 5,6,7,3',4',5'-hexamethoxyflavone, 5,6,7,3',4'-pentamethoxyflavone (= sinensetin) and 5,6,7,3',4',5'-hexamethoxy-8-hydroxyflavone. Flavones from *A. houstonianum* include 5,6,7,8-tetramethoxy-3'4'-methylenedioxyflavone (= lucidin dimethylether), eupalestin, 5,6,7,8,2',4',5'-heptamethoxyflavone (= agecorynin C), 5,6,7,8,2',3',4',5'-octamethoxyflavone (= agehoustin A) and 5,6,7,2',3',4',5'-heptamethoxyflavone (= agehoustin B).
The pyrrolizidine alkaloids 9-angeloylretronecine, lycopsamine and echimidine have been isolated

from *A. conyzoides*. Furthermore, both species contain friedelin, β-sitosterol and stigmasterol; *A. houstonianum* additionally contains friedelan-3β-ol and also accumulates benzofuran derivatives in the roots.

Precocenes I and II have been synthesized in a single step in 2 hours, starting from a substituted monophenol and 3-methyl-2-butenal in pyridine at 140°C.

Tests with oral administration of a leaf extract to rats in Africa showed that *A. conyzoides* has analgesic properties, but less than morphine. In tests with mice, an extract of whole plants induced hemagglutination against sheep red blood cells at a concentration of 24 μg/ml. A fairly good antiphlogistic effect by comparison with hydrocortison and inhibiting activity on experimentally induced tumour development in mice have been reported from Vietnam. The flavones have been suggested as the substances responsible for the promotion of wound healing. Crude material isolated from *A. conyzoides* leaves exhibited antibacterial activity in vitro against *Staphylococcus aureus*. *Ageratum* oil showed antibacterial activity against 20 bacteria in a test using 22 bacteria.

The essential oil has antifungal properties; in tests it inhibited the growth of *Alternaria alternata*, *Aspergillus* spp., *Colletotrichum truncatum*, *Fusarium oxysporum*, *Helminthosporium tericum*, *Penicillium italicum*, *Rhizoctonia solani* and *Trichoderma viride*. An aqueous extract of *A. conyzoides* also showed nematicidal activity against *Meloidogyne incognita*. Moreover, it exhibited insecticidal activity against diamondback moth (*Plutella xylostella*) in cruciferous crops, pulse beetles (*Callosobruchus chinensis* and *C. maculatus*) in stored leguminous seed, and corn weevils and red flour beetles (*Tribolium castaneum*) in stored maize. At concentrations of less than 10 mg/l it significantly inhibits emergence of adult mosquitoes; this inhibition has been attributed to the antijuvenile hormone activity of the chromenes. Precocene I and precocene II are able to induce precocious metamorphosis, cause sterilization and/or force diapause in certain insects, especially Heteropterans. The methoxyflavones possibly also have toxic effects on insects. A chloroform extract of leaves showed insecticidal activity against *Drosophila melanogaster* and *Dysdercus cingulatus* which was comparable to the standard insecticide malathion and better than the activity of the natural insecticide rotenone. Extracts derived from flowers of *A. houstonianum* have also shown ovicidal, antifeedant and repellent properties against several insects; acetone extracts were more effective than ethyl acetate extracts, and leaf and shoot extracts were less effective than flower extracts. Precocene II showed toxicity for American dog ticks (*Dermacentor variabilis*). A 2 cm thick layer of powdered leaves can control potato tuber moth (*Phthorimaea operculella*) in stored potatoes for up to 120 days. Locusts (*Locusta migratoria*) fed on goatweed during the nymphal stage were sterile; this implies that goatweed might be used for biological control if planted near breeding sites or on possible migration routes. Whitefly was disrupted in its development by *A. houstonianum*, though female insects were attracted by the plant to lay their eggs; this too indicates good prospects for biological control.

Antiviral activity against some legume viruses has also been reported.

In tests with rats in the Philippines, crude aqueous extracts of *A. conyzoides* applied through stomach intubation caused severe poisoning at concentrations of 15–20% after 5 days. The extract retarded follicular development in the ovary, and caused inflammation and degeneration of liver cells. Goatweed is also suspected of hepatotoxicity in livestock. Cattle deaths from liver damage in northern Sumatra have been attributed to pyrrolizidine alkaloid poisoning.

Goatweed shows allelopathic effects on crops such as rice and wheat by inhibiting seed germination and root elongation of seedlings.

Goatweed pollen is reported to cause commonly respiratory tract allergy, even in very low concentration.

Adulterations and substitutes Other plant sources of insecticides include *Azadirachta indica* A.H.L. Juss., *Derris elliptica* (Wallich) Benth. and other composites such as *Tagetes* spp. and *Tanacetum cinerariifolium* (Trev.) Schultz-Bip. Flavones with supposedly anti-inflammatory activity are also found in other *Compositae* such as *Achillea millefolium* L.

Description Annual erect herbs, at the base sometimes decumbent and rooting, up to 120 (–150) cm tall; roots fibrous. Leaves opposite in lower part of plant, higher ones alternate, simple, serrate-crenate above the entire base, with sparse long hairs above and below, glandular on lower side, pinnately veined or faintly 3-veined, distinctly petiolate; stipules absent. Inflorescence consisting of (1–)4–18 peduncled heads arranged in cymose clusters; involucre campanulate, involucral bracts 2–3-seriate, 2-ribbed, green with a pale or reddish-violet top; head 60–100-flowered. Flowers usually bisexual, 5-merous; corolla tubular in varying shades of blue and lavender or white, corolla lobes short, triangular; stamens inserted on inner side of the corolla, with fused anthers forming a ring around the style, with an apical appendage; ovary inferior, 1-celled, with 1 erect ovule on the bottom of the cell, style with 2 long filiform arms with thickened hairy tops, far exserted from the corolla. Fruit an oblong achene, dry and indehiscent, 1–2 mm long, 5-angular, scabrous on the angles, blackish with a pale base, on the outer margin of the top with a pappus consisting of 5(–6) free, membranous, awn-tipped, off-white scales 1.5–3 mm long. Seedling with epigeal germination; cotyledons leafy, arbicular, glabrous; hypocotyl up to 5 mm long, epicotyl absent or extremely short.

Growth and development A single plant of goatweed can produce up to 40 000 seeds. There is no marked dormancy and germination is promoted by light and inhibited by burial. Seed of *A. conyzoides* can germinate at comparatively low temperatures (10–20°C), which explains its occurrence at higher altitudes, whereas maximum temperature for germination is around 30°C. For seed of *A. houstonianum*, the minimum temperature for germination is reported as 20°C and the maximum temperature 35°C.

The life cycle can be completed in less than 2 months. Flowers and fruits may be present throughout the year. The occurrence of male sterility has been documented for both *A. conyzoides* and *A. houstonianum*. The usually male fertile *A. conyzoides* is self-pollinated and cross-pollinated by insects. *A. houstonianum* has been reported as self-incompatible. Fruits are dispersed by wind but may also cling to the fur of animals.

Other botanical information *A. conyzoides* and *A. houstonianum* are closely related, and the latter has even been considered as merely a variety of the former (*A. conyzoides* var. *houstonianum* (Miller) Sahu). Although both resemble each other closely and are often confused, there are some reliable morphological distinguishing characteristics, particularly in the involucral bracts and leaf-bases. There are also minor differences in number of flowers per head (on average more in *A. houstonianum*), and length of corolla, anthers and style (on average longer in *A. houstonianum*). Both grow in similar habitats and both may become weeds. *A. conyzoides* has a short-day ecotype and a day-neutral ecotype.

Several cultivars of *A. houstonianum* are popular garden plants, e.g. cultivar 'Blaue Donau' in Europe.

Ecology Goatweed can be found from sea-level up to 2500 m altitude. It is a very common weed in numerous annual and perennial crops. It commonly grows in roadsides, waste places and grassy fields. In shifting cultivation in Thailand, *A. conyzoides* is one of the dominant species in the second year after clearing of the forest, together with *Chromolaena odorata* (L.) R. King & H. Robinson. *A. houstonianum* has a more restricted altitudinal range than *A. conyzoides*; in Java it occurs up to 1700 m altitude.

Propagation and planting Propagation by stem cuttings is more efficient in *A. houstonianum* than by seed or root, resulting in rapid growth and reproduction. Protoplasts have been isolated from leaves, stems and callus of *A. houstonianum*, and callus has regenerated.

Diseases and pests *A. conyzoides* is the host to several pathogens causing serious diseases in commercial crops: for *Pseudomonas solanacearum* attacking Irish potato in India and for the nematodes *Meloidogyne incognita* (despite the reported nematicidal activity against the same species) and *M. javanica* causing yellowing and wilting in black pepper and vegetables in the Philippines and *Pratylenchus* sp. attacking upland rice in the Philippines. A geminivirus called ageratum yellow vein virus, which is transmitted by the whitefly *Bemisia tabaci*, causes a vein-yellowing disease in *A. conyzoides*; it has been reported from Malaysia and Singapore. A similar virus, the tobacco krupuk virus, is reported for Indonesia. *A. conyzoides* is a host of cotton bollworm in Thailand and for *Nysius inconspicuous* in India (a pest on sesame). *A. houstonianum* has been reported in India as a host for green scale (*Coccus viridis*) which is a major pest of coffee.

Both species are important weeds in arable and plantation crops. The lepidopterous insect *Paurauchaetes pseudoinsulata* can complete its life cycle on *A. conyzoides* and might be a promising agent to control this species biologically in areas where it is a serious weed.

Genetic resources and breeding Both goatweed species are widespread in anthropogenic habitats, suggesting a broad genetic variability. The existence of different photoperiodic ecotypes is of interest for breeding, as it provides an opportunity to obtain planting material adapted to specific conditions. Breeding programmes could focus on optimum medicinal and insecticidal activity which is reflected in high concentrations of active compounds such as precocenes. The breeding value of male sterility is rated as low.

Prospects Goatweed has several widespread and comparatively well-documented medicinal applications. It has outstanding prospects as an insecticide. The insecticidal properties offer possibilities for the control of mosquitoes that are vectors of malaria and filariasis, and for the control of insects like locusts, bugs and mites. The effect on phytophagous mites in citrus deserves further research. Goatweed is easy to cultivate, which makes it suitable for large-scale production for industrial use as well as for home gardening for local use.

Since goatweed establishes spontaneously, it is a cheap and beneficial soil cover crop. Moreover, certain forms of goatweed are attractive ornamental plants.

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Selection of species

Ageratum conyzoides L.

Sp. pl. 2: 839 (1753).

Vernacular names Goatweed (En). Eupatoire bleue (Fr). Indonesia: babadotan (Sundanese), wedusan (Javanese), dus-bedusan (Madurese). Malaysia: tahi anjing, rumput pereh jarang, rumput sekedok (Peninsular). Philippines: bulakmanok (Tagalog), singilan (Iloko), bahug-bahug (Panay Bisaya). Thailand: thiam mae haang (Loei), saapraeng saapkaa (Chiang Mai), ya saap raeng (Ratchaburi). Vietnam: c[aa]y b[oo]ng c[uws]t heo, c[aa]y hoa c[uws]t l[owj]n, c[aa]y b[oo]ng th[us]i.

Distribution Originating from Central and South America, but now a pantropical weed that is very common throughout India, Burma (Myanmar), Indo-China, southern China, Thailand and Malesia.

Uses The most widespread medicinal uses are externally to heal wounds and to treat skin diseases, and internally to treat diarrhoea, as a febrifuge and as an anti-allergenic agent. The plant yields an insecticide. It is sometimes planted as a ground cover in plantations, e.g. of rubber and citrus.

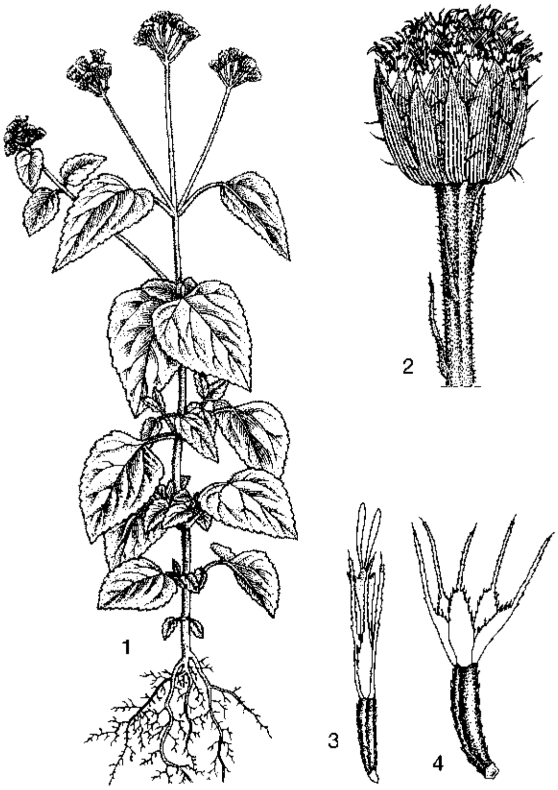
Observations An annual erect herb, at the base sometimes decumbent and rooting, up to 120(–150) cm tall, stems with rather long hairs on the nodes and younger parts; leaves ovate, triangular-ovate or rhomboid-ovate, (0.5–)1–10 cm × 0.5–7 cm, with obtuse or rounded base; head 4–6 mm long, 60–75-flowered, outermost involucral bracts beset with only simple eglandular hairs, inner involucral bracts with abruptly contracted apex; corolla 1–2.5 mm long; fruit glabrous or very sparingly hairy. *A. conyzoides* is very common in fields, roadsides and waste places up to 2500 m altitude.

Selected sources 18, 96, 156, 202, 332, 350, 383, 495,496, 549, 580, 597, 614, 616, 685, 713, 876, 928, 929, 996, 1034, 1035, 1090, 1126, 1131, 1178, 1246, 1268, 1294, 1324, 1386, 1408, 1517, 1570, 1593, 1659.

Ageratum houstonianum Miller

Gard. dict. ed. 8: Ageratum No 2 (1768).

Synonyms *Ageratum mexicanum* Sims (1825).



Ageratum conyzoides L. – 1, plant habit; 2, flowering head; 3, flower; 4, fruit with pappus.

Vernacular names Goatweed (En). Probably many of the vernacular names listed under *A. conyzoides* also refer to *A. houstonianum*.

Distribution Originating from Central America, but cultivated in tropical, subtropical and temperate regions. It is found naturalized in many warmer regions including China, India and locally in South-East Asia (e.g. Peninsular Malaysia, Java, the Philippines, Vietnam).

Uses Probably *A. houstonianum* has similar medicinal applications as *A. conyzoides*, but there is little information in literature about its actual uses. The plant yields an insecticide, and it is commonly planted as ornamental.

Observations An annual erect herb, at the base sometimes creeping and rooting, up to 70(–90) cm tall, stems clothed with patent white hairs; leaves subtriangular, ovate to deltoid, 2–8.5(–9.5) cm × (1.5–)3–6.5(–8) cm, with cordate to truncate base; head 5.5–7 mm long, 75–100-flowered, outermost involucral bracts with both simple hairs and shorter glandular hairs, inner involucral bracts gradually tapering into an acute apex; corolla 2.5–3 mm long; fruit hairy. *A. houstonianum* is locally common in fields, roadsides and waste places up to 1700 m altitude.

Selected sources 96, 232, 549, 614, 685, 929, 966, 1073, 1175, 1268, 1324, 1354, 1438.

Slamet Sutanti Budi Rahayu, Rina Ratnasih Irwanto & L.J.G. van der Maesen

Allium L.

Sp. pl. 1: 294 (1753); Gen. pl. ed. 5: 143 (1754).
ALLIACEAE

$x = 8$; *A. cepa*: $2n = 16$, *A. chinense*: $2n = 32$, *A. fistulosum*: $2n = 16$, *A. sativum*: $2n = 16$, *A. tuberosum*: $2n = 32$

Major species *Allium cepa* L., *A. sativum* L.

Vernacular names Onion (En). Indonesia: bawang.

Origin and geographic distribution *Allium* comprises 500–700 species and is mainly distributed in the Northern Hemisphere. Centres of diversity are in regions that are seasonally dry, particularly around the Mediterranean in Europe, in central Asia and North America. The Malesian region has no indigenous species, but several introduced species are cultivated.

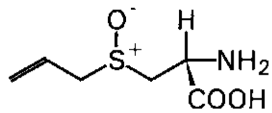
Uses *Allium* species have been used since antiquity for their antiseptic properties. Besides its antibacterial properties, onion (*A. cepa*) juice is known for its diuretic, lipid- and blood-pressure lowering and anti-asthmatic/anti-allergic properties. Onion is used in traditional medicine to treat boils, wounds, stings and felons externally, and internally to relieve coughs, bronchitis, asthma, gastro-intestinal disorders (e.g. flatulence, diarrhoea) and headache.

Garlic (*A. sativum*) is valued worldwide as a 'panacea' to cure an array of diseases and to strengthen the body. Phytotherapeutical products based on garlic are traditionally used to treat minor vascular disorders. Garlic is recommended against high blood pressure. Oral administration of garlic (and, to a lesser extent, onion) juice or oil has been reported to prevent hyperlipemia, arteriosclerosis and myocardial infarction. Other traditional uses include the treatment of coughs, bronchitis and gastro-intestinal disorders (flatulence). Garlic oil is used as rubefacient (to treat muscle pains, lumbago, arthritis and ischias) and as vermifuge (especially against enterobiasis). Garlic juice is used externally in the treatment of *Taenia versicolor*, ringworms and chronic wounds. It is also believed that garlic juice promotes

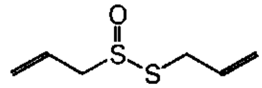
longevity and has aphrodisiac properties.
A. chinense ('rakkyo') is used against fever, stomach-ache and eye-infections. In China, it is reputed to be effective in the treatment of stenocardia, angina pectoris and so-called stagnant blood, and it is included in some traditional preparations. *A. tuberosum* (Chinese chives) is reportedly effective against tumours, toothache and intestinal disorders. Welsh onion (*A. fistulosum*) is considered to have strong stimulant properties.
Allium species are well known for their worldwide use as a vegetable and condiment, which often goes hand in hand with their attributed medicinal properties.

Production and international trade Onion (*A. cepa*) is economically the most important *Allium* crop in South-East Asia. In 1990 Indonesia produced about 500 000 t onion (mainly shallot) and 100 000 t garlic. In that year the Philippines exported 12 000 t onion and Thailand 18 000 t, but other countries of South-East Asia imported large amounts: Indonesia 16 000 t, Malaysia 125 000 t, Singapore 65 000 t (of which 34 000 t was re-exported), Brunei 2000 t and Papua New Guinea 2000 t. Shallot bulbs are traded fresh, fried or pickled, whereas garlic is sold fresh or dry and in the form of pills, drinks and powders based on extract.

Properties *Allium* species release characteristic odours when the tissue is damaged (the 'onion odour' or 'garlic odour'). They are known for their sulphur-containing compounds, such as S-alkyl-L-cysteine sulphoxides (alkyl is e.g. methyl, propyl, vinyl, allyl) and γ-glutamyl-S-alkyl-cysteines.
The main constituent of fresh undamaged garlic is alliin (S-allyl-L-(+)-cysteine sulphoxide, > 0.3%), which is degraded by the enzyme alliinase (C-S-lyase) to pyruvic acid and 2-propenesulphenic acid upon cutting or bruising the tissue (alliin and alliinase are localized in separated compartments in the undamaged plant material). 2-Propenesulphenic acid is immediately transformed into allicin (diallyldisulphide-mono-S-oxide). Air oxidation of allicin leads to diallyldisulphide (1,7-dithiaocta-4,5-diene), which is the chief constituent of garlic volatile oil, and together with related tri- and oligosulphides is responsible for the characteristic garlic smell. Allicin condensation products such as ajoenes and vinyldithiines are also present in alcoholic garlic extracts. The drug also contains carbohydrates (fructans) and steroidal saponins.
Fresh onion bulbs also contain fructans, and also flavonoids and sulphur compounds (trans-(+)-S-(1-propenyl)-L-cysteine sulphoxide (about 0.2%) and other cysteine derivatives). Upon bruising the bulb, the sulphoxides are degraded by alliinase to release pyruvic acid and alkyl-thiosulphinates, which rapidly turn into disulphides, the predominant compounds in *A. cepa* extracts. The volatile aliinase split product (Z)-thiopropanal-S-oxide (from trans-(+)-S-(1-propenyl)-L-cysteine sulphoxide) is the well-known lacrimatory factor in onions.



alliin



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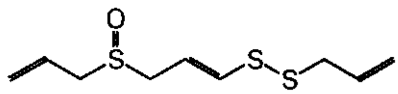

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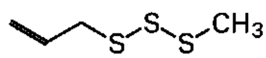

methyl-allyl-trisulphide

The growing conditions affect the proportion of different thiosulphinates; for instance, garlic grown in cooler climates shows a higher allyl to methyl ratio than garlic grown in warmer climates.
Several effects of *A. cepa*, *A. sativum* and other *Allium* species have been well investigated. In in vitro experiments, garlic, onion and Chinese chives showed antibacterial and antifungal activity against both gram-positive and gram-negative bacteria (including enteropathogens), pathogenic yeasts (*Candida* spp.) and some skin-pathogenic fungi. In an in vivo study, rabbits and guinea-pigs with experimentally induced dermatophyte infections (*Microsporum canis*, *Trichophyton rubrum*) were treated locally with a garlic extract. After 7 days of treatment, it took another 7–10 days for the skin lesions to completely recover.
Tests with rabbits and rats demonstrated that garlic extract lowers blood cholesterol and triglyceride and also has antihypertensive and anti-hyperglycaemic effects. Onion juice has been shown

to have anti-hyperglycaemic activity and anti-asthmatic activity in guinea-pigs. Furthermore, the saponin fraction prepared from the methanolic extract of rakkyo bulbs, is reported to exhibit inhibitory activities on cyclic AMP phosphodiesterase and Na^+/K^+-ATPase. The action was almost as potent as that of papaverine; this makes the saponins interesting for their cardiotonic effect.

The best investigated activity, however, is the effect on thrombocyte aggregation. Garlic and onion extracts have been found to show in vitro activity against platelet aggregation. Excessive platelet aggregation is recognized to be a dangerous contributory factor to thrombosis and arteriosclerosis, possibly leading to myocardial and cerebral infarctions. Several compounds have been reported as active principles against thrombocyte aggregation; for instance, the activity has been attributed to the ajoenes (inhibiting lipoxygenases), but also to methyl-allyl-trisulphide (the inhibitory effect depends on the content of this compound in the oil). Dimethyl- and diphenylthiosulphinate (from *A. cepa*) inhibited thromboxane synthesis, whereas the acid amides N-p-coumaroyltyramine and N-trans-feruloyltyramine, lunularic acid and p-coumaric acid, all sulphurless compounds isolated from the ethylacetate-soluble fraction of *A. chinense* bulbs, were shown to inhibit prostaglandin and thromboxane synthetases. Compared with aspirin, the compounds from *A. chinense* were more potent. Adenoside was isolated from the n-butanol soluble fraction of *A. sativum* and *A. chinense* bulbs; it showed very significant inhibitory activity against the aggregation of human platelets in vitro. Finally, chinenosides (furostanol saponins from *A. chinense* bulbs) inhibited ADP-induced aggregation of human blood platelets, the effect being comparable to that of aspirin.

Clinical tests have been conducted (inhibition of thrombocyte aggregation, lipid-lowering activity), but the results are usually conflicting or inconsistent, possibly because of the non-standardized preparations or questionable protocols used. In a double-blind, placebo-controlled experiment on the inhibition of blood-platelet aggregation in a group of patients in which this parameter was constantly and/or spontaneously increased the results were significant. After taking a standardized garlic preparation (800 mg daily, containing 1.3% allicin) for a period of 4 weeks, the spontaneous thrombocyte aggregation disappeared, and several other parameters (e.g. microcirculation of the skin and plasma viscosity) improved. Furthermore, another placebo-controlled, double-blind experiment seemed to demonstrate the effectiveness of a standardized garlic powder (containing 1.3% alliin, 800 mg daily, administered for 4 months) as a blood-cholesterol lowering agent. Other trials seem to indicate a fibrinolytic activity for both garlic and onion.

An inverse correlation has been reported between regular consumption of garlic and onion and the risk of stomach cancer. S-allylcysteine has been found a chemopreventive agent for hepatocarcinogenesis in rats. From tests with mice it was suggested that garlic may provide an effective form of therapy for transitional cell carcinoma of the bladder. Other studies gave evidence of a direct effect of S-allylmercaptocysteine, one of the stable components present in aged garlic extract, on established cancer cells of breast and prostate.

In a test with alloxan diabetic rats, treatment with S-allyl-cysteine sulphoxide isolated from garlic ameliorated the diabetic condition almost to the same extent as did insulin. A garlic extract cured experimentally infected mice of trypanosomiasis in 4 days, with diallyldisulphide as the probable active compound. Garlic may improve arterial oxygenation and symptoms in patients with hepatopulmonary syndrome; this warrants further investigation. Extracts of *A. tuberosum* have been reported to have anti-tumour activity in vitro and in vivo.

Extracts of welsh onion showed allelopathic effects; in tests, they inhibited the growth of *Compositae* crops such as lettuce, marigold, *Aster* and *Chrysanthemum*. However, a 1% extract was highly effective in stimulating mycelial growth of the edible mushroom *Lentinus edodes*.

Description Perennial or biennial herbs, often grown as annual from bulbs or seed, up to 100(–150) cm tall; roots adventitious, up to 30 cm long; bulb usually present and distinct, with papery or chartaceous protective coats (tunics); real stem very short, forming a disk at the base of the bulb; pseudostem on top of bulb formed by the sheathing bases of successive leaves. Leaves basally concentrated but sometimes sheathing the scape for a considerable distance and then appearing cauline, alternate, often distichous, blades flat, terete, fistulose or angular, usually filiform-linear with acute apex, glabrous. Inflorescence umbellate, spherical or subspherical, on top of a terete or fistulose scape usually exceeding the leaves, initially surrounded by 2 hyaline bracts which are normally almost fused, composed of flowers, bulbils or both. Flowers bisexual, often with slender pedicel, actinomorphic, campanulate to urceolate; tepals 6, in 2 whorls, free or almost free; stamens 6, filaments inserted at the base of the tepals, anthers dehiscing with longitudinal slits; ovary superior, 3-locular, style simple, often subgynobasic. Fruit a globular capsule, splitting loculicidally, several-seeded. Seeds broad and triangular, often blackish and wrinkled after drying; embryo more or less curved.

Growth and development Bulbs of *Allium* species are formed from the lower parts of the leaf-sheaths, as a result of photosynthate mobilization from the leaf-blade to the base of the leaves. A bulb is only formed when the plant has reached a certain stage of growth and when the daylength is long enough and temperature sufficiently high. When the bulb has reached full maturity, the leaf-blades start to wither. The bulbils that are often present in the inflorescence can be useful for vegetative propagation, especially in taxa with poor seed-setting.

Pollination is by insects such as bees, bumble-bees and hover flies. Onion is a facultative cross-pollinator, the percentage of selfing amounting to 10–20%. Flowers are often protandrous. In Chinese chives, more than 90% of the seed develops apomictically. Flower induction is controlled by temperature and daylength, and for several species (particularly rakkyo, welsh onion, Chinese chives) flowering is rare in the tropics.

Other botanical information There are numerous cultivars, particularly of garlic and onion. Only short-day cultivars are of interest to the tropics. There is no appropriate cultivar classification for South-East Asia. The presumed wild ancestors and some related species of cultivated *Allium* have been determined, e.g. *A. longicuspis* Regel which is the presumed wild ancestor of garlic, and *A. altaicum* Pallas which is a closely related species of welsh onion.

Ecology Tropical shallot requires an average day temperature of 20–26°C and a daylength of at least 11 hours, whereas common onion prefers slightly lower temperatures and a daylength of at least 13 hours. In Indonesia, shallot is mainly grown in the lowlands below 450 m altitude, preferably on well-drained alluvial clay soil, whereas Chinese chives, welsh onion and garlic are grown in the highlands up to 2200 m altitude. Most tropical onions are grown during the dry season, as too much rain will result in a high incidence of fungal diseases. They require well-drained soils.

Propagation and planting Several *Allium* species (shallot, rakkyo) are commonly propagated by bulbs. To avoid problems of dormancy, the bulbs should first be stored for some months. Garlic is normally propagated by lateral bulbs (cloves) and seldom by bulbils from the inflorescence. In South-East Asia, welsh onion is propagated mainly from basal tillers, and Chinese chives by division of clumps. Propagation by seed may enhance the size and shape of bulbs and minimize diseases. The seed for propagating common onion is produced in the subtropics, where the climatic conditions are more favourable. Some cultivars are direct-seeded, whereas others are transplanted from nurseries where the seed is usually sown under a mulch. Planting distance varies according to species and conditions, but is usually 10–15 cm × 15–20 cm. Intercropping with other vegetables, e.g. hot pepper, carrot, Irish potato and mustard, is common.

Husbandry Weeds are often a serious problem and weeding should be done regularly; it is mostly done by hand, although chemical weed control is increasing. The crop must be irrigated regularly during dry weather. Organic and/or chemical fertilizers are generally applied. Crop rotation is important to avoid the build-up of diseases and pests such as *Fusarium*, *Sclerotium* and nematodes.

Diseases and pests Fungal diseases are common, particularly during the rainy season. *Alternaria*, *Fusarium*, *Stemphylium*, *Aspergillus* and *Colletotrichum* species may cause severe losses in onion. Viruses may also cause problems, which may be overcome by visually inspecting the planting material in the field and destroying any affected plants, or by the use of true-seed cultivars. Nematodes can be very harmful, especially in upland soils at higher altitudes, and without adequate crop rotation. Army worms (*Spodoptera exigua*) and thrips (*Thrips tabaci*) are reported as serious pests in shallot, common onion, welsh onion and garlic.

Harvesting Bulbs are often harvested after the leaves have wilted, usually 2–3 months after planting, but after 3–5 months in common onion and garlic. The bulbs are usually pulled out by hand, tied into bunches, and dried in the sun, usually with the bulbs covered by the leaves to protect them. Often, some bulbs are kept as planting material for the next growing season. Chinese chives is a ratoon crop: leaves are harvested repeatedly from the same plants the year round.

Yield Yields of common onion in South-East Asia range from 7–20 t/ha; average yields of shallot (6 t/ha), rakkyo, welsh onion (7 t/ha) and garlic

(2.5–4.5 t/ha) are generally lower.

Handling after harvest After drying, the bulbs (or plants of welsh onion) are tied into bunches which are sold directly or stored, often by hanging them on racks in well-ventilated places. For long-distance transport, the dry leaves are cut off and the bulbs are packed in bags or crates. The bulk of rakkyo is steeped in brine and subsequently processed into sweet or sour pickles. Chinese chives leaves are marketed as fresh as possible.

Genetic resources and breeding Germplasm collections of common onion, garlic and welsh onion are maintained at several institutes in Europe, the United States and Japan. Smaller collections of shallot and garlic are available at research institutes in South-East Asia, e.g. Lembang Horticultural Research Institute (LEHRI), Indonesia. Evaluation of the South-East Asian germplasm collections led to the recommendation of some local cultivars, e.g. of shallot. Breeding objectives are resistance to diseases and improvement of bulb quality and yield. It would be a breakthrough to find seed-producing selections, e.g. in rakkyo and garlic.

Prospects *Allium* species have an outstanding reputation as phytotherapeutic. The ability to inhibit thrombosis seems to be of remarkable medicinal value. The medicinal reputation might further stimulate the interest in *Allium* as vegetable as well. Some medicinal properties have been confirmed by in vitro tests, animal tests and/or clinical tests (e.g. antimicrobial activity, activity against platelet aggregation, blood cholesterol lowering activity), but other attributed properties (e.g. diuretic activity, anti-cancer activity) have not been demonstrated conclusively. Well executed clinical tests with standardized preparations are needed to confirm these properties. Garlic has potential for the preservation of processed foods because of the inhibitory activity against pathogenic bacteria such as *Salmonella typhi* and *Escherichia coli*.

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Selection of species

Allium cepa L.

Sp. pl. 1: 300 (1753).

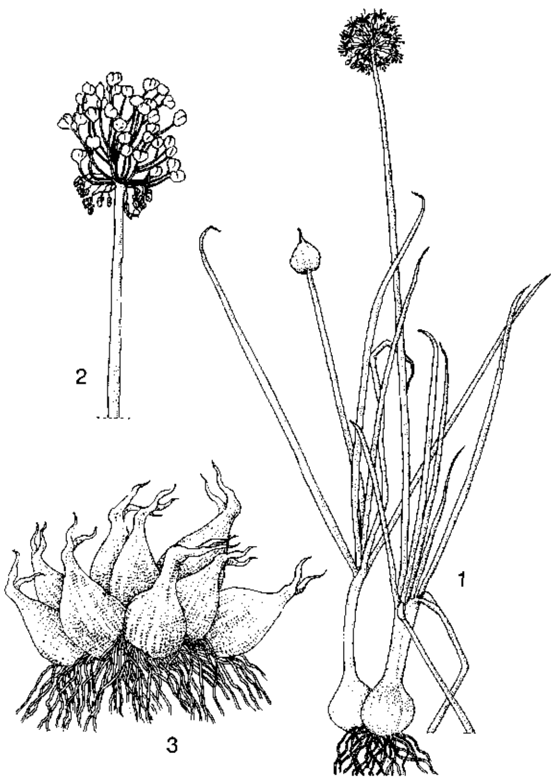
Vernacular names Onion, common onion, shallot onion (En). Echalote, oignon (Fr). Brunei: bawang besar. Indonesia: bawang merah, bawang beureum, bawang bombay. Malaysia: bawang merah, bawang kecil, bawang besar. Papua New Guinea: lip anian, anian (Pidgin). Philippines: sibuyas tagalog (Tagalog), bauang pula (Tagalog), lasona (Iloko). Cambodia: khtüm krâhââm, khtüm barang. Laos: hoom bwàx, bwàx fàlangx. Thailand: hom farang, hom hua yai (central). Vietnam: h[af]nh t[aa]y, h[af]nh c[ur], h[af]nh t[aw]m.

Distribution Probably originating from central Asia, but nowhere truly wild. Cultivated all over the world; cv. group Aggregatum (shallot) predominates in the tropical lowland of South-East Asia, but cv. group Common Onion is grown in the

Philippines, Papua New Guinea and Thailand.

Uses Onion plays an important role in traditional medicine; it is used as diuretic and suppresses the blood sugar level and platelet aggregation. Shallot is used traditionally as febrifuge and as a poultice to cure wounds. In the Philippines the bulbs are considered anthelmintic and stomachic, and used to treat diarrhoea, headache, earache and amenorrhoea. Shallot stimulates the appetite.

Observations A biennial herb, usually grown as an annual, up to 100 cm tall; mature bulb up to 15 cm in diameter; leaves 3–8, blades semiterete, at first solid, later becoming hollow, glaucous; scape 1-several, terete, often inflated in the middle or in the lower part, hollow, inflorescence with up to 2000 flowers; flowers with greenish-white to purplish tepals, stamens sometimes slightly exceeding tepals, style shorter than stamens at anthesis; fruit 4–6 mm in diameter, containing up to 6 seeds; seeds about 3 mm × 2 mm. In cv. group Common Onion the bulbs are large and normally single, and plants reproduce from seed or from seed-grown bulbils; in cv. group Aggregatum (shallot) the bulbs are smaller, several to many forming an aggregated cluster, and plants reproduce vegetatively via lateral bulbs.



Allium cepa L. cv. group Aggregatum – 1, flowering plants; 2, inflorescence; 3, mature bulbs.

Selected sources 76, 193, 205, 332, 549, 977, 1178, 1356, 1446.

Allium chinense G. Don

Mem. Wernerian Nat. Hist. Soc. Edinb. 6: 83 (1827).

Synonyms *Allium bakeri* Regel (1875), *Allium schoenoprasum* auct. non L.

Vernacular names Rakkyo (En). Indonesia: bawang ganda. Malaysia: lokyo. Thailand: krathi-am-chin (Bangkok), hom-prang (central), hom-paenyuak (northern). Vietnam: ki[eej]u.

Distribution Native to central and eastern China; widely grown in China and Japan and to a limited extent in South-East Asia.

Uses Medicinally, the bulbs are of interest in the prevention of thrombosis. They are used for the treatment of heart failures in Chinese medicine. Rakkyo is also used against fever, stomach-ache and eye infections.

Observations A biennial herb, up to 60 cm tall; bulb ellipsoid, up to 4 cm × 1.5 cm; leaves 3–4(–5), D-shaped or nearly triangular in transverse section, 3–5-ridged; scape terete, solid, inflorescence with up to 30 flowers, without bulbils; flowers with purplish tepals, stamens and style much longer than tepals.

Selected sources 76, 205, 490, 549, 799, 1081, 1082, 1123, 1356.

Allium fistulosum L.

Sp. pl. 1: 301 (1753).

Synonyms *Allium bouddhae* O. Debeaux (1877), *Allium bakeri* Hoop. (1929) non Regel.

Vernacular names Welsh onion, (Japanese) bunching onion, spring onion (En). Ciboule (Fr). Indonesia: bawang daun, bawang bakung (Sundanese), bawang oncang (Javanese). Malaysia: daun bawang. Philippines: buyah (Ifugao). Cambodia: khtüm sânlök. Thailand: hom-ton (central), hom-cheen (peninsular). Vietnam: h[af]nh hoa, h[af]nh h[uw][ow]ng.

Distribution Probably originating from north-western China, but nowhere truly wild; cultivated all over the world.

Uses The therapeutic qualities attributed to the welsh onion are many, especially in Chinese medicine. It is used to improve the functioning of internal organs and the metabolism, and to prolong life. It is further reported to improve eyesight, to aid digestion and perspiration, and to enhance recovery from common colds, headaches, wounds and festering sores. The plants are said to reduce or prevent white ant infestation in gardens, and in China the diluted juice is used against aphids.

Observations A perennial herb, usually grown as an annual or biennial, up to 150 cm tall; bulb indistinct, gradually passing into the scape; leaves 4–12 (actively growing green leaves 3–6), blades terete, hollow, bluish-green; scape 1, terete, hollow, inflorescence composed solely of flowers or of bulbils; flowers with greenish-white to white tepals, stamens and style much longer than tepals; fruit about 5 mm in diameter; seeds 3–4 mm × 2–2.5 mm.

Selected sources 76, 205, 549, 1356.

Allium sativum L.

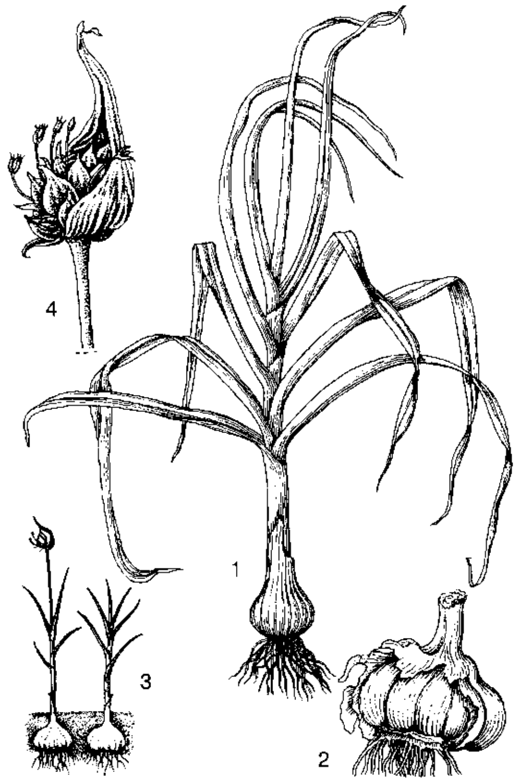
Sp. pl. 1: 297 (1753).

Vernacular names Garlic (En). Ail (Fr). Indonesia: bawang putih, bawang bodas (Sundanese). Malaysia: bawang putih. Papua New Guinea: galik (Pidgin). Philippines: bawang (Tagalog, Ilocano), ajos (Bisaya), ahus (Ibanag). Cambodia: khtüm sââ. Laos: kath'ièm. Thailand: krathiam (general), hom-tiam (northern). Vietnam: t[or]i.

Distribution Probably originating from central Asia (Tien Shan), but nowhere truly wild; cultivated all over the world at latitudes between 5–50° in both hemispheres.

Uses Garlic is much valued as a medicinal crop. It has a strong reputation for lowering the blood sugar and cholesterol levels and inhibiting thrombus formation. It is used externally to cure headache, insect bites, rheumatism and toothache, and a decoction internally as febrifuge. Leaves and bulbs are considered to have hypotensive, carminative, antiseptic, anthelmintic, diaphoretic and expectorant properties. Many attributed prophylactic activities are questionable, but have resulted in a rich supply of and demand for medicinal pills, drinks and powders based on garlic extracts.

Observations An erect herb, usually grown as an annual, up to 150 cm tall; bulb composed of (1–)4–15 lateral bulbs (cloves), up to 7 cm in diameter; leaves 4–10, blades flat or V-shaped in transverse section; scape 1, solid, inflorescence composed solely of bulbils or of bulbils and flowers; flowers often rudimentary or absent, with greenish-pink to purplish tepals, stamens and style shorter than tepals; fruit abortive, seedless. Two groups of cultivars are often distinguished: cv. group Common Garlic with a straight scape, and



Allium sativum L. – 1, plant habit; 2, bulb; 3, plantlets; 4, inflorescence.

cv. group Ophioscorodon (rocambole or serpent garlic) with a scape having a distinct curve or coil towards the top.

Selected sources 5, 76, 82, 193, 205, 332, 549, 729, 794, 825, 883, 1046, 1081, 1178, 1231, 1356, 1357, 1440, 1446.

Allium tuberosum Rottler ex Sprengel

Syst. veg. 2: 38 (1825).

Synonyms *Allium uliginosum* G. Don (1827), *Allium senescens* Miq. (1867), *Allium odorum* auct. non L.

Vernacular names Chinese chives (En). Indonesia: kucai. Malaysia: kuchai. Philippines: kutsay (Tagalog), ganda (Bisaya), amput di imayyaw (Ifugao). Cambodia: kachaay. Thailand: kuichai (Bangkok), hom-paen (northern). Vietnam: h[ej], n[es]n t[af]u.

Distribution Probably native in eastern Asia; cultivated in the United States, Nepal, India, China, Taiwan, Korea, Japan, Indo-China, Thailand, Indonesia and the Philippines.

Uses Chinese chives is used medicinally against tumours and intestinal disorders, as a stomachic and as bactericide in pulmonary infections, and is considered to promote recovery from fatigue. Leaves and bulbs are used in the Philippines as antiseptic and vulnerary. The seed is used in Thailand and Indo-China against toothache, as an antiseptic mouthwash.

Observations A perennial herb forming dense clumps, up to 50 cm tall; bulb indistinct, narrowly ovoid, about 2 cm × 1.5 cm; leaves 4–9, blades flat above, slightly keeled below; scape 1, compressed, solid, inflorescence many-flowered, without bulbils; flowers with white tepals, stamens and style about as long as tepals; fruit 5–6 mm in diameter; seeds 3–4 mm long.

Selected sources 76, 205, 332, 549, 778, 1035, 1178, 1356.

Diah Sulistiarini, Juliasri Djamal & Iman Raharjo

Aloe L.

Sp. pl. 1: 319 (1753); Gen. pl. ed. 5: 150 (1754).

ASPHODELACEAE

$x = 7$; *A. ferox*, *A. vera*: $2n = 14$

Major species *Aloe vera* (L.) Burm.f.

Vernacular names Aloe (En). Indonesia: lidah buaya. Vietnam: l[oo] h[ooj]i.

Origin and geographic distribution The approximately 330 species of *Aloe* originate from Africa, Madagascar and Arabia. The centres of diversity are South Africa (Transvaal) and the region of Eritrea, Ethiopia and northern Somalia. Over 100 species are cultivated and there is an overwhelming number of hybrids and cultivars. All Malesian *Aloe* have been introduced and are popular garden and pot plants. *A. vera* was formerly produced on Barbados, where it had been introduced early in the 16th Century. Nowadays, it is cultivated commercially in the United States, Mexico, the Caribbean, Israel, Australia, Thailand and South Kalimantan. Commercial plantations of *A. ferox* have been established in Albertinia in South Africa.

Uses *Aloe* juice, contained in the pericyclic cells of the vascular bundles in the leaf, is used to make the laxative drug known as 'aloe', 'aloes' or 'bitter aloes'. *Aloe* gel, the mucilage from polyhedral cells in the central part of the leaf, is claimed to have healing properties as well.

The three main types of commercial aloe drug are 'Curaçao aloe', from *A. vera*, 'Cape aloe', mainly from *A. ferox* and 'Socotrine aloe', from *A. perryi* Baker. Aloe was already known to the Greeks as early as the 4th Century B.C. The drug was used by Alexander the Great, Dioscorides, Celsus and Pliny and by later Greek and Arabian physicians. It is used as a laxative, purgative and vermifuge. An ordinary dose takes 15–18 hours to produce an effect. It acts mainly on the large intestine. The effect of aloe can be strong, and nowadays it is used in combination with weaker purgatives or antispasmodic drugs. 'Cape aloe' has more powerful purgative properties than the other two; 'Socotrine aloe' is the mildest. In Thai traditional medicine, aloe is always included in the drug recipe because traditional doctors believe that patients will recover faster if unwanted material is expelled from the body. Both 'Curaçao aloe' and 'Cape aloe' are used for veterinary purposes in Europe.

Externally, aloe gel has proven effective in the treatment of skin burns by X-ray radiation. Furthermore, *A. vera* gel has gained popularity as a folk remedy worldwide, and numerous claims have been made for its medicinal properties. However, experimental results only support its applications for wound healing, treatment of burns, anti-inflammatory and diabetic activities. *A. vera* gel has been approved by the US Federal Drug Administration only for first aid treatment of burns and cuts. *Aloe* gel is widely used as a hydrating and skin-protecting agent in creams and liquids such as sun lotion, shaving cream, lip balm and healing ointments. It is also gaining importance as a refreshing and nutritive ingredient in food and drinks in Indonesia and Thailand.

Many other *Aloe* species are popular pot plants or garden ornamentals in the Malesian region (e.g. *A. arborescens* Miller, *A. saponaria* (Aiton) Haw.). Apart from their ornamental value they are often used in folk medicine as hair lotion and to promote wound healing. The sticky leaf sap of *A. camperii* Schweinf. is reported to be used in Papua New Guinea to treat severe burns. In Vietnam, an *Aloe* species is applied as a laxative and emmenagogue, whereas the leaves are eaten cooked with sugar or made into a potage.

Production and international trade In 1992 the local *Aloe* industry based on *A. ferox* in South Africa was worth about US$ 0.5 million. Though considerable quantities are marketed and used locally, most of the 'Cape aloe' produced in South Africa is exported to Europe, especially to Italy, France and Germany.

The international market for *Aloe* gel is not very open. Most gel is bought by the cosmetic industry which demands high quality. An export permit is compulsory because all *Aloe* species are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II.

Properties The aloe drug contains 15–40% aloe-emodin-anthrone 10-C-glucosides (hydroxy-anthraquinone derivatives) such as aloin, hydroxyaloins and (in *A. ferox*) aloinoside. Aloin, sometimes referred to as barbaloin, is a mixture of aloin A and aloin B, which interconvert through the anthranol form. Furthermore, the juice contains a pyrone derivative (aloenin) and resins: free and 8-C-glucosylated-2-acetonyl-7-hydroxy-5-methylchromones (e.g. aloesone, furoaloesone, aloeresin A, aloeresin B (aloesin) and aloeresin C). *A. ferox* also contains free or glycosylated feroxidin (a tetralin) and feradolide (a dihydroisocoumarin). 'Cape aloe' drugs must contain at least 18% hydroxy-anthraquinone derivatives, 'Curaçao aloe' at least 28%. 'Curaçao aloe' is almost entirely soluble in 60% alcohol and does not contain more than 30% of substances insoluble in water. It should not contain more than 12% moisture and 3% ash. 'Cape aloe' should not contain more than 12% moisture and 2% ash, and should have a water-soluble fraction of at least 45%.

The compound responsible for the laxative properties is aloin. Experiments with rats have shown that aloin itself is inactive as a laxative, but that it is activated to aloe-emodin anthrone, a purgative component, by *Eubacterium* sp. In the diarrhoea induced by aloin, the increase in water content might be a more important factor than the stimulation of peristalsis. Daily and prolonged use of laxatives of this type may lead to serious problems, such as dependence and 'cathartic colon'. Anthraquinone laxatives should not be used longer than 8–10 days, or by children younger than age 12. Contra-indications for aloe drugs include pregnancy, breast-feeding, intestinal inflammations and haemorrhoids. Preferably, aloin should be administered together with an anti-spasmodic, to moderate its griping action. Possible side-effects of aloin include congestion and irritation of the pelvic organs. Anthranoid-containing laxatives such as aloe may play a role in colorectal cancer. There are some published data on the genotoxic potential of anthranoids, and there is evidence of a tumorigenic potential in rodents.

A. vera gel has earned a reputation as a miracle drug. It is very rich in water, but does not appear to contain very specific compounds. The major constituents are polysaccharides (pectins, hemicelluloses), plus amino acids, lipids, sterols and enzymes. It has been proven to be effective for burn treatment, because of its anti-inflammatory and wound-healing properties. The active constituents are aloctin A, aloctin B, bradykininase and magnesium lactate. Its healing properties may also be due to hydrating, insulating and protective activities resulting from the high water content. Furthermore, it has been claimed that acemannan, the major carbohydrate fraction of *A. vera* gel, has various therapeutic properties, including acceleration of wound healing, immune stimulation, anti-cancer and antiviral effects, and that acemannan may partly function through macrophage activation. In experiments with rats both topical and oral treatments with *A. vera* had a positive influence on the synthesis of glycosamino glycans, thereby beneficially modulating wound healing. The healing of dermal wounds in diabetic rats is also positively influenced by oral and topical application of *A. vera*. The antidiabetic effects of aloe gel probably have an influence on phases such as inflammation, fibroplasia, collagensynthesis and maturation and wound contraction. These antidiabetic effects have been confirmed in animal experiments. Subsequently, clinical trials in Thailand gave satisfactory results. Active constituents identified in this research were polysaccharides and glycoprotein. Besides the activities mentioned above, aloe gel also exhibited antiviral effects. a placebo-controlled, double-blind study showed that a topically applied *A. vera* extract of 0.5% in a hydrophylic cream is beneficial for patients suffering from psoriasis. It did not show toxic or any other objective side-effect. A clinical test with patients with advanced solid tumours, for whom no standard effective therapy is available, suggested that *A. vera* extract in combination with the immunomodulating neurohormone melatonin may produce some therapeutic benefits, at least in terms of stabilization of disease and survival.

Adulterations and substitutes Psyllium (*Plantago* spp.), which is a natural bulk laxative, is one of the substitutes for anthraquinone-containing laxative drugs such as aloe, that may cause dependency and/or cathartic colon. However, in Thailand, anthraquinone-containing preparations from *Senna alata* (L.) Roxb. and other *Senna* and *Cassia* species are also sometimes recommended as substitutes for aloe. *Centella asiatica* (L.) Urb. is recommended as a substitute for aloe gels in wound treatments. Its triterpenes have exhibited both wound healing and antibacterial activities.

Description More or less succulent shrubby perennials, often with very short stem and fleshy fibrous roots. Leaves arranged spirally in a rosette, sometimes distichous, linear to lanceolate or triangular, very thick and fleshy, sheathing at the base, margins usually sinuate-dentate, often spiny apically, sometimes entire, surface sometimes spiny, containing colourless, yellow, brown or purple sap. Inflorescence a pseudo-lateral, simple or branched, long-cylindrical raceme. Flowers bisexual, protandrous, pedicellate; tepals 6, usually connate into a tube, sometimes outer 3 free, fleshy, apices sub-acute to obtuse; stamens 6, in 2 rows of 3; ovary superior, 3-locular, style filiform, longer than stamens, stigma small. Fruit a loculicidal capsule, many-seeded. Seeds elongate and ovoid, grey or black, arillate.

Growth and development *Aloe* species follow the Crassulacean acid metabolism (CAM) pathway. CAM plants are able to fix CO_2 at night and to photosynthesize with closed stomata during the day, thus minimizing water loss under arid conditions. This, plus their succulent leaves, stems and the presence of a thick cuticle, makes them well adapted to dry conditions.

The flower morphology of *A. ferox* suggests that the flowers are pollinated by birds. However, in Africa honey bees also play a role in the pollination. *A. ferox* is self-incompatible and only a few flowers per raceme flower simultaneously, apparently to promote cross-pollination. The stamens are exserted in the morning, then wither and withdraw in the afternoon, whereas the style is exserted on the second day of anthesis. In Africa, *A. vera* flowers and fruits normally. In India and other areas outside its natural range, however, fruit formation is rare, and any fruits that do form have seeds which do not germinate. This failure to set fruit is presumed to be caused by pollen sterility and self-incompatibility.

Other botanical information *Aloe* was formerly (and sometimes still is) included in the family *Liliaceae* s.l. Nowadays, it is usually placed in *Asphodelaceae* and sometimes in a separate family *Aloeaceae*. *Aloe* and related genera like *Haworthia*, *Gasteria* and *Astroloba* can be distinguished by their succulent leaves, vascular bundles in a ring around ground parenchyma, a cap of aloin cells at the phloem pole, chemical properties of the often coloured and/or pungent sap, and the homogeneity of the chromosome composition. The numbers of species described in *Aloe* differs considerably and synonymy and names for subspecific rank are overwhelming. The names *A. vera* and *A. barbadensis* are still contentious among specialists.

Ecology *Aloe* grows in a wide range of climatic conditions. Though the root system is shallow, it can be grown under dry conditions. Waterlogging should be avoided and *Aloe* thrives best on well-drained, rich soils.

A. ferox is one of the dominant species in the 'succulent bushland' vegetation in South Africa. It is especially abundant on arid rocky hillsides up to about 1000 m elevation, where mean temperatures range from 27–31°C and annual rainfall from 50–300 mm. Severe drought is said to stop juice production.

Propagation and planting *Aloe* can be propagated vegetatively, through suckers, offsets or cuttings, or by seed.

In *A. vera* cultivation, vegetative propagation is usually preferred above propagation by seed, because of the poor seedling emergence and the faster initial growth of suckers. Water deficiency may lead to decreased sucker formation. Suckers can be cut from the mother plant when they are 15–20 cm long. They may be grown in a nursery during the first year. After transplanting, the distances between and within rows in large-scale *Aloe* plantations are usually at least 0.5 m.

In vitro reproduction of *Aloe* is also possible, but has received little attention. With *A. ferox*, only plant regeneration from root and embryo tissue has succeeded. In the case of *A. vera*, micropropagation through in vitro culture of vegetative meristems, as well as in vitro regeneration of leaf base explants appears to be possible.

In vitro production of active compounds Aloin, aloesin and aloeresin have been found in *A. ferox* plantlets regenerated in vitro from root and embryo tissue, but could not be detected in the callus.

Husbandry *Aloe* species need to be left 2–3 years after transplanting before they can be used to obtain juice. However, for the production of gel in Thailand the first cut is made 6–12 months after transplanting. Weeding may be carried out mechanically or chemically; glyphosate is reported not to cause damage to *A. vera*. As the formation of too many suckers may retard growth and reduce yields of the mother plant, early removal of suckers is recommended, to obtain larger leaves. Water requirement for gel production is much higher than that for juice production, as gel yields are directly related to the amount of water available for the crop. Therefore, gel production may be increased through irrigation. The application of nitrogen may result in higher gel yields, because of faster leaf formation and higher yields per leaf. However, applying large amounts of water and nitrogen may reduce gel quality. Other cultural practices that may favour leaf production are mulching, shading and furrow cultivation.

Diseases and pests No serious diseases are known for *A. vera*. In India, *Alternaria alternata* and *Fusarium solani* are causes of leaf spot disease. In Aruba, leaf rot caused by *Erwinia chrysanthemi* occurs occasionally.

Harvesting *Aloe* juice is often collected by cutting off the leaves transversely close to the stem and positioning them in such a way that the juice drains into pots, tubs, vessels or even a simple canvas placed over a depression. The juice may also be obtained by squeezing the leaves or by warm or cold water retting. In South Africa, *A. ferox* is preferably tapped during the rainy season, because then the juice is more abundant, but tapping is also carried out in other periods of the year, except for the driest months. The leaves are usually cut in the morning and it takes 4–5 hours for the juice to drain from a pile of leaves. Only older leaves are cut; younger ones and growing tips are spared. In *A. ferox* in South Africa, the aloin content of the leaf juice was found to differ markedly between provenances. Large variations in aloin content have been found in *A. vera* too, with the highest concentration in exudates from younger mature leaves.

Aloe gel is obtained after eliminating the outer tissues of the leaf. In Aruba, gel is obtained by cutting open the leaves lengthwise and scraping the gel from the leaf blade. The youngest leaves (< 25 cm) are not suitable because of the small amount of gel, but the leaves should not be too old, because gel quantity and quality may decline. Individual *A. vera* leaves in Aruba reach their maximum fresh weight after about 40 weeks of growth. In a system where only selected leaves are cut, the possibilities for mechanical harvesting are limited.

Yield In Aruba, *A. vera* plants can produce 16–20 leaves per year under optimal moisture supply and sufficient nitrogen fertilization. With a plant density of 50 000 plants/ha and an average fresh leaf weight of 0.2 kg, this implies a gel yield of 160–200 t (560–840 kg dry matter) per ha.

Handling after harvest Collected *Aloe* juice is usually concentrated by boiling and then cooling. 'Curaçao aloe' may also be vacuum evaporated and then concentrated. On cooling, a solid, amorphous extract forms, which constitutes the drug. Its appearance varies with the concentration process used and the species. If the juice has been concentrated slowly, for instance in the sun or over a low fire, the cooled extract is opaque and waxy ('hepatic aloe') and aloin crystals are visible under the microscope. If, on the other hand, the juice has been concentrated rapidly, for instance over a fierce fire, the cooled extract is semi-transparent ('glassy aloe') and no aloin crystals are visible under the microscope. Aloe from *A. vera* is usually 'hepatic', aloe from *A. ferox* 'glassy'. Collected gel in Aruba is purified by centrifugal removal of cell wall material, and the liquid pure gel is stabilized by adding chemicals.

Genetic resources and breeding As a result of the continuous vegetative propagation, the genetic variability within *A. vera* in cultivation seems to be rather small. Nevertheless, high-yielding plants of *A. ferox* and *A. vera* may be selected and propagated for commercial cultivation. Many *Aloe* species hybridize in the wild if their area of distribution and period of flowering overlap, and it is easy to produce hybrids in cultivation. Because of their popularity as a greenhouse plant various *Aloe* species are potentially at risk of extinction. No germplasm collections and breeding programmes are known to exist.

Prospects *A. vera* and *A. ferox* might be potential crops in arid regions. *A. vera* is of particular interest, since its gel can be used in burn and wound care. It still remains beneficial as a household remedy: fresh gel can easily be prepared and applied to the wound. In its use as a laxative, however, the drug is tending to be replaced by other laxatives such as purified anthraquinones from *Cassia* and *Senna* species and bulk laxatives as from *Plantago* spp.

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Selection of species

Aloe ferox Miller

Gard. Dict. ed. 8: n. 22 (1768).

Vernacular names Cape aloe (En).

Distribution Indigenous over a vast area in South Africa. Plants introduced in the Malesian region probably originate from the Dutch East India Company's garden in the Cape. *A. ferox* is cultivated in Java.

Uses *A. ferox* is the source of 'Cape aloe'. Medicinal uses of fresh *A. ferox* in South-East Asia are probably similar to those reported for *A. vera*. In Africa, the inspissated leaf juice is used as a purgative in human and veterinary medicine and fresh juice is applied in cases of ophthalmia and syphilis. The flower nectar is said to be narcotic. The leaves have also been used in South Africa to make a jam tasting like watermelon jam.

Observations A perennial succulent shrub, up to 3(–5) m tall, usually with a single stem, densely covered with the persistent remains of the old leaves; leaves 50–60 in a dense capitate rosette, lanceolate, up to 100 cm × 15 cm, fleshy, upper surface flat, lower surface convex, smooth to spiny, margins sinuate-dentate, dull green, sometimes tinged red; inflorescence branched with 5–8 erect racemes, racemes very densely flowered, 50–80 cm × 9–12 cm; flowers with a dark red to orange perianth, filaments and style exserted. In its native area *A. ferox* is a rather variable species.

Selected sources 202, 350, 580, 596, 900, 1084, 1180, 1218, 1219, 1222, 1510, 1554, 1574, 1584.

Aloe vera (L.) Burm.f.

Fl. ind.: 83 (1768).

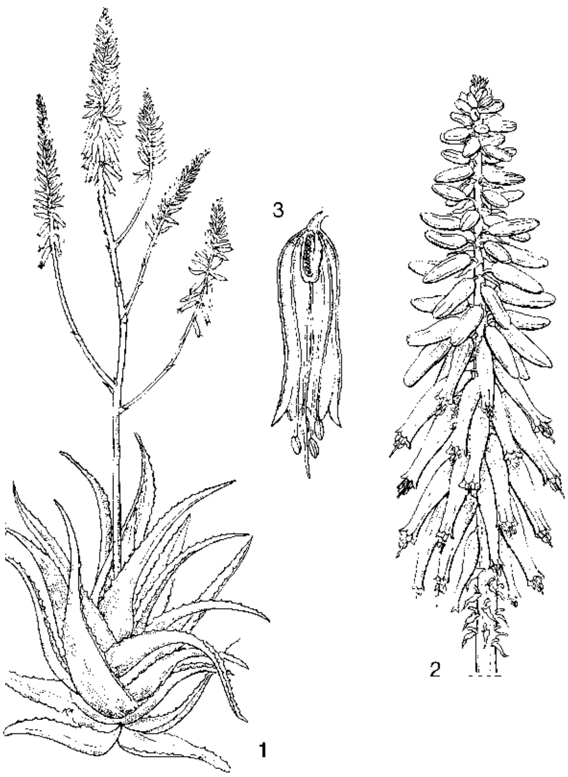
Synonyms *Aloe perfoliata* L. var. *vera* L. (1753), *Aloe barbadensis* Miller (1768).

Vernacular names Barbados aloe, Curaçao aloe (En). Indonesia: lidah buaya. Malaysia: lidah buaya (Peninsular), bunga raja raja (Sabah). Philippines: sabila (Tagalog), dilang-buwaya (Bikol), dilang-halo (Bisaya). Thailand: waan faimai (northern), waan hang chorakhe, haang takhe (central). Vietnam: l[oo] h[ooj]i, l[uw] h[ooj]i, nha d[ar]m.

Distribution Origin unknown; some authors presume the Macaronesian region, others prefer Arabia. At present *A. vera* is widely distributed throughout the tropics and subtropics. It was already common in India in the first Century AD. *A. vera* is grown as a pot plant and ornamental throughout Malesia.

Uses The fresh yellow leaf juice is often used as a laxative or purgative and refrigerant. Externally, it is often used to treat burns, wounds, abrasions, skin diseases, irritations and alopecia. Fresh *A. vera* has a multitude of medicinal applications in South-East Asia. The leaf sap or juice is applied externally to treat pimples, blackheads or cuts. The sap mixed with other ingredients to mask its bitter taste is taken in Indonesia against asthma and to treat coughs. In the Philippines, similar mixtures are taken to cure dysentery and kidney problems or against dyspepsia. In Indo-China, the fresh leaf juice is considered purgative, anthelmintic, depurative and an emmenagogue. In Papua New Guinea, the juice is used internally to treat stomach ulcers. The leaf gel or peeled leaves are generally externally applied to treat skin afflictions and as a poultice on contusions or as a general refrigerant. The gel may also be applied externally on haemorrhoids. It is furthermore used as a hairwash to promote hair growth and as a general cosmetic to improve the complexion and to smoothen the skin. Sometimes the peeled leaves are eaten to relieve sore throat and coughs and as a mild laxative. *A. vera* is the source of the 'Curaçao aloe' drug, which is used as a purgative, vermifuge, emmenagogue and stomachic. The aloe drugs ('jadam') used in Malaysia and South-East Asia are mostly imported. 'Jadam' is used as an aperient, but it is also put on wounds and swellings, and daubed on the abdomen in the case of fever and after confinement. Furthermore a dye can be obtained from the dried leaf sap.

Observations A perennial shrub, with very short stem, taproot 5–10 cm long with many sec-



Aloe vera (L.) Burm. f. – 1, plant habit; 2, part of inflorescence; 3, flower in longitudinal section.

ondary roots in the upper soil, freely suckering and forming dense groups; leaves about 16, erect to slightly spreading, narrowly triangular, 40–50 cm × 6–7 cm, upper surface grey-green to pale green with few to many spots, lower surface generally lighter, margin with firm deltoid pale teeth of 2 mm; inflorescence simple or sparsely branched, 60–100 cm tall, racemes 30–40 cm × 5–6 cm, densely flowered; flowers with yellow, orange or red perianth, stiffly pendulous, anthers and stigma exserted. The long history of cultivation has led to various selections that are sometimes given formal ranking.

Selected sources 27, 36, 97, 104, 143, 190, 193, 198, 199, 201, 202, 204, 216, 222, 223, 250, 251, 275, 287, 322, 323, 332, 350, 378, 408, 426, 439, 508, 509, 510, 531, 570, 580, 585. 587, 597, 602, 603, 638, 659, 669, 679, 847, 869, 900, 978, 979, 1035, 1084, 1126, 1128, 1178, 1192, 1218, 1219, 1222, 1248, 1256, 1269, 1355, 1426, 1429, 1430, 1451, 1476, 1506, 1574, 1575, 1635, 1651.

N.O. Aguilar & M. Brink

Alternanthera Forssk.

Fl. aegypt.-arab.: 28, lix (1775).

AMARANTHACEAE

x = unknown; *A. ficoidea*: $n = 34$, *A. philoxeroides*: $2n = 28, 100$, *A. sessilis*: $n = 17, 18, 20$, $2n = 34, 96$

Major species *Alternanthera sessilis* (L.) DC.

Origin and geographic distribution *Alternanthera* comprises approximately 150 species and is distributed in all tropical and subtropical regions, but the New World tropics are by far richest in species. Seven species have been found in Malesia, only one of which (*A. sessilis*) is indigenous; the other species have been introduced and are often locally naturalized.

Uses An infusion of the entire plant of *A. sessilis* is used in Indonesia as a remedy against intestinal cramps, diarrhoea and dysentery, and externally as a cooling agent to treat fever. In Malaysia it is used internally against intestinal inflammation and fever, and externally to treat wounds. *A. sessilis* is used in local medicine in Taiwan, often in mixtures with other medicinal plants such as *Eclipta prostrata* (L.) L., *Hypericum ascyron* L. and *Wollastonia chinensis* (Osbeck) Merr., to treat hepatitis, tight chest, bronchitis, asthma and lung troubles, to stop bleeding and as a hair tonic. It is used locally in Thailand and India against dysentery, as cholagogue, abortifacient and febrifuge, and to treat snake bites, inflamed wounds and boils, and in Thailand and Sri Lanka as a galactagogue. An extract from *A. philoxeroides* is used medicinally in India to treat 'female diseases'. *A. pungens* is reported in India to be useful as diuretic and to treat gonorrhoea.

The densely matted growth of some species (e.g. *A. ficoidea*) makes them useful for protecting soil against erosion. *A. philoxeroides* can be used as a tertiary filtration system for domestic sewage. Several species are planted in gardens as ornamentals. Some *Alternanthera* species are valued for aquarium decoration. Cooked leaves of *A. sessilis* are sometimes eaten as vegetable.

Production and international trade Dried plants of *Alternanthera* are only occasionally traded on local markets and by herbalists. They are not traded on the international market.

Properties Little is known about the chemical constituents of the various *Althernanthera* species. A C-glycosylated flavonoid, alternanthin, has been isolated from *A. philoxeroides*. The triterpenes α-spinasterol and β-spinasterol have been demonstrated to occur in several *Alternan-*

thera species, among which *A. sessilis*. This species is also reported to contain stigmasterol, β-sitosterol, oleanotic acid and its derivatives, and saturated (aliphatic) esters. A high iron content (about 2%) has been found in *A. philoxeroides*.
A. sessilis leaves contain 12 g/100 g dietary fibre. Incorporation of about 75 g of this vegetable fibre in the daily diet of diabetics, significantly reduced the postprandial blood glucose level. The leaves of *A. sessilis* are rich in β-carotene.
In tests in India, leaf pastes of *A. sessilis* exhibited inhibition of mutagenicity in *Salmonella typhimurium* strains. They inhibited the formation of the potent environmental carcinogen nitrosodiethanolamine from its precursors such as triethanolamine. The aqueous alcohol extract of the entire plant exhibits hypothermic and histaminergic activities and relaxes smooth muscles. An ether extract of *A. sessilis* yielded an active principle having anti-ulcerative properties.
An aqueous extract of *A. philoxeroides* inhibited the growth of the human immunodeficiency virus (HIV-1) in vitro at concentrations non-toxic to the host cells (H9 cells, human T-helper lymphocytes). It was also inhibitory to the growth of the herpes simplex (HSV) and respiratory syncytial viruses (RSV). The infectivity of extracellular virions of HIV-1, HSV and RSV was partially destroyed by the extract, but no activity on extracellular virions, or on virus growth was found for vesicular stomatitis virus (VSV), adenovirus (AV) or polio virus (PV). Chemical studies have indicated that the active anti-HIV-1 component was heat-stable, water-soluble and non-dialysable. Preliminary chemical characterization revealed that it might be a partially sulphonated polysaccharide.
A. philoxeroides extracts can markedly protect suckling mice from being infected by epidemic haemorrhagic fever virus (EHFV). After the infected mice were treated, their survival rate increased and pathological lesions and virus antigen in the tissues mitigated as compared with the controls. However, therapeutical doses caused slight deformations of the hepatic cells. Preliminary chemical investigations revealed that the active component might be a coumarin analogue.
Extracts prepared (leaves, cold water) from *A. brasiliana* and *A. ficoidea* showed antiviral activity against herpes simplex (HSV-1) virus in HEp-2 cells in vitro at non-toxic concentrations. The activity is however, influenced by the process of extracting. Using hot water or a lyophilization procedure might drastically decrease the activity. Crude aqueous extracts of *A. brasiliana* and *A. ficoidea* also showed antiviral activity against Aujeszky disease virus (ADV) in IB-RS-2 pig cell cultures, and bovine diarrhoea virus (BVD) in GBK bovine cell lines. The antiviral activity might vary depending on the temperature used during extraction.
Antiviral activity against tobacco mosaic virus in beans and tobacco has also been demonstrated for several *Alternanthera* species.

Description Annual or perennial herbs, erect, ascending, creeping, clambering or floating, often much branched, often hairy with dentate or smooth hairs. Leaves opposite, simple and entire, with short petiole; stipules absent. Inflorescence an axillary or rarely terminal head, sessile or stalked, sometimes a short spike. Flowers bisexual, solitary in axils of bracts, subtended by 2 scarious bracteoles; perianth often dorsally compressed, with 5 free, equal or unequal tepals; stamens 2–5, sometimes some without anthers, filaments united at the base into a short cup or longer tube, usually alternating with staminodes, anthers small, 1-celled; ovary superior, 1-celled, often compressed, style short with capitate stigma. Fruit an indehiscent utricle, sometimes corky, 1-seeded, falling off with the perianth and with or without bracteoles. Seed variably lenticular. Seedling with epigeal germination; cotyledons leafy, glabrous, apex rounded; hypocotyl and epicotyl elongated, purplish.

Growth and development *A. philoxeroides* is a C_3 plant. Each stem node is capable of producing a new plant under favourable conditions.
The dark brown, corky fruits of *A. sessilis* often float in great quantities on the water. Some of the introduced species (*A. ficoidea*, *A. philoxeroides*) do not set fruit in Malesia.

Other botanical information *Alternanthera* is closely related to *Gomphrena*, which differs particularly in the shape of the androecium.
There is much confusion about the correct name for the taxon which is dealt with here under the name *A. ficoidea*. In 1989 the Committee for Spermatophyta of the International Association for Plant Taxonomy recommended maintaining the much used name *A. ficoidea* for this species, even though it is nomenclaturally incorrect (the correct name is *A. tenella*), in order to stabilize the nomenclature. *A. ficoidea* cultivated in South-East Asia should be considered as a cultigen of the South American species.

Ecology *Alternanthera* species are usually found in moist localities. *A. sessilis* prefers open places such as roadsides, gardens and along rice fields, but *A. brasiliana* shows a preference for shaded localities (e.g. on slopes). *A. philoxeroides* can tolerate a large range of habitats, growing out over water as dense floating mats or on moist soil as individual plants. Plants of this species can grow at NaCl concentrations of 400 mol/m^3. *A. pungens* is adapted to more dry locations.

Several species are noxious weeds, e.g. *A. sessilis* in upland rice, carrot and tomato, *A. philoxeroides* in irrigated rice and *A. brasiliana* in coffee. *A. ficoidea* is a dreaded weed in beans, soyabeans, groundnuts, plums and cotton in America.

The leaves of some *Alternanthera* (e.g. *A. sessilis*) can be purplish pigmented by the occurrence of anthocyanins and betalains. An inverse correlation has been observed between pigmentation intensity and soil moisture.

Propagation and planting *A. ficoidea* and *A. philoxeroides* do not produce ripe seeds in Malesia. However, *A. ficoidea* can easily be propagated from cuttings or divisions, whereas *A. philoxeroides* can rapidly develop new plants from stem parts. *A. sessilis* can probably also be propagated very easily from seed and vegetatively.

In vitro production of active compounds Cell suspension cultures of *A. philoxeroides* have been derived from leaf callus grown at 25°C in the dark in Murashige and Skoog medium containing 1 mg/ml 2,4-D. After an abrupt and substantial increase in salinity, the suspension cells exhibited a rapid attainment of water balance and cell growth. Concomitant with the ability of these cultures to withstand an increase in NaCl are the abilities to produce betaine and to take up exogenous betaine.

Husbandry In general, *Alternanthera* can stand pruning well.

Diseases and pests A leaf spot disease of *A. sessilis* caused by *Fusarium pallidoroseum* has been described in Nigeria. It may spread to crops in which *A. sessilis* occurs as a weed, e.g. okra, yams, potatoes, onions and carrots.

Introduction of the lepidopterous *Vogtia malloi* from Argentina and the alligator weed flea beetle (*Agasicles hygrophila*) from the United States into several countries has successfully reduced populations of the noxious aquatic weed *A. philoxeroides*.

Genetic resources and breeding *Alternanthera* species are not endangered. On the contrary, they are often noxious weeds expanding their area of distribution (e.g. *A. philoxeroides* in Australia). However, the genetic variability of the species originally introduced in South-East Asia is rather small because of the limited number of introductions and the vegetative mode of reproduction. It is unclear whether the medicinal properties attributed to these introduced species apply to the present South-East Asian populations as well.

Prospects Some of the medicinal properties of *Alternanthera* warrant further research. The antiviral effects of *A. philoxeroides*, and the anti-ulcerative properties of *A. sessilis* seem to be the most promising.

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Selection of species

Alternanthera brasiliana (Torner) O. Kuntze

Revis. gen. pl. 2: 537 (1891).

Synonyms *Alternanthera strigosa* Hassk. (1839).

Distribution Native of tropical America; introduced and naturalized in western and central Java.

Uses *A. brasiliana* might be useful as an antiviral agent.

Observations A perennial herb up to 3 m tall, decumbent at base, ascending-erect or clambering higher up, often widely branched, stems solid; hairs minutely dentate; leaves ovate-lanceolate, 3.5–10 cm × 1–4 cm, densely appressed pilose on both surfaces when young but later slowly glabrescent, petiole 0.5–1.5 cm long; flowering heads stalked; tepals strongly 3-veined, yellowish-white, filaments united at base into a distinct tube; fruit ellipsoidal, about 2 mm long. *A. brasiliana* occurs locally gregariously in Java, on moist, shaded localities on ravine slopes and stream banks, at 200–600 m altitude.

Selected sources 47, 93, 97, 773, 805, 1056.

Alternanthera ficoidea (L.) P. Beauv.

Fl. Oware 2: 66, pl. 99, fig. 1 (1818; 'ficoides').

Synonyms *Gomphrena ficoidea* L. (1753), *Alternanthera tenella* Colla (1828).

Vernacular names Indonesia: bayam merah (general), jukut jatinangor (Sundanese), kecicak abang (Javanese). Thailand: phakpet daeng, phrommi daeng, phakpet farang. Vietnam: rau d[eej]u d[or].

Distribution Native of tropical South America; introduced in Malesia (e.g. Sumatra, Java, Papua New Guinea) and elsewhere in South-East Asia as an ornamental.

Uses *A. ficoidea* might be useful as an antiviral agent. The densely matted growth makes it suitable to be used to protect soil against erosion. It is commonly planted in gardens as ornamental. The leaves are sometimes eaten as a vegetable, e.g. in Sri Lanka.

Observations A perennial herb up to 50 cm tall, erect or decumbent and rooting in lower part, often much branched and forming dense tufts, stems solid; hairs dentate; leaves oblong, oblong-obovate to spatulate, 1–6 cm × 0.5–2 cm, finely pilose when young but later glabrescent, often variegated with brownish-red, red, pink or yellow, petiole 1–4 mm long; flowering heads sessile; 3 outer tepals distinctly 3-veined, shiny white or yellowish, filaments united at base into a very short cup; fruit not produced in Malesia. In South-East Asia only var. *versicolor* (Lem.) Backer (synonyms: *Alternanthera amoena* Backer & v. Slooten, *A. bettzickiana* (Regel) Nicholson, *A. ficoidea* (L.) P. Beauv. var. *bettzickiana* (Nicholson) Backer, *A. manillensis* (Walp.) Kanis (1972), *A. tenella* Colla var. *versicolor* (Lem.) Veldk.) is cultivated. In fact, this taxon should be considered as a cultivar. It hardly ever sets fruit and besides being cultivated as an ornamental, is known as a non-persisting escape.

Selected sources 47, 93, 97, 580, 773, 805, 816, 1055, 1470.

Alternanthera philoxeroides (Mart.) Griseb.

Goett. Abh. 24: 36 (1879).

Synonyms *Telanthera philoxeroides* (Mart.) Moq. (1849).

Vernacular names Alligator weed (En). Indonesia: tolod, krokot (Java). Burma (Myanmar): kanabaw. Thailand: phakpet-nam, phakpet.

Distribution Native of tropical South America; introduced and naturalized in western Java, and very locally elsewhere in Malesia (e.g. found in south-eastern Kalimantan).

Uses An extract is used medicinally in India to treat 'female diseases'. In Indonesia young tops are eaten raw or cooked. It can be used as a tertiary filtration system for domestic sewage. In China *A. philoxeroides* is cultivated for compost-making, whereas in the United States it is grown as food for lobsters. In watercourses it is a noxious weed.

Observations A perennial herb up to 1 m tall, ascending from a creeping or floating, rooting base, often much branched and forming a dense mass, stems fistulose in lower part; hairs smooth; leaves oblong or oblong-obovate, 2–8 cm × 0.5–2.5 cm, glabrous or ciliate, petiole 3–6 mm long; flowering heads stalked or occasionally sessile; tepals 1-veined, shining white, filaments united at base into a distinct tube; fruit not produced in Malesia. *A. philoxeroides* occurs locally gregariously in Java, in stagnant or slow-moving water in pools and ditches.

Selected sources 93, 97, 106, 288, 868, 888, 1056, 1174, 1344, 1356, 1616.

Alternanthera pungens Kunth

Humb., Bonpland & Kunth, Nov. gen. sp. 2: 206 (1818).

Synonyms *Alternanthera repens* (L.) Link

(1821) non Gmelin, *Telanthera pungens* (Kunth) Moq. (1849).

Vernacular names Thailand: khok krasun, khok krasun lek.

Distribution Native of tropical America; introduced and naturalized locally in Java, Thailand and India.

Uses In India, it is said to possess diuretic properties, and a decoction is used internally to treat gonorrhoea.

Observations A perennial prostrate herb up to 50 cm tall, with robust taproot, often woody at base of stem, much branched, stems solid; hairs minutely dentate; leaves elliptical-obovate, 1–4.5 cm × 0.5–2 cm, glabrous or slightly appressed pilose, petiole 2–10 mm long; flowering heads sessile; tepals 3-veined in the lower half, white, filaments united at base into a very short cup; fruit broadly ovoid, much compressed, about 1.5 mm long. *A. pungens* occurs locally in Java and Papua New Guinea, on waste land, dockyards and roadsides in the lowland near the coast. In India it is a weed of pebbly soils and dry locations.

Selected sources 93, 97, 288, 704, 816, 1470.

Alternanthera sessilis (L.) DC.

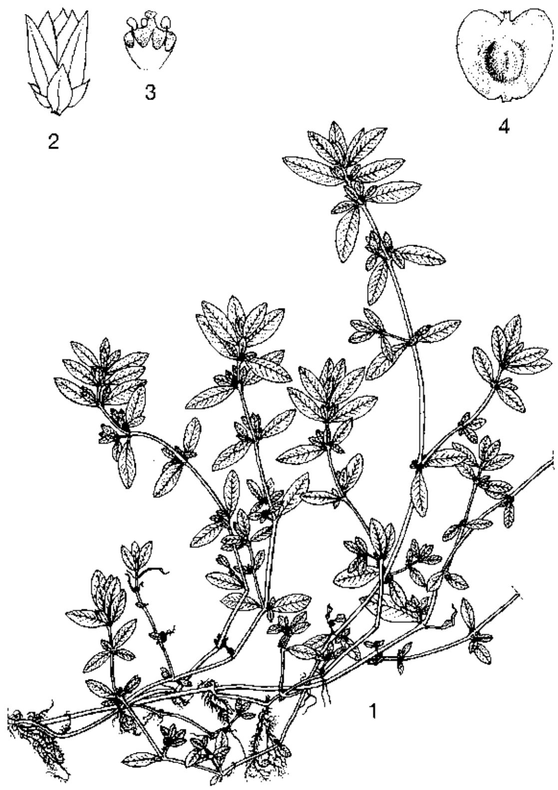
Cat. pl. horti monsp.: 77 (1813).

Synonyms *Alternanthera triandra* Lamk (1783), *Alternanthera denticulata* R.Br. (1810), *Alternanthera nodiflora* R.Br. (1810).

Vernacular names Indonesia: kremek (Sundanese), bayem kremah (Javanese), daun tolod (Moluccas). Malaysia: keremak, pudoh, kermak bukit. Philippines: bunga-bunga (Tagalog), bilanamanut (Magindanao), gogoat (Bontok), Cambodia: chë:ng bângko:ng (Kompong Thom). Laos: khaix ped, phak ph'ê:w (Louang Prabang), nê: ti:d kho:x (Vientiane). Thailand: phakpet khaao, phakpet thai. Vietnam: rau d[eej]u (general).

Distribution Throughout the tropics and subtropics of America, Africa and Asia; throughout Malesia.

Uses An infusion of the entire plant is used in Indonesia as a remedy against intestinal cramps, diarrhoea and dysentery, and externally as a cooling agent to treat fever. In Malaysia it is used internally against intestinal inflammation and fever, and externally to treat wounds. *A. sessilis* is used in local medicine in Taiwan, often in mixtures with other medicinal plants, to treat hepatitis, tight chest, bronchitis, asthma, and lung troubles, to stop bleeding and as a hair tonic. It is used locally in India against dysentery, as a cholagogue, abortifacient and febrifuge and to treat snake bites, inflamed wounds and boils, and in Thailand and Sri Lanka as galactagogue. It is eaten as a vegetable, e.g. in Vietnam and Sri Lanka.



Alternanthera sessilis (L.) DC. – 1, plant habit; 2, flower with bract and bracteoles; 3, flower with tepals removed; 4, fruit.

Observations A perennial, sometimes annual herb up to 1 m tall, erect, ascending or creeping, often widely branched, taproot robust, stems solid, sometimes floating in water and then stems fistulose in lower part; hairs smooth; leaves linear-lanceolate, oblong to ovate or obovate, 1–15 cm × 0.5–3 cm, glabrous or sparsely pilose, petiole 1–5 mm long; flowering heads sessile; tepals 1-veined or only 3-veined at the very base, shiny white or purplish, filaments united at base into a very short cup; fruit obreniform, corky, about 2 mm long. *A. sessilis* is a very common plant of constant or periodically humid, open localities in roadsides, gardens, ditches, swamps, rice fields and tea plantations, up to 1250 m altitude.

Selected sources 93, 97, 202, 288, 350, 580, 704, 783, 816, 860, 868, 1035, 1083, 1178, 1370, 1394, 1470.

R.H.M.J. Lemmens & S.F.A.J. Horsten

Amaranthus spinosus L.

Sp. pl. 2: 991 (1753).
AMARANTHACEAE
$2n = 34$

Vernacular names Spiny amaranth, prickly amaranth, spiny pigweed (En). Epinard malabre (Fr). Brunei: bayam berduri (Malay). Indonesia: bayam duri (general), bayem eri (Javanese), senggang cucuk (Sundanese). Malaysia: bayam duri, bayam hutan (general). Philippines: urai (Tagalog), harum (Bisaya), kalunai (Iloko). Cambodia: phti: bânla: (Pursat). Laos: hôm hna:m (general). Thailand: mang-lang-du (Karen-Mae Hong Son), pa-tue (Khmer), phak hom nam (peninsular). Vietnam: rau d[eef]n gai (general), gi[eef]n gai (Ha Nam Ninh).

Origin and geographic distribution *A. spinosus* occurs in all tropical and subtropical regions, including the whole of South-East Asia, often gregariously and as a weed. It is sometimes found in temperate zones as well. It has been suggested that spiny amaranth originates from lowland tropical South and Central America, and that it was introduced in other warmer parts of the world from about 1700 AD onwards. Nowadays it is rarely cultivated.

Uses The root of spiny amaranth is known as an effective diuretic. In the Philippines, India, Thailand and Indo-China, a decoction of the root is used to treat gonorrhoea. It is also applied as an emmenagogue and antipyretic. In many countries, including Indonesia, the bruised leaves are applied externally in cases of eczema, burns, wounds and boils. The leaves are considered a good emollient. In Malaysia, spiny amaranth is used as an expectorant and to relieve breathing in acute bronchitis. In mainland South-East Asia, it is also used as a sudorific, febrifuge, antidote to snake poison, galactagogue, and to treat menorrhagia. Spiny amaranth is reported to be used to treat haemorrhoids in Africa. Some tribes in India apply spiny amaranth to induce abortion.

In Indo-China and India, spiny amaranth is used as forage, and it is said to increase the yield of milk in cattle. However, cases of poisoning in cattle have also been reported. Spiny amaranth is browsed by sheep and goats and is a highly nutritious feed at any time during the year. The young leaves are sometimes eaten as a vegetable.

Production and international trade Spiny amaranth is not traded commercially, and is rarely found in local markets.

Properties Little is known about the specific constituents of *A. spinosus*. The roots contain α-spinasterol and some saponins. Sterols (β-sitosterol, stigmasterol, campesterol and cholesterol), n-alkanes, fatty acids (e.g. stearic-, oleic- and linoleic acid) and free alcohols have also been found in the petroleum-ether extract of the herb. The flavonoid rutin has been found in the aboveground matter of spiny amaranth in a concentration up to 1.9%, and traces of hydrocyanic acid in the leaves. Spiny amaranth is furthermore reported to contain a considerable amount of potassium, up to 4.5% in the dried leaves, which might explain the known diuretic properties.

A lectin has been purified from the seeds by means of chromatographic procedures. Its reaction was non-specific in general: it reacted with human and various animal erythrocytes. Its unique carbohydrate specificity will prove useful in biochemistry. Lecithins are also known to occur in the seeds of several other *Amaranthus* species, e.g. *A. caudatus* L. and *A. leucocarpus* S.Watson.

Spiny amaranth possesses a strong phagocytic effect. No antibacterial activity has been demonstrated, but crude aqueous extracts showed fungicidal activity against *Cercospora cruenta*, which causes a leafspot disease in mung bean (*Vigna radiata* (L.) Wilczek). However, these extracts were inferior to benomyl in controlling the disease. Furthermore they showed antiviral activity against Aujeszky virus (ADV) in IB-RS-2 pig cell cultures and bovine diarrhoea virus (BVD) in GBK bovine cell lines. The antiviral activity against BVD, however, was lost upon heating the extract for 30 minutes at 50–60°C. Thus it is possible that at least a part of the antiviral activity resides in proteins or glycoproteins that are largely inactivated by heating for 10 minutes above 60°C.

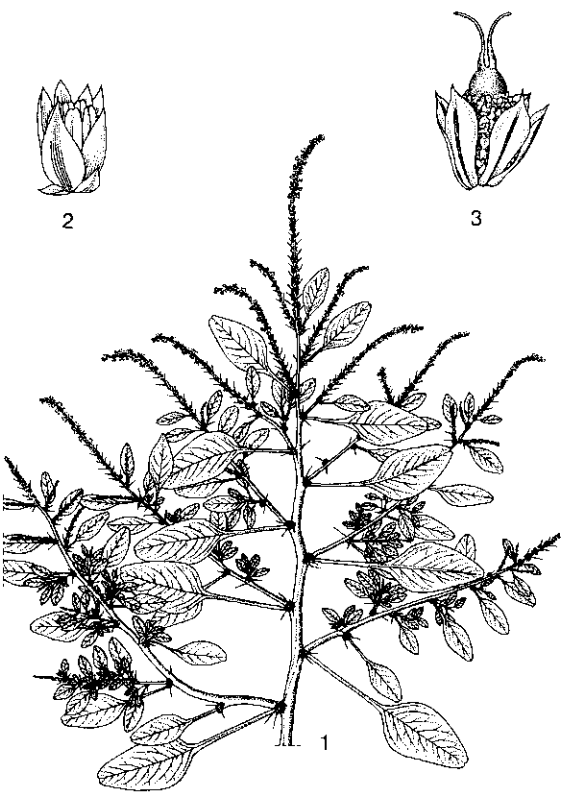
Spiny amaranth has considerable nutritional value. The high foliar content of the amino acid lysine could make it a valuable protein supplement in cereal-based diets. However, cases of spontaneous poisoning by spiny amaranth in cattle have been reported, particularly after severe droughts when few other forages were available. It was suggested that the spiny amaranth caused renal failure.

A. spinosus pollen may cause hay fever, but the reaction is usually milder than that caused by some grass pollen. Hypo-sensitization injection treatment with a mixture of 3 allergenic grasses and spiny amaranth for at least one year gave significant improvement in patients with allergic rhinitis and/or seasonal asthma in the Philippines.

Allelochemicals have been isolated and identified from aerial plant parts. These are volatile aliphatic compounds which inhibit germination of seeds of crops like carrot, tomato and onion. The most active alcohols present in spiny amaranth are 3-methyl-1-butanol and 3-hexen-1-ol; the most active aldehyde is 3-methylbutanal, and the most active ketone is 2-hepatanone.

Adulterations and substitutes The *Amaranthaceae* genus *Aerva* has similar properties to spiny amaranth and is used for similar complaints. It seems probable that *Amaranthus* and *Aerva* are related not only botanically but also chemically.

Description An annual, erect monoecious herb up to 100(–130) cm tall, much branched; stem terete or obtusely angular, glabrous or slightly pubescent, green or variably suffused with purple. Leaves alternate, simple and entire, ovate-lanceolate to rhomboid, 3.5–11 cm × 1–4.5 cm, acute and often slightly decurrent at base, obtuse, rounded or slightly retuse and often short mucronate at apex, glabrous or slightly pubescent on veins when young; petiole rather long, approximately as long as leaf-blade; stipules absent. Inflorescence consisting of dense clusters, lower ones axillary, higher ones often collected in an axillary and terminal spike which is often branched in its lower part; axillary clusters usually armed with (1–)2(–3) very sharp spines up to 2 cm long. Flowers solitary in the axil of a bract, subtended by 2 bracteoles, bracts and bracteoles scarious, mucronate from a broad base, shorter or as long as the perianth, unisexual; male flowers usually arranged in a terminal spike above the base of the inflorescence, green; tepals 5 or in male flowers often 3, free, subequal, ovate-oblong to oblong-spatulate, up to 2.5 mm long, very convex, membranous, with transparent margins and green or purple median band; stamens 5, about as long as tepals; ovary superior, oblong, 1-celled, styles 2–3, ultimately recurved. Fruit an oblong utricle with persisting styles, circumscissile a little below the middle or indehiscent, 1-seeded. Seed about 1 mm in diameter, shiny black or brownish-black with thin margin. Seedling with epigeal germination; cotyledons leafy, glabrous, apex rounded to slightly acute; hypocotyl up to 12 mm long, epicotyl absent.



Amaranthus spinosus L. – 1, part of flowering plant; 2, male flower with bracteoles; 3, fruit.

Growth and development In India spiny amaranth flowers twice a year. Seeds mature in about one month after flowering. They are scattered around the mother plants or distributed by animals feeding on the plants. It has been observed that large numbers of seedlings emerge from decaying cattle faecal deposits. Seeds are eaten by birds.

In India, seeds germinate throughout the year but seedlings exhibit a high degree of mortality. Less than 1% of them reach the first leaf stage; less than 5% of these reach the 4-leaf stage and continue growing.

Other botanical information Some other species of the genus *Amaranthus* (about 40 species worldwide) are also used medicinally, but have other primary uses. The leaves of the well-known vegetable *A. tricolor* L. are considered as a good emollient in Vietnam, and are used in Malaysia to treat haemorrhagia. The leaves of the lesser-known vegetable *A. viridis* L. are used in Africa as a febrifuge and as a poultice to treat inflammations, boils and abscesses. In South and Central America, they are used as a diuretic and galactagogue (applied as an infusion) and as emollient. In India, they are used to treat snake bites and scorpion stings, and in New Britain to treat mosquito bites and insect stings. The seeds of the grain amaranth *A. cruentus* L. are used in India as diuretic and to treat scrofulous sores.

Ecology Spiny amaranth is adapted to a wide range of climatic and edaphic factors. It grows best in the sun or in light shade; a light intensity of less than 30% completely suppresses flowering. Flowering is earliest and most abundant in areas with daylengths of 11–12 hours. It is nitrophilous and prefers soils with a high organic matter content, but is also able to grow on sandy soils. Optimal growth is obtained on soils with moderate moisture content, but spiny amaranth is capable of growing on wet soils as well. It is drought-resistant and can even grow under arid conditions.

Spiny amaranth is a very noxious weed in many parts of the world. It is, for instance, troublesome in upland rice, sugar cane and carrot in Indonesia, in maize in the Philippines, in groundnut and soya bean in Taiwan, and in tomato and field pea in India. In South-East Asia, it is very common in roadsides, waste places, railway yards, cropped land and gardens, up to 1400 m altitude.

Propagation and planting Spiny amaranth is propagated by seed. Some types are known to produce 235 000 seeds per plant. The weight of 100 seeds is 14–25 mg. Freshly collected seeds may germinate at temperatures as high as 40°C, with a germination rate of up to 95%. After storage, however, temperature requirements are lower. Seeds stored for one month at room temperature have almost 100% germination, and after 5 months they have approximately 90% germination. When they are stored for one year at 20°C the germination rate will drop to about 50%, but storage at lower temperatures gives a higher rate.

Husbandry As a weed in tomato in India spiny amaranth has been successfully controlled by the application of geraniol, which completely blocked the germination of the weed without affecting the the tomato crop. An ethanolic extract of seeds of *Coffea arabica* L. (with 1,3,7-trimethylxanthine as active ingredient) at a concentration of 1.2 g/l, completely inhibited germination of spiny amaranth in a crop of black gram (*Vigna mungo* (L.) Hepper) without negative effects for this pulse crop.

Diseases and pests Spiny amaranth is a host plant for, among others, tobacco mosaic virus, groundnut rosette virus, cucumber mosaic virus and root-knot nematodes (*Meloidogyne* spp.), which attack some commercial crops. When the world's worst weeds are ranked on the basis of the number of pests hosted, spiny amaranth is placed number 6, hosting 15 pests that may affect crops. Some natural insect enemies of spiny amaranth have been recorded from Mexico: the pyralid *Herpetogramma bipunctalis* and the curculionid *Conotrachelus seniculus*. These might be useful for biological control. In India, the bud weevil *Ceuthorhynchus asperulus*, a pest of pigeon pea (*Cajanus cajan* (L.) Millsp.), has been found feeding on *Amaranthus* species including spiny amaranth.

Genetic resources and breeding The genetic variability of spiny amaranth is great because of its enormous area of distribution and its wide ecological adaptation.

Prospects The medicinal properties of spiny amaranth have received very little attention. The diuretic and anti-inflammatory properties in particular deserve more research, as these properties are valued in many different regions of the world. Moreover, the reputed high nutritional value of the leaves offers good prospects for more common use as a vegetable or a forage.

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Other selected sources 190, 202, 303, 332, 580, 868, 1035, 1169, 1178, 1234, 1424, 1470.

R.H.M.J. Lemmens & N. Bunyapraphatsara

Amomum Roxb.

Fl. Ind. 1: 317 (1820); Pl. Coromandel 3: 75 (1820).

ZINGIBERACEAE

$x = 24$; *A. aculeatum*: $n = 24$, *A. krervanh*: $2n = 48$, *A. longiligulare*: $2n = 48$, *A. squarrosum*: $n = 24$, *A. uliginosum*: $n = 24$, *A. villosum*: $2n = 48$, *A. xanthioides*: $2n = 48$

Major species *Amomum krervanh* Pierre ex Gagnep., *A. villosum* Lour., *A. xanthioides* Wallich ex Baker.

Vernacular names Thailand: krawaan. Vietnam: sa nh[aa]n.

Origin and geographic distribution *Amomum* consists of about 100 species and is distributed in eastern Asia, from India and China, throughout the Malesian region, to tropical Australia. In Vietnam 22 species have been found. The total number of species in Malesia is difficult to estimate, but Peninsular Malaysia has approximately 18 species, Java about 13, and Borneo about 30; the distribution of the genus in other areas is very incompletely known.

Uses Several *Amomum* species (for instance *A. krervanh*, *A. villosum* and *A. xanthioides*) are well known medicinal herbs in China, Indo-China and Thailand, particularly their fruits. They are mainly used to treat gastric and digestive disorders (e.g. vomiting, poor appetite, poor digestion, colic, diarrhoea). Besides their tonic, carminative and stomachic properties, the fruits are also considered to have emmenagogue and febrifugal properties. They are also sometimes prescribed to treat tuberculosis with hemoptysis, liver and uterine affections, and rheumatism. Seeds of *A. villosum* are known as 'saren' in China, and the fruit shells as 'sake'. Some medicinal uses have been reported from the Malesian region; *Amomum* seeds are often included in stomachics and in preparations for coughs and colds.

The fruits of several species are commonly used as cooking ingredient, and are sometimes also used in perfumery. They may serve as antioxidant in foods.

Production and international trade The fruits have importance in southern China (Yunnan). The total cultivated area is estimated to be over 13 000 ha. Around 1993 the dried fruits of *A. villosum* had a value of US$ 5.5/kg. Vietnam exports seed to China yearly, e.g. of *A. villosum* and *A. xanthioides*. In Cambodia, the fruits are mainly collected from the natural forest, whereas in Thailand the plants are mainly cultivated.

Properties Fruits contain an essential oil, which is colourless and transparent and has the characteristic odour of the fruit and the seed. The fruits of *A. krervanh* contain approximately 3-4% essential oil with 1,8-cineol (eucalyptol) as main compound (60-80%). Further constituents are camphene, p-cymene, α-humulene, limonene, α-pinene, terpinene and α-terpineol. The pharmacological activities reported for *A. krervanh* include antifungal, antipyretic, smooth muscle relaxant and hypotensive activity. Fruits of *A. villosum* are reported to contain 3% essential oil consisting of bornylacetate (34%), camphor (27%), borneol (13%), camphene (10%), limonene (7%) and the minor compounds α- and β-pinene and myrcene.

Fruits of *A. xanthioides* contain 1.7-3% oil. The essential oils from *A. xanthioides* can be divided into 3 groups, based on the nature of their main compounds; the first group mainly containing camphor and bornylacetate, the second one mainly composed of linalool and nerolidol, and the third one with a high content of β-caryophyllene. The oil of the first group in general consists of camphor (29%), bornylacetate (22%), camphene (13.5%), limonene (10%), myrcene (4%), β-pinene (4%) and α-pinene (3%).

Investigations of *A. villosum* cultivated in Yunnan (China) revealed the presence of ethyl-octacosate, docosyl hexylate, stigmast-4-ene-1,3-dione, β-sitosterol and daucosterol in the roots and rhizomes.

A diterpene peroxide has been isolated from *A. krervanh* fruits in Thailand. This compound exhibited potent activity against *Plasmodium falciparum* and is thus of interest in combating malaria. In vitro experiments showed that the compound has roughly one-tenth the activity of artemisinin (from *Artemisia annua* L.) and the same level of activity as arteflene, which is an effective synthetic antimalarial agent structurally related to artemisinin. It is interesting to note that *A. fenzlii* Kurz is used to treat malarial fever in India, as is *A. tsao-ko* Crevost & Lem. in China.

Crude drugs prepared from *A. xanthioides* showed antifungal activity using organic solvents. At 3000 ppm the Indian *A. subulatum* Roxb. showed 100% inhibition for the storage fungus *Aspergillus flavus*; it showed a broad range of fungitoxicity in tests with plant pathogens, and had no adverse effect on the germination of rice; the seed oil was also highly active against keratinophilic fungi. *A. subulatum* also showed some insecticidal activity against the storage pest *Sitophilus oryzae*.

It has been reported from the Andaman Islands that sap of an *Amomum* species (doubtfully identified as *A. aculeatum*) acts as a tranquillizer for bees (rock bees, *Apis dorsata*), and is used in harvesting honey. When a mangled stem is held near the bee hives, the sap tranquillizes the vindictive worker bees to such an extent, that they do not sting. Reportedly, the sap's tranquillizing effect is specific to rock bees.

Adulterations and substitutes Fruits and seeds of several other *Zingiberaceae* (e.g. *Alpinia*, *Elettaria* and *Globba* species) are used for similar purposes, and are sometimes mixed with *Amomum* seeds, but often they are less valuable.

Description Medium-sized to large aromatic herbs up to 400 cm tall, with creeping rhizome near the soil surface or above ground, occasionally elevated on short stilt roots, sometimes emitting long stolons, several-stemmed; spurious stems erect, swollen near base. Leaves distichous, numerous, usually lanceolate, finely veined, distinctly or indistinctly petiolate, lower ones sheathing with the sheath open on the side opposite the lamina, sheath apically produced into an erect, short or long ligule. Inflorescence either lateral immediately from the rhizome near the base of a leafy stem, or lateral on stolons arising from the rhizome, capitulate, usually globose to ovoid, sometimes elongate; peduncle often short and shallowly hidden under earth or litter, with biseriate, persistent scales; bracts often numerous, arranged spirally, persistent or becoming slimy and disappearing, each bract embracing one usually tubular-sheathing bracteole and one flower. Flowers bisexual, zygomorphic, 3-merous; calyx tubular, indented on one side, unequally 3-dentate on the other side; corolla with tube shorter to longer than calyx and lobes about as long as tube, superior lobe broadest and hollowed near apex, lateral lobes appressed against the labellum; labellum longer than corolla-lobes, very variable, lower part erect, tubular and connate with base of filament, upper part spreading, essentially 3-lobed and folded over the stamen, usually yellow or orange in the centre and with purplish markings, the sides often white; functional stamen 1, usually with distinct filament, anther elongate with connective developed into a large 3-lobed appendage, staminodes 2, small or absent; ovary inferior, 3-locular with axile placentation, style filiform with nectaries at base, stigma widened at apex, fimbriate. Fruit berry-like or capsular, indehiscent or dehiscent with 3 valves, aculeate, ribbed or smooth, many-seeded. Seeds angular, surrounded by an aril.

Growth and development When cultivated, *Amomum* usually forms a dense ground cover. Plants are shallow-rooted, with about 80% of the root mass in the upper 10 cm of the soil. Flowering and fruiting start 4–5 years after planting.

The flowers, which usually last less than one day, are pollinated by insects, whose numbers and frequency of visits seriously affect seed production. Shedding of young fruits can be serious but can be reduced by proper use of 2,4-D and colchicine at the time of flowering. The fruits ripen in 3–4 months.

Other botanical information *Amomum* belongs to the tribe *Alpinieae*, which also includes the small genus *Elettaria*, the large genus *Alpinia*, and the medium-sized genus *Riedelia*, which is centred in New Guinea.

A. compactum Soland. ex Maton is mainly cultivated for its seeds, which are used as a condiment, but it also has medicinal properties. *A. subulatum* Roxb. and *A. fenzlii* Kurz are used medicinally in India and Nepal. *A. tsao-ko* Crevost & Lem., whose fruits are used as a condiment, is also applied in traditional medicine in northern Vietnam and southern China. Its fruits are mixed with other medicinal plants to produce a reputed remedy for malaria. *A. cardamomum* L. is a synonym of *Elettaria cardamomum* (L.) Maton; several parts of this spice are used medicinally.

Ecology Like other members of the *Zingiberaceae*, *Amomum* is almost a characteristic element of the ground flora of primary rain forest, often in moist locations and in lower montane forest (in Vietnam even up to 2200 m altitude). *Amomum* is humid-thermophilous and moderately shade tolerant, but intolerant of drought. The climatic conditions most suitable for *A. villosum* are 1000–2400 mm annual rainfall, about 80% relative humidity and a mean annual temperature of 19–22°C. It prefers loose, moist and humus-rich soils with a pH 6–7.5. These requirements seem to be applicable to many other *Amomum* spp.

Most *Amomum*-underplanted forests are located in valleys or on hillsides with a moderate slope at 500–1400 m altitude. The fruit production of *A.*

krervanh in the lowland is inferior to that in the highlands.

Propagation and planting In southern China, *Amomum* is preferably propagated by cuttings from stolons of 1–2-year-old plants with 2 horizontal branches. These cuttings may produce 3–4 shoots in the first year and 20–30 stems/m^2 within 3 years, which are ready for flowering and fruiting. Plants propagated from cuttings flower approximately 1 year earlier than seedlings. Sometimes rhizomes for planting are collected from the natural forest.

In southern China, shade-tolerant *Amomum* spp. like *A. villosum* are underplanted either in natural forest or as part of an agroforestry system. In natural forest, planting of seedlings or cuttings is preceded by thinning to give 30–40% light intensity, with retention of shade trees. In agroforestry, *Amomum* spp. are planted in plantations of rubber (*Hevea brasiliensis* (Willd. ex A.L. Juss.) Muell.-Arg.), *Cinnamomum porrectum* (Roxb.) Kosterm., mango (*Mangifera indica* L.), *Albizia chinensis* (Osbeck) Merr., *Paraserianthes falcataria* (L.) Nielsen and *Cassia siamea* Lamk. Satisfactory results were obtained by planting *A. villosum* seedlings or cuttings at 1 m × 1 m in 4 years old rubber plantings, spaced at least 6 m × 6 m.

Husbandry Newly planted *Amomum* must be weeded frequently. In China, the application of fertilizer containing traces of manganese sulphate often effectively prevents leaf yellowing in *A. villosum* plantations.

Diseases and pests Leaf blight of *A. villosum* caused by *Glomerella cingulata* occurs in China. Other diseases reported to affect *A. villosum* include seedling anthracnose (caused by *Colletotrichum zingiberis*) and fruit rot (caused by *Rhizoctonia solani* and *Fusarium* spp.). The insect pest *Prodioctes* sp. seriously affects cultivated *A. compactum* in West Java.

Harvesting Fruits are usually hand-picked when they start darkening.

Yield The mean annual yield of *A. villosum* planted in natural forest in southern China is about 375 kg/ha, with a maximum of 650 kg/ha. A 1-ha plot of *A. villosum* underplanted in rubber yielded about 190 kg/year of dried fruits.

Handling after harvest After harvest fruits need to be dried immediately. To avoid the quality reduction of the seed and the oil evaporating rapidly they should not be peeled until after drying. Dried seeds are kept in jute or nylon bags stored in cool, dry and well-ventilated conditions. In Thailand, the volatile seed oil is obtained by water distillation.

Genetic resources and breeding Many *Amomum* species seem to have a limited geographical distribution, but lack of botanical knowledge might be at least partly responsible for this. Most *Amomum* species occur in primary rain forest, and large-scale destruction of this forest type undoubtedly puts them at risk of genetic erosion or even extinction.

There is great market demand for *Amomum* in Indo-China and China, and natural populations are dwindling rapidly. *A. villosum* had become so scarce in China by the mid 1980s that considerable areas have since been planted with this species. In Vietnam and elsewhere, the scope for cultivation is increasing, which helps to protect *Amomum* species from genetic erosion.

Prospects Although *Amomum* has a considerable reputation in Chinese medicine, it is not much used medicinally in South-East Asia. Little research has been done on the pharmacological characteristics, and more is needed to confirm the claimed medicinal properties. The antimalarial activity of fruit extracts of some *Amomum* species deserves further attention.

The successful cultivation of *Amomum* spp. in agroforestry systems in tropical China might also be applicable to South-East Asia, if there is a potential market for their products. The annual revenue from an agroforestry system of rubber and *Amomum* in tropical China is about 4 times that of a pure rubber plantation.

A thorough taxonomical revision of *Amomum* is badly needed. The species most interesting medicinally, now often cultivated in Indo-China and Thailand, could probably also be cultivated at higher elevations in Malesia.

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Selection of species

Amomum aculeatum Roxb.

Asiat. Res. 11: 344, t. 6 (1810).

Synonyms *Amomum ciliatum* Blume (1827), *Amomum flavum* Ridley (1909).

Vernacular names Indonesia: parahulu, prahulu (Sundanese), wola waliyan (Javanese). Papua New Guinea: apiyamga (Gulf), qulengapaie (Morobe).

Distribution Vietnam, Peninsular Malaysia (Penang), Sumatra, Java, Papua New Guinea; sometimes cultivated in Java.

Uses In Java drops of juice from the leaf-stalks are applied to the eyes of women after childbirth. In Papua New Guinea, leaves are chewed in combination with other plants and traditional salt to soothe headaches and backache. The sap is drunk to treat fever and influenza. The sourish and sweet fruits are edible.

Observations A large herb up to 400 cm tall, with stout and long underground rhizome and rather slender, up to 1.5 cm thick, leafy stems; leaves lanceolate, 10–60 cm × 2–9 cm; inflorescence with base in the ground, up to 10 cm long, dense and rounded, bracts about 3.5 cm × 1.5 cm, thin, brownish and soon disintegrating, bracteoles about 1 cm long, tubular at the base; flowers pedicelled, far exserted from bracts, corolla tube about as long as calyx, lobes pale flesh-coloured to orange, labellum orange-yellow with many small crimson spots and lines, forming a closed cup with dorsal petal, anther with considerably spreading crest; fruit 2–3.5 cm × 1.5–2 cm, dark purplish, covered with fleshy greenish spines. *A. aculeatum* occurs in Java in primary forest and teak forest up to 800 m altitude.

Selected sources 97, 115, 580, 609, 615, 1227, 1494.

Amomum gracile Blume

Enum. pl. Javae 1: 49 (1827).

Vernacular names Indonesia: ela-ela (Java).

Distribution Western and central Java.

Uses Fruits are chewed to treat nausea and indigestion.

Observations A medium-sized to fairly large herb up to 110(–200) cm tall, with poorly developed rhizome and slender, up to 0.6 cm thick, branched stolons and slender, up to 1 cm thick, leafy stems which are bulbous at base; leaves lanceolate, larger ones 25–35 cm × 3–4 cm; inflorescence short, up to 5.5 cm long including peduncle, few-flowered, bracts few, up to 1.5 cm long, outer 1–2 sterile, bracteoles about 1 cm long, tubular at the base; flowers more or less sessile, exserted from bracts, corolla tube about as long as calyx, labellum white with red tubercles at base, a red band in the centre and margins edged with red, stamen much shorter than labellum, anther with large 3-lobed appendage; fruit 1–1.5 cm long, 3-grooved, red, densely covered with minute straight prickles. *A. gracile* occurs below 100 m altitude, often in teak forest.

Selected sources 97, 580, 1494.

Amomum hochreutineri Valeton

Icones Bogoriensis 2(4): t. 195 (1906).

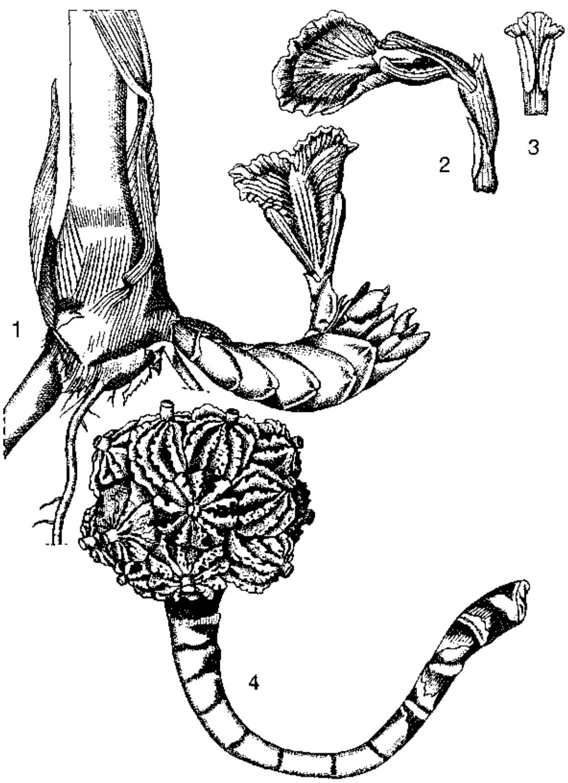
Vernacular names Indonesia: kihitir, cacabutan (Sundanese).

Distribution Very locally in western Java.

Uses Rhizomes and fruits are used as poultice to treat lumbago.

Observations A medium-sized herb up to 100 cm tall, with stout and long rhizome, whitish and up to 1 cm thick, and slender, red leafy stems; leaves lanceolate, larger ones 55–70 cm × 7.5–9 cm; inflorescence ascending, hardly raised above the ground, up to 30 cm long, few-flowered, bracts few, up to 3.5 cm long, outer 1–2 sterile, bracteoles about 2 cm long, hardly sheathing; flowers sessile, exserted from bracts, corolla tube about as long as calyx, labellum erect, much exserted, white, greenish-yellow in the centre and red-streaked, stamen hardly shorter than corolla, anther with 3-lobed appendage; fruit about 1.5 cm long, 9–12-ribbed, ribs with curled-crenate margins, white with red stripes. *A. hochreutineri* occurs in primary lower montane forest at 1000–1400 m altitude.

Selected sources 97, 580.



Amomum hochreutineri Valeton – 1, stem base with inflorescence; 2, flower; 3, stamen; 4, infructescence.

Amomum krervanh Pierre ex Gagnep.
Bull. Soc. Bot. Fr. 53: 138 (1906).

Vernacular names Round Siam cardamom, comphor seed (En). Cambodia: kreko krervanh, karvanh, krewanh. Thailand: krawaan khaao (central). Vietnam: b[aj]ch d[aaj]u kh[aas]u, sa nh[aa]n nam vang.

Distribution Laos, Cambodia, Vietnam, southern China and Thailand; also cultivated there.

Uses Fruits are used to treat indigestion, liver and uterus diseases, rheumatism, diarrhoea and asthenic after dysentery, and as febrifuge, antiemetic and antitoxic of alcohol. In Indo-China, they are traded as a condiment and spice.

Observations A large herb up to 300 cm tall, with superficial rhizome; leaves lanceolate, up to 60 cm × 12 cm; inflorescence cylindrical to conical, up to 11 cm long, bracts about 4 cm long, bracteoles tubular at the base; flowers with corolla tube about as long as calyx, labellum elliptical, rounded at apex, white with a yellow patch in the centre and yellow at margins, anther with a 3-lobed appendage; fruit about 1.5 cm in diameter, slightly ribbed. *A. krervanh* occurs in Cambodia and Vietnam in mountainous regions, and could well be cultivated in mountainous areas in Malesia. It is possibly conspecific with *A. testaceum* Ridley from Thailand, Peninsular Malaysia and Borneo.

Selected sources 455, 699, 1035, 1126, 1227.

Amomum ligulatum R.M. Smith
Notes Roy. Bot. Gard. Edinb. 42(2): 298 (1985).

Vernacular names Indonesia: ubut bele sa'ai (Kenyah Dayak, East Kalimantan).

Distribution Borneo (Sabah, East Kalimantan).

Uses Locally in East Kalimantan, the tender inner pith of leafy stems is roasted or boiled and eaten to treat stomach-ache and diarrhoea.

Observations A large herb up to 250 cm tall; leaves narrowly lanceolate, 25–80 cm × 3–5 cm; inflorescence narrowly ellipsoid, about 12 cm long, on peduncle up to 10 cm long, bracts about 2 cm long; flowers yellowish-orange, with pedicels up to 1 cm long, corolla tube about as long as calyx, labellum broad, orange with darker spot, anther with an undulate crest; fruit ovoid, about 2 cm long, pale yellowish-brown. *A. ligulatum* occurs in forest up to 1200 m altitude.

Selected sources 829, 1379.

Amomum longiligulare T.L. Wu
Fl. Hainan. 4: 533 (1977).

Vernacular names Vietnam: sa nh[aa]n, m[ef] tr[as] l[af].

Distribution Hainan, northern and central Vietnam; also cultivated in Vietnam.

Uses Seeds are used to treat indigestion, diarrhoea, vomiting and toothache, whereas the roots are applied against rheumatism.

Observations A large herb up to 250 cm tall, with rhizome creeping on the ground; leaves narrowly elliptical, 20–30 cm × 5–6 cm; inflorescence small, on a 2–4 cm long peduncle, few-flowered, bracts few; flowers subsessile, corolla tube about as long as calyx, labellum rounded and concave, with yellow margins, anther with clearly 3-lobed appendage; fruit 1.5–2 cm in diameter, brownish-purple, short-thorned. In Vietnam, *A. longiligulare* occurs in mountainous areas.

Selected sources 1037.

Amomum squarrosum Ridley
Journ. Roy. As. Soc. Straits Br. 57: 104 (1910).

Vernacular names Malaysia: puar tadah embun (Peninsular).

Distribution Peninsular Malaysia.

Uses Flowers are made into a poultice which is applied to the head to treat giddiness.

Observations A large herb up to 400 cm tall, with rhizome sometimes supported by stilt roots, leafy shoots close together; leaves narrowly lanceolate, up to 55 cm × 6 cm; inflorescence oblong, up to 10 cm long, on peduncle up to 15 cm long, bracts about 2 cm long, almost persistent, bracteoles up to 2 cm long, funnel-shaped; flowers with corolla tube shorter than calyx, labellum distinctly 3-lobed, white with a yellow median band flanked by red lines, anther with a 3-lobed appendage; fruit about 1.3 cm in diameter, smooth or slightly ribbed towards the apex. *A. squarrosum* occurs locally in the lowland, up to 300 m altitude.

Selected sources 202, 615, 1227.

Amomum stenocarpum Valeton

Bull. Jard. Bot., ser. 3, vol. 2: 354 (1920).

Vernacular names Indonesia: kaol haol (Simeuluë).

Distribution Simeuluë (Indonesia).

Uses The stem juice is used to treat cough. The sourish fruits are edible.

Observations A large herb up to 300 cm tall; leaves lanceolate, larger ones up to 90 cm × 13 cm; inflorescence elongate, with distinct peduncle, bracts up to 4.5 cm long, persistent; flowers unknown; fruit narrowly fusiform, about 2.5 cm long, greenish. *A. stenocarpum* is found in secondary forest.

Selected sources 580, 1497.

Amomum uliginosum J.G. König ex Retz.

Observ. bot. 3: 56 (1783).

Vernacular names Malaysia: puar hijau, puar gajah, tepus merah (Peninsular). Thailand: krawaan paa (Pattani).

Distribution Thailand and Peninsular Malaysia.

Uses Seeds are used medicinally in Thailand, whereas rhizomes are possibly used as a stomachic. Fruits are edible, and leaves are sometimes used for making temporary shelters.

Observations A large herb up to 300 cm tall, with subterranean, long and much branched rhizome, leafy shoots widely apart; leaves narrowly lanceolate, up to 50 cm × 7 cm, with caudate apex; inflorescence small and globose, up to 5 cm long, on peduncle up to 10 cm long, bracts 2.5–3 cm long, bracteoles about 2 cm long, tubular at the base; flowers with corolla tube as long as or slightly longer than calyx, labellum ovate and strongly concave, white, sometimes with 2 dark red spots at base and with a dark crimson stripe on each side, anther with a 3-lobed appendage having spreading side lobes; fruit up to 2 cm long, covered by slender and soft red spines. *A. uliginosum* is locally abundant in lowland forest and on river banks, up to 1000 m altitude.

Selected sources 202, 615, 1227.

Amomum villosum Lour.

Fl. cochinch.: 4 (1790).

Synonyms *Amomum echinosphaera* K. Schumann ex Gagnep. (1902).

Vernacular names Thailand: reo dong (Trat). Vietnam: sa nh[aa]n, m[ef] tr[es] b[af], d[uw] [ow]ng xu[aa]n sa.

Distribution Southern China, Vietnam and Thailand; also cultivated there.

Uses In Chinese and Vietnamese traditional medicine the fruits are used to treat indigestion, diarrhoea, flatulence, toothache, and as febrifuge and antiseptic. They are also used as spice and condiment.

Observations A large herb up to 300 cm tall, with thick rhizome; leaves narrowly ovate-lanceolate, up to 40 cm × 9 cm; inflorescence ascending, on peduncle up to 8 cm long, with few flowers scattered from base to top, bracts membraneous, bracteoles tubular at the base; flowers with corolla tube slightly longer than calyx, labellum spoon-shaped to almost circular and concave with emarginate apex, white with prominent middle vein, anther with a 3-lobed appendage having ear-shaped side lobes; fruit up to 2 cm long, reddish-brown and covered by small flexuous spines, difficult to break into 3 fragments. *A. villosum* occurs in forest, often in mountainous areas, and usually on wet soils.

Selected sources 455, 1035, 1126, 1658.

Amomum xanthioides Wallich ex Baker

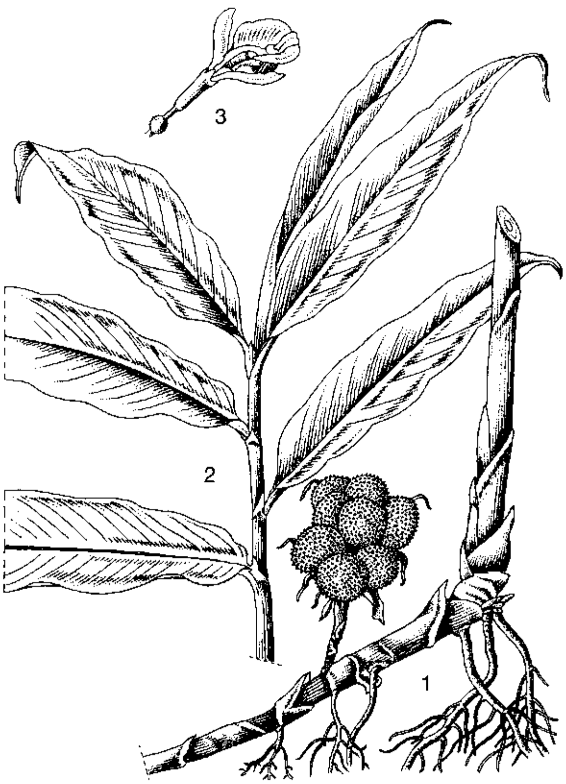
Hook.f., Fl. Brit. India 6: 239 (1892).

Synonyms *Amomum villosum* Lour. var. *xanthioides* (Wallich ex Baker) T.L. Wu & S.J. Chen (1978).

Vernacular names Bastard cardamom, tavoy cardamom (En). Thailand: phaa laa (Shan, Chiang Mai), maak ee (Chiang Mai), neak naeng (north-eastern). Vietnam: sa nh[aa]n, s[us]c sa m[aaj]t.

Distribution India, Laos, Cambodia, Vietnam, southern China and Thailand.

Uses In Chinese and Vietnamese traditional



Amomum villosum Lour. – 1, plant base with infructescence; 2, part of leafy stem; 3, flower.

medicine, fruits are used to treat indigestion, diarrhoea, flatulence, gastralgia, toothache, and as febrifuge and antiseptic. They are also used as a spice and condiment. Thai traditional doctors also apply the fruit to treat cough, against asthma and as an anti-emetic.

Observations A large herb up to 300 cm tall, with thick rhizome; leaves narrowly ovate-lanceolate, up to 40 cm × 9 cm; inflorescence ascending, on peduncle up to 8 cm long, with few flowers, bracts membraneous, bracteoles tubular at the base; flowers with corolla tube slightly longer than calyx, labellum spoon-shaped to almost circular and concave with emarginate apex, white with prominent middle vein, anther with a 3-lobed appendage having ear-shaped side lobes; fruit 1.5–2 cm long, yellowish-green and covered by small spines, difficult to break into 3 fragments. *A. xanthioides* occurs in forest, often in mountainous areas, and usually on wet soils.

Selected sources 313, 1035, 1126.

Nguyen Quoc Binh

Andrographis paniculata (Burm.f.) Wallich ex Nees

Wallich, Pl. asiat. rar. 3: 116 (1832).

ACANTHACEAE

$2n = 50$

Synonym *Andrographis subspathulata* C.B. Clarke (1884).

Vernacular names Creat, green chireta (En). Roi des amers (Fr). Indonesia: ki oray (Sundanese), sambilata (Javanese), ampadu (Padang). Philippines: aluy, lekha (Tagalog), sinta (Bikol). Thailand: fa thalaai (Bangkok), khee-pang-hee (Chinese), yaa kannguu (Songkhla). Vietnam: c[oo]ng c[ooj]ng, kh[oor] di[eej]p, xuy[ee]n t[aa]m li[ee]n.

Origin and geographic distribution *A. paniculata* is probably native to India, but has been introduced and cultivated as a medicinal plant in many parts of Asia including Indo-China, China, Thailand, Peninsular Malaysia, Indonesia, the Philippines and Australia. It is now widely naturalized in most of these regions. It has also been introduced, possibly for its ornamental value, in the West Indies and Central America.

Uses The roots and leaves of *A. paniculata* have a well-known application in traditional medicine in India, various parts of South-East Asia, Central America and the Caribbean. It used to be considered an effective remedy against snake bites; in India, it is locally still used for this. It has also been reported as useful to treat insect bites and, in combination with *Orthosiphon aristatus* (Blume) Miq., as a remedy for diabetes. An infusion or sap from the crushed leaves has been recommended for the treatment of fever, as a tonic, and for itching skin eruptions. A decoction of the leaves or roots is used against stomach-ache, dysentery, typhus, cholera, influenza and bronchitis, as a vermifuge, and is considered a diuretic. Another use is as a poultice on swollen legs or feet, vitiligo and piles. Pills or infusions are also recommended to treat female disorders, dyspepsia, hypertension, rheumatism, gonorrhoea, amenorrhoea, torpid liver and jaundice. Furthermore, *A. paniculata* is considered to be anti-inflammatory and immunosuppressive, but reports on antibacterial activity are contradictory.

Properties Phytochemical studies on *A. paniculata* have resulted in the isolation of a number of diterpenes from the aerial parts, of which the most important are:

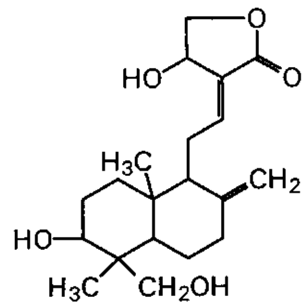
- Diterpenoids of the ent-labdane type, e.g. andrographolide, 14-epi-andrographolide, isoandro-

grapholide, 14-deoxyandrographolide, 14-deoxy-12-methoxyandrographolide, 12-epi-14-deoxy-12-methoxyandrographolide, 14-deoxy-12-hydroxy-andrographolide, 14-deoxy-11-hydroxyandrographolide, 14-deoxy-11,12-dihydroandrographolide, ent-14β-hydroxy-8(17),12-labdadien-15,16-olide-3β,19-oxide.
- Diterpene glucosides, e.g. andrographiside, deoxyandrographiside, 14-deoxy-11,12-dihydroandrographiside, neoandrographolide, 6'-acetyl-neoandrographolide.
- Bis-andrographolides A, B, C, and D.

The presence of flavones in the root has also been reported. Extracts and purified diterpenes and flavonoids have been investigated for a multitude of pharmacological effects.

In a placebo-controlled double-blind study, performed as a pilot trial in 50 patients, the effect of a standardized *A. paniculata* extract was evaluated in the initial treatment of the common cold and sinusitis. Patients were advised to take 4 tablets (containing 85 mg of the extract, or placebo) 3 times daily. Furthermore, they were given a self-monitoring form, and were assessed at the clinic after 5 days. In the *A. paniculata* group the subjective symptoms and symptom duration were both significantly reduced. In another double-blind study, patients with common cold were treated with *A. paniculata* extract (dose 1200 mg powdered leaves/day) or placebo. A significant reduction in clinical symptoms was observed in the treated group on day 4 of administration. It was concluded that powdered *A. paniculata* leaves have the capacity to significantly shorten the duration of common colds. When the efficacy of a high dose of powdered *A. paniculata* leaves (6 g/day) was compared with either a low dose of powdered leaves (3 g/day) or paracetamol (acetaminophen, 3 g/day) in a randomized double blind design in patients with pharyngotonsilitis, the paracetamol and the high dose of the powdered leaves produced significantly better effects than the low dose of *A. paniculata* on day 3, in terms of relief of fever and sore throat. On day 7 the clinical effects were no longer different. Furthermore, minimal, self-limiting side effects were found in about 20% of each of the groups.

The anti-inflammatory effect (carrageenin-induced oedema model) of an orally administered infusion of leaves at 51.4 mg/100 g bodyweight has been tested in mice; it was similar to 10 mg phenylbutazon/100 g. Andrographolide at 100 or 300 mg/kg also shows anti-inflammatory activity and significantly inhibits hind paw oedema in-



andrographolide

duced by carrageenin, kaolin and nystatin. Furthermore, an ethanol extract stimulates both antigen-specific and nonspecific immune responses in mice more than the purified andrographolides.

An ethanolic extract of *A. paniculata* administered orally to rats with yeast-induced fever showed significant antipyretic activity. Andrographolide at 100 or 300 mg/kg also exhibits significant antipyretic properties in rats. Evaluated for its analgesic effects in mice, a dose of 8 mg/kg of a 10% infusion of the herb, applied intraperitoneally, is comparable with 48 mg/kg phenylbutazon. At a per oral dose of 300 mg/kg, purified andrographolide shows significant analgesic activity in the acetic acid-induced writhing test in mice and in Randall Selitt's test in rats.

The crude water extract of *A. paniculata* as well as the semi-purified n-butanol and aqueous fractions produced a significant fall in mean arterial blood pressure in anaesthetized Sprague-Dawly rats; the ED_{50} values were respectively 11.4 mg/kg, 5.0 mg/kg and 8.6 mg/kg. The aqueous extract exhibits a dose-dependent hypotensive activity on the systolic blood pressure in spontaneously hypertensive rats, when chronic intraperitoneal infusions are administered by osmotic pumps. Mechanistic studies indicate that the effect might be due to a reduction of circulating angiotensin-converting enzyme levels, as well as to a reduction of numbers of free radicals in the kidneys. Furthermore, a 10% infusion of the herb applied intravenously to rabbits at 1 ml/kg bodyweight reduced the blood pressure by 6–10 mm Hg in 10–20 seconds.

An *A. paniculata* extract was found to significantly alleviate atherosclerotic iliac artery stenosis induced by both de-endothelialization and high cholesterol diet in rabbits. It may therefore play an important role in preventing restenosis after coronary angioplasty, which normally can be 30–40%. Observations in dogs with experimentally induced myocardium infarction indicate that an aqueous extract may also limit the expansion of localized anaemia of the myocardium and exert a marked protective effect on reversibly ischemic myocardium. In these experiments, antithrombotic effects were also observed in the animals, e.g. inhibition of thromboxane (TBX2) synthesis and of platelet aggregation. It is believed that these effects might be at least partially due to flavones present in the extract.

When administered intraperitoneally (100 mg/kg) in mice, andrographiside and neoandrographolide have a significant protective effect on hepatotoxicity induced by carbontetrachloride or tert-butylhydroperoxide. Andrographolide is also hepatoprotective against galactosamine and paracetamol induced liver damage in rats. An extract of *A. paniculata* showed antidiarrhoeal activity in rabbit and guinea-pig ileal loop models. The diterpenes andrographolide and neoandrographolide isolated from the alcoholic extract showed potent antisecretory activity against *Escherichia coli* enterotoxin induced secretions. Andrographolide at 100 or 300 mg/kg is also known to exhibit significant anti-ulcer properties in rats. Furthermore, apigenin 7,4'-di-o-methyl-ether (a flavonoid) shows anti-ulcer effects in experimentally induced ulcers in guinea-pigs and rats. It is suggested that this effect is due to the antisecretory activity and protective effect on the gastric mucosa.

Other pharmacological effects reported in literature include:

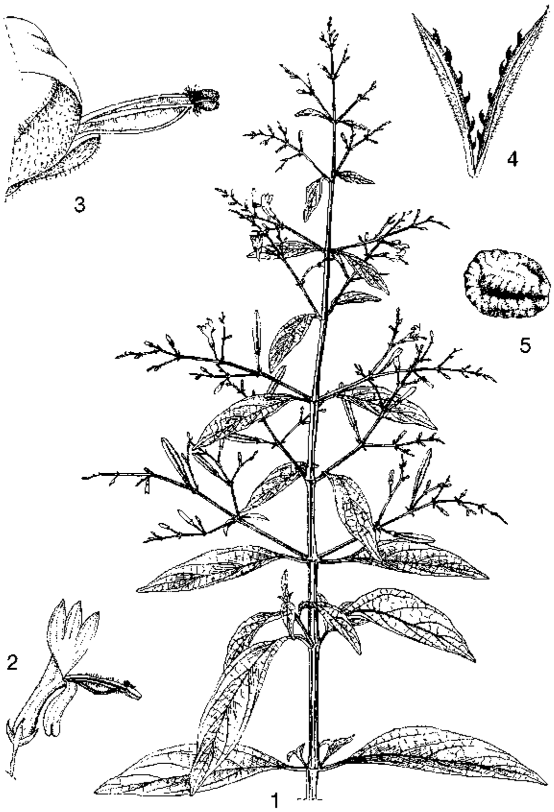
- The water extract administered at 10 mg/kg can significantly prevent glucose-induced hyperglycaemia in rabbits, but has no effect on adrenaline-induced hyperglycaemia. Furthermore, a hypoglycaemic effect in rabbits was observed when a 20% infusion was administered orally at doses of 12.5 and 37.5 ml/kg.
- The chloroform extract administered orally in rats at a dose of 8 mg/kg has a diuretic effect similar to 25 mg furosemide/kg.
- Platelet aggregation in humans was significantly reduced by *A. paniculata* extracts.
- Oral administration of 20 mg of the dry leaf powder for 60 days has an antifertility effect (antispermatogenic and/or anti-androgenic) in male albino rats.
- The alcoholic extract of the rhizomes of *A. paniculata* exhibits good in vitro anthelmintic activity against *Ascaris lumbricoides*.
- Andrographolide exhibits a strong choleretic action when administered intraperitoneally to albino rats.
- Neoandrographolide isolated from *A. paniculata* exhibits significant antimalarial activity against *Plasmodium berghei* NK 65 in the mouse *Mastomys natalensis*.
- Dehydroandrographolide succinic acid monoester, derived from andrographolide, has been found to inhibit the human immunodeficiency virus (HIV) in vitro.
- Several of the ent-labdane type diterpenoids (e.g. andrographolide, 14-epi-andrographolide, isoandrographolide, 12-epi-14-deoxy-12-methoxyandrographolide) show potent induction of cell differentiation towards M1 cells. In general, the activity of the dimers (bis-andrographolides A, B, C) is even more potent in this model system; the glucosides are only weakly active.

It has also been found that the ether extract of *A. paniculata* leaves has a fairly high anti-alkylating effect against ethyl-methane sulphonate. In general, anti-alkylating substances are associated with anti-carcinogenicity.

A leaf infusion administered intraperitoneally in mice, has an LD_{50} at 71.1 mg/10 g body weight (acute toxicity). At a concentration of 1 mg/kg it lowers the body temperature at least 2°C. In guinea-pigs, a leaf infusion of 5%, 10% and 15% at a dose of 8 ml/kg lowers the body temperature by 0.9–1.1°C. The possible testicular toxicity of a dried extract of *A. paniculata* was investigated in male Sprague Dawley rats. No testicular toxicity was found with the treatments of 20, 200 and 1000 mg/kg during 60 days as evaluated by reproductive organ weight, testicular histology, ultrastructural analysis of leydig cells and testosterone levels after 60 days of treatment. It was concluded that *A. paniculata* extract did not produce subchronic testicular toxicity in male rats.

Finally, *A. paniculata* extract is reported to have antifeedant and anti-oviposition activity against a number of crop pests like *Callosobrunchus chinensis*, *Darcus dorsalis*, *Nephotettix cincticeps*, *Plutella xylostella*, *Sitophilus oryzae* and *Spodoptera litura*.

Description A perennial herb 30–100 cm tall; stems distinctly 4-angular, glabrous apart from a few hairs at the nodes. Leaves opposite, simple, narrowly ovate to lanceolate, 5–10 cm × 1.2–2.5 cm, base long attenuate, apex long acuminate, margin entire, glabrous but often gland-dotted; petiole short, up to 6 mm long, connected with the opposite one by transverse ridges. Flowers in lax, axillary and terminal racemes or panicles combined into a pyramidal inflorescence, with 2 small bracteoles at base of the 1–7 mm long pedicel, bi-



Andrographis paniculata (Burm. f.) Wallich ex Nees – 1, flowering stem; 2, flower; 3, flower with detail of style and stamen arrangement; 4, dehisced fruit; 5, seed.

sexual, zygomorphic; calyx segments 5, jointed at base, with glandular and aglandular hairs; corolla bilabiate, white or rose with purple markings on the upper lip, tube 5–6 mm long, slightly enlarged below the limb, lower lip 4–6 mm long, oblong, 2-toothed at the apex, upper lip deeply 3-lobed, as long as the lower; stamens 2, inserted at the corolla tube apex and exserted, filaments hairy, anthers inserted at equal level, basally connate, bearded at base, deep purple to black; ovary superior, 2-locular with 3–7 ovules in each cell, style curved upwards, stigma entire. Fruit an erect, loculicidal, narrowly ellipsoidal, glandular hairy capsule, 14–20 mm × 3–3.5 mm, many-seeded. Seeds held up on well-developed hooks (retinaculae), almost rectangular, rugosely furrowed, with 2 deep furrows.

Growth and development In India, leaves of *A. paniculata* start to redden in October and are shed in December, after which the plants dry from the top down, leaving only a small portion of the stem green. New flushes emerge towards the end of the dry season. There are two distinct flowering periods: in India October and March-May, although plants growing under shaded conditions flower from October through to May. In Java, flowers and fruits of *A. paniculata* have been observed throughout the year. In northern Australia, flowering and fruiting specimens have been collected from November to June.

Other botanical information *Andrographis* comprises about 18 species occurring originally from India to China and western Malesia. It belongs to the small tribe *Andrographideae* of the subfamily *Acanthoideae*. This tribe is characterized by its articulated shoots and epidermis with cystoliths in combination with a 2-lipped corolla with ascending lobes and many ovules per locule. The pollen shows a unique structure as well.

Within various populations of *A. paniculata* in India and Bangladesh 9 different cytotypes have been identified. These proved to be related to the environment, particularly to soil conditions.

Ecology *A. paniculata* is locally common and often gregarious. It exhibits weedy characteristics and occurs from sea-level up to 1600 m altitude in village groves, roadsides, waste places, open sandy locations and fields, but also in monsoon and teak forest receiving only 10–20% of full light.

Propagation and planting Propagation of *A. paniculata* by seed is possible. Seed should be soaked during 24 hours and dried before being sown. Germination starts after 1 week and the mean germination rate is about 80%. Cuttings consisting of 3 nodes taken from the upper third of 1-year-old plants have given the best results in vegetative propagation, with 80–90% rooting. In India, seed is sown in May-June, and seedlings are transplanted at 60 cm × 30 cm.

In vitro production of active compounds A distinct cell line from callus culture of *A. paniculata* proved capable of synthesizing andrographolide in greater quantity than in the intact plant. Plantlets differentiated from this line were also high-yielding.

Husbandry In shading experiments with *A. paniculata* the optimal proved to be 20% shade with average dry-matter production of 13.2 g per 5-month-old plant. In India, irrigation may be necessary during dry periods.

Diseases and pests *Sclerotium* sp. occasionally causes wilt disease in *A. paniculata* during the rainy season. Eugenol at 200 ppm or clove powder containing 0.2 % eugenol could inhibit the growth and development of *Sclerotium* myceliae; its establishment is inhibited by eugenol at a concentration of 300 ppm or by clove powder containing 0.3% eugenol.

Harvesting Leaves of *A. paniculata* should be harvested when the inflorescence axis starts to grow, because the maximum accumulation of andrographolide is at that stage. In India, harvesting is in February-March, i.e. 9 months after planting. In Vietnam, where the crop is grown as an annual, the leaves are hand picked before flowering and roots are harvested when leaves start discolouring or wilting.

Yield Yields of 1–1.5 kg fresh weight/plant are obtained from 7-month-old *A. paniculata*.

Handling after harvest In general, harvested plant parts of *A. paniculata* are used fresh and consumed within a few days after collection. However, leaves and roots should be washed and dried in the sun or artificially before storage.

Genetic resources and breeding *A. paniculata* is relatively widespread and has a tendency to naturalize in areas where it has been introduced. Locally it is cultivated both for its ornamental and medicinal value. Therefore, the risk of genetic erosion seems rather limited. Selection should be directed to plant material with a higher content of medicinally important constituents. Preliminary results from callus culture techniques show considerable potential for improvement.

Prospects Extracts of *A. paniculata* as well as isolated compounds show a broad range of interesting pharmacological effects. In particular, the treatments for the common cold, the anti-inflammatory effects and the prevention of restenosis after coronary angioplasty deserve further attention. Furthermore, *A. paniculata* preparations may remain of local importance as a general tonic.

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Sri Sugati Sjamsuhidajat, Sudjaswadi Wiryowidagdo, Rini Sasanti & Wien Winarno

Angelica acutiloba (Siebold & Zucc.) Kitagawa

Bot. Mag., Tokyo 51: 658 (1937).

UMBELLIFERAE

$2n = 22$

Synonym *Ligusticum acutilobum* Siebold & Zucc. (1845).

Vernacular names Thailand: tang kui.

Origin and geographic distribution *Angelica* comprises about 110 species, widely distributed in the temperate regions of the northern hemisphere. *A. acutiloba* is indigenous in Japan and was introduced for cultivation in mountainous regions in West Java in the 1970s.

Uses The root of *A. acutiloba* ('Angelica Radix') is traditionally used in Japan and China as a general tonic and prescribed in the treatment of dysmenorrhoea, phthisis and haemorrhage. Furthermore, it is used as an emmenagogue, a remedy for anaemia, to alleviate pain during parturition and, in Indo-China, as a carminative and galactagogue. Two other *Angelica* species with a long history of medicinal use have been successfully introduced in Vietnam: *A. dahurica* (Fisch. ex Hoffm.) Benth. & Hook.f. ex Franchet & Savat. and *A. polymorpha* Maxim. (synonym: *A. sinensis* (Oliv.) Diels). In Western Europe various parts of *A. archangelica* L. have been used since ancient times as a vegetable and medicinal plant (to treat dyspeptic syndromes and as appetite stimulant).

Production and international trade Although there is a long tradition of trade of *A. acutiloba* from Japan to China and Indo-China, no trade figures are available.

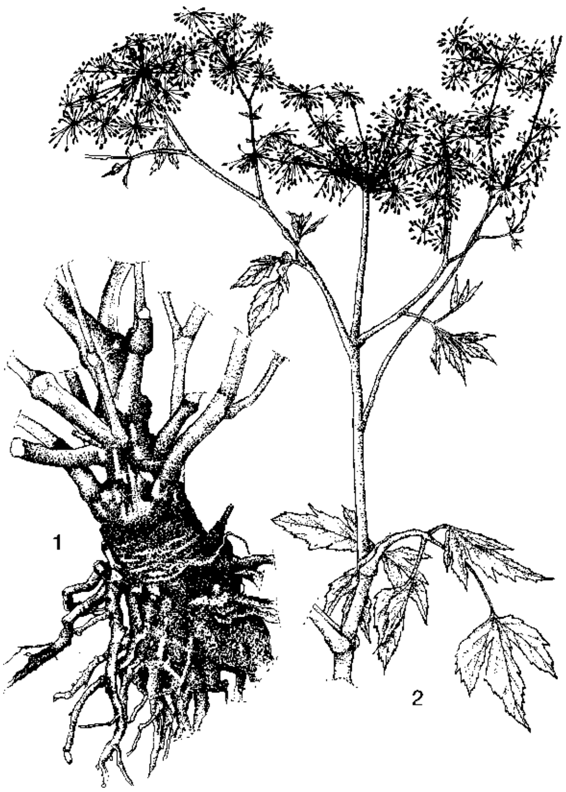
Properties Extensive chemical studies on *A. acutiloba* have revealed a wide array of compounds including polysaccharides, lactones and alkynes, some of which are medicinally active. The roots of *A. acutiloba* contain two anticholinergic compounds: ligustilide and butylidenephthalide. They also contain seven analgesic compounds: falcarinol, falcarindiol and falcarinolone (polyacetylenes), and choline, scopoletin, umbelliferone and vanillic acid. The latter compounds inhibit writhing in mice induced by acetic acid. The three polyacetylenes were the most active in the writhing test. Falcarindiol and choline also showed anti-nociceptive activities in the retrograde injection test of bradykinin into a carotid artery on rats. The polysaccharide fraction of a hot water extract of the roots of *A. acutiloba* showed a mitogenic activity on B-lymphocytes, polyclonal B cell activator activity, antitumour activity against Erhlich ascites cells, interferon-inducing activity and anticomplementary activity. These biological activities are caused by different water-soluble fractions. The action of Angelica immunostimulating polysaccharide (AIP) fraction on murine lymphocytes participating in antibody responses has been investigated. When AIP fraction was injected concomitantly into mice immunized with antigens, immunoglobulins G and M (IgG, IgM), antibody responses against sheep erythrocytes increased significantly, but IgM response against specific T-independent antigens did not augment. Furthermore, murine B lymphocytes were polyclonally activated in vitro and in vivo by AIP fraction to differentiate into antibody-forming cells as functionally matured cells. The differentiation of B lymphocytes to an intermediate stage capable of responding to helper T-lymphocytes was also stimulated by administering AIP fraction to CDF1 and C3H/HeJ mice. Stimulation of T-lymphocytes was also found.

An anticomplementary active arabinogalactan IIb-1 (AGIIb-1) and an inactive arabinogalactan IIb-2 (AGIIb-2) were isolated from an extract of the root of *A. acutiloba*. AGIIb-1 mainly consisted of arabinose, galactose, rhamnose and galacturonic acid in a molar ratio of 2.2:1.0:0.3:0.4. AGIIb-1 was found to form molecular self aggregation, caused by hydrogen bonding and ionic interaction. However, it was independent of Ca^{2+} ions. The anticomplementary activity of AGIIb-1 seemed to be dependent upon the degree of molecular aggregation; the aggregate in water showed the greatest activity. Further separations of AGIIb-1 revealed that it constisted of one neutral unit (N-I), one neutral arabinan unit (N-II) and two acidic arabinogalactan (A-I and A-II) units. N-I showed the most potent anticomplementary activity. AGIIb-1, A-I, and A-II had similar moderate activities, but N-II had weak activity. Digestion products prepared from the latter fractions by treatment with purified enzymes yielded several polysaccharides that also showed (modified) anticomplementary activity. In general, the anticomplementary activity of AGIIb-1 was expressed mainly through the classical pathway, whereas some modified polysaccharides had markedly increased activity through the alternative pathway.

The crude polysaccharide fraction (AR-1), prepared by ethanol precipitation and dialysis of the hot water extract from the root of *A. acutiloba* showed a potent antitumour activity against ascitic forms of sarcoma-180, IMC carcinoma and Meth A fibrosarcoma, as well as the solid form of MM-46 tumour. AR-1 was further fractionated into a pectic (AR-2) and a arabinogalactan (AR-4) fraction. An antitumour active component from AR-4 was identified as polysaccharide AR-4E-2, which consisted of arabinose, galactose and rhamnose in the molar ratio of 3.3:1.0:0.7. It also contains a rhamno-galacturonan moiety in which 2,4-di-substituted rhamnose residues are attached to 4-substituted galacturonic acid through position 2 of rhamnose. Furthermore, four pectic polysaccharides with anticomplementary activity were isolated from fraction AR-2. These compounds have been named AR-2 IIa–IId.

A root extract of *A. acutiloba* showed potent inhibitory effects on 12-O-tetradecanoylphorbol-13-acetate stimulated ^{32}P incorporation into phospholipids of cultured cells. The hot water extract of roots also exhibited antipyretic, central nervous system depressant, cardiac depressant, and hypotensive, antispasmodic and radioprotective activities.

Description A medium-sized perennial herb up to 70(–100) cm tall, tuberous root short with a few thickened secondary roots; stems glabrous, striate, solid. Leaves alternate, long-petiolate in lower part of stem, 1–2 ternately pinnate, deltoid in outline, 10–25 cm long, glabrous, leaf sheaths present, stipules absent; leaflets trifid, 5–10 cm × 1–2.5 cm, cuneate, truncate or rounded at base, ultimate segments lanceolate, long-acuminate, margin dentate, reticulate venation prominent. Inflorescence a compound many-flowered umbel, papillate, rays 30–40, 3–8 cm long, secondary rays (pedicels) 0.7–1.8 cm long; involucre consisting of a few filiform-linear bracts. Flowers with obsolete calys, petals unobtrusive white, ovary inferior, styles 2. Fruit consisting of two 1-seeds mericarps, oblong, 4–5 mm long, slightly compressed, narrowed towards the base, mericarps with slender ribs, lateral ribs slightly winged, vittae 3–4 in the intervals, 4 on the commissure.



Angelica acutiloba (Siebold & Zucc.) Kitagawa – 1, root; 2, stem with flowers and fruits.

Other botanical information Several subspecies and varieties have been distinguished within *A. acutiloba*. This variation can be partly attributed to geographical origin, but also the long tradition of cultivation has resulted in selections that can be morphologically distinguished. The differences are to some extent supported by karyological research.

Ecology *A. acutiloba* occurs naturally at higher elevations in mountainous regions. It is cultivated under similar conditions in Java.

Propagation and planting *A. acutiloba* can be propagated by seed as well as by somatic embryogenesis from hypocotyl and cotyledon material in Murashige and Skoog medium with 3% sucrose supplemented with 2,4-D (0.5–2 ppm) and kinetin (0.5–1 ppm). Regenerated plants can be obtained from the embryoids in Murashige and Skoog medium with 2% sucrose. Seedlings are usually transplanted. The spacing in experimental plantings in Java is 40 cm × 40 cm.

Harvesting Whole plants are uprooted, the tuberous roots separated, small rootlets removed, and finally the tuberous roots are washed and dried in the sun or shade.

Yield Intercropping *A. acutiloba* planted at 40 cm × 40 cm with maize and cabbage did not affect the yield of *Angelica* tuberous roots. In a field experiment in West Java, plantings of cultivar 'Siguyama Hikino' were harvested 6, 8, 10, 12, 14 and 16 months after transplanting. Root yields were 65–70% greater after 10 months than after 6–8 months.

Handling after harvest Roots of *A. acutiloba* were experimentally dried to a moisture content of about 11% and extracted with ethanol. The quality of the roots harvested after 10 months was of export grade with an ethanol extract percentage of 42%.

Genetic resources and breeding Breeding efforts in *A. acutiloba* are aimed at increasing the yield of tuberous roots and the concentration of active compounds. Experimental crosses between the cultivars 'Yamato Toki' (var. *acutiloba*) and 'Ibuki Toki' (var. *iwatenis* (Kitagawa) Hikino) showed a heterosis effect in the F-1 with respect to yield of tuberous roots and their sucrose content. However, the concentration of pharmacologically important compounds was intermediate between those of the parents. For industrial processing, breeding efforts should focus on obtaining plant material with a uniform concentration of pharmacologically important compounds in the roots. Somatic embryogenesis appears to be a successful method for this purpose. Breeding programmes in Vietnam to promote the cropping of *Angelica* at lower elevations through adapted cultivars have been successful with *A. dahurica* and *A. polymorpha*.

Prospects The polysaccharides from *A. acutiloba* show promise in antitumour activity and immunology (anticomplementary activity). Research on their actions thus deserves further attention.

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Antiaris toxicaria Lesch.

Ann. Mus. Natl. Hist. Nat. 16: 478 (1810).
MORACEAE
$2n = 24, 28$

Synonyms *Antiaris macrophylla* R.Br. (1814), *Antiaris africana* Engl. (1902), *Antiaris welwitschii* Engl. (1902).

Vernacular names Upas tree, sacking tree (En). Indonesia: upas (general), ancar (Javanese), tatai (Sumatra). Malaysia: ipoh (Peninsular), tasem (Sarawak). Papua New Guinea: antiaris. Philippines: dalit (Tagalog), ipo (Tagalog, Bisaya). Burma (Myanmar): aseik, hymaseik. Laos: 'nong^2, nong. Thailand: yang nong (central, northern), yuan (peninsular). Vietnam: c[aa]y sui, thu[oos]c b[aws]n.

Origin and geographic distribution *Antiaris* is a monotypic genus. The only species, *A. toxicaria* is found throughout the Old World tropics, from West Africa to Madagascar, and in Sri Lanka, India, Indo-China, southern China, Thailand, throughout the Malesian region, the Pacific (east to Fiji and Tonga), and northern Australia.

Uses The latex of *A. toxicaria* obtained from the bark is one of the principal components of dart and arrow poisons in South-East Asia, used by many peoples for hunting and warfare. It is usually mixed with poison obtained from *Strychnos* species and components from other plants or poisonous animals. Its effectiveness is thought to be enhanced by the synergy of its poisonous and irritating components. The latex is also reported to be used as fish poison and birdlime. Although a single species, old reports claim that trees from regions outside South-East Asia are less poisonous or even innocuous. It is possible that these reports refer to the latex being used differently, not as a dart or arrow poison, and thus not entering the bloodstream.

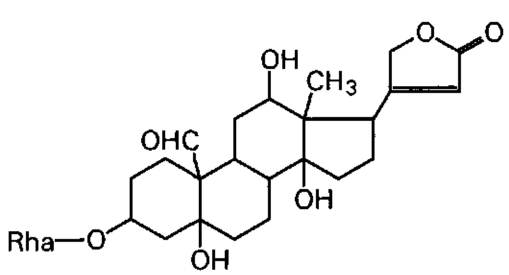
Seeds, leaves and bark are used as a febrifuge and the seeds also as an antidysentric. The latex is reported to be a mild circulatory and cardiac stimulant when used in very small amounts, but in large amounts it is a myocardial poison. In the Philippines, the soft wood is macerated and the fluid is used as a poultice for swellings. In India, upas tree is used as a febrifuge and to treat dysentery and epilepsy. In Vietnam, Cambodia and Laos, it is not used medicinally.

A. toxicaria is a sacred tree among some South-East Asian peoples. The fruit contains latex, but is reported to be edible. The bark yields fibre to make clothing, cordage, sacks, mats and paper. The bark has also been used for dyeing. The wood is used in light construction, furniture, interior finish, pallets, crates and plywood.

Production and international trade The wood of *A. toxicaria* enters international trade, but the other products are for local use only.

Properties The active principles in the latex of *A. toxicaria* are the cardiac glycosides (cardenolides) e.g. α, β and γ-antiarin, which have digitalis-like effects on the heart. In larger amounts they lead to cardiac arrest and secondary effects such as vomiting and convulsions. Reports on lethal dosage, administered intravenously, specify 0.3 mg as lethal within 12 minutes for a rabbit, and 1 mg to cause death within 3–9 minutes in dogs.

When administered to anaesthetized rats, the crude latex of *A. toxicaria* results in changes in the electrocardiogram (ECG) and systemic blood pressure. The extract inhibited the Na^+K^+ATPase that was partially purified from guinea-pig heart muscle. When the extract, and ouabain as a reference compound were applied to isolated frog heart muscles a decrease of twitch frequency together with an increased twitch tension were observed. All these facts together suggest that the main components of the latex are cardiac glycosides, which affect Na^+K^+ATPase activity of the heart muscle membrane. The poison must enter the bloodstream to be effective; the latex can be ingested without any effects. However, a fatal case of rhabdomyolysis and acute oliguric ranal failure following oral ingestion of blowpipe dart poison prepared from *Antiaris* and *Strychnos* has been reported. The influence of intravenous administration or otherwise promoting the poison to enter the bloodstream was illustrated in an experiment with dogs. When administered subcutaneously in pure form, there was no permanent toxic effect; when diluted with a decoction of *Strychnos ignatii* Bergius and administered in the same way the latex provoked a higher frequency of respiration, vomiting, convulsions and a rapid death. The sequence of the effects on toads were mild convulsions, violent peristalsis, an acceleration of the heartbeat followed by a deceleration, a contraction of the blood vessels, and death.

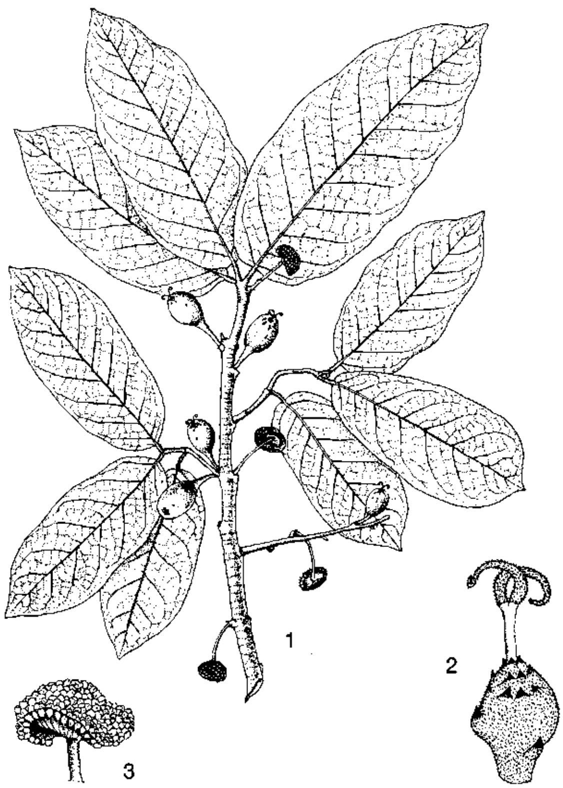


β-antiarin (Rha = rhamnose)

Prenylaurones (antiarone A and B), prenylchalcones (antiarone C, D and E) and prenylflavanones (antiarone F, G, H and I) have been isolated from the root bark. An aqueous ethanol extract of the bark exhibited cytotoxic activity against CA-9KB cells.

Adulterations and substitutes Cardiac glycosides are found in several dozen genera. In Vietnam, for example, other plants containing cardiac glycosides include *Asclepias curassavica* L., *Calotropis gigantea* (L.) Dryander, *Cerbera odollam* Gaertner, *Corchorus capsularis* L., *C. olitorius* L., *Digitalis* spp., *Nerium oleander* L., *Strophanthus* spp. and *Thevetia peruviana* (Pers.) K. Schumann. In western medical practice, pure glycosides produced by the extraction industry are used instead of crude plant products.

Description A monoecious, small to large tree up to 45(–60) m tall; bole straight, up to 180 cm in diameter, sometimes with steep buttresses up to 3 m high; bark surface smooth becoming slightly fissured, greyish-white, inner bark soft and fibrous, exuding a creamy copious latex which soon darkens to dirty brown and becomes granular upon exposure; twigs hairy. Leaves alternate, distichous, rounded to slightly heart-shaped, ovate or oblong, 7.5–20 cm × 3.5–8.5 cm, simple, slightly unequal at base, entire to denticulate; petiole 0.2–1 cm long, hairy; stipules free, caducous. Inflorescence on a short shoot, in leaf axils or below the leaves, subtended by involucral bracts, solitary or in groups of 2–4, the male ones below the female ones on the same twig. Male inflorescence a stalked discoid head with many flowers; each flower with 2–7 tepals and 2–4 stamens. Female inflorescence with 1–2 flowers, sessile or stalked; flower pear-shaped; perianth 4-lobed; ovary adnate to the perianth, 1-locular with a single ovule, styles 2. Fruit forming a drupaceous whole together with the enlarged, fleshy receptacle, ellipsoidal to pear-shaped, velvety. Seed one, cotyledon



Antiaris toxicaria Lesch. – 1, fertile twig; 2, female inflorescence; 3, male inflorescence.

fleshy. Seedling with hypogeal germination, the epicotyl with a few scale leaves, followed by spirally arranged, conduplicate, dentate leaves.

Growth and development Trees of *A. toxicaria* develop according to Roux's architectural tree model, characterized by a continuously growing monopodial orthotropic trunk and plagiotropic branches. In a 27-year-old trial in Indonesia trees measured on average 17 m in height and 27 cm in diameter. In Java the trees flower in June on the new shoots.

Other botanical information Formerly, *Antiaris* comprised several species, but is now regarded monotypic. The variable species *A. toxicaria* has been divided into 5 subspecies. Subsp. *toxicaria* and subsp. *macrophylla* (R.Br.) C.C. Berg occur within the Malesian region; the first is found from Sri Lanka to Sulawesi, the second from the Philippines to Tonga. The size of the fruit increases from Africa to Polynesia.

The vernacular names 'upas' and 'ipoh' refer to plant poisons acting on the blood in general. Similarly, these names are used for *Strychnos* ('ipoh akar') and *Sophora tomentosa* L. ('upas biji' or 'upas kamarunggi').

Ecology *A. toxicaria* is a rare, scattered tree in primary forest up to 1500 m altitude. It is occasionally found in grassy savanna and on coastal plateaus. The morphological variation as observed in habit and various parts of the plant may well be linked to environmental factors. In Africa, it occurs under semi-arid conditions as well as in rain forest areas, or even in swamp forest.

Propagation and planting *A. toxicaria* can be propagated by seed. About 70–90% of sown stones germinate in 18–89 days.

Husbandry Trees of *A. toxicaria* have a good self-pruning ability; they are not resistant to fire.

Harvesting The latex of *A. toxicaria* is tapped by making scores in the bark with a knife. It is only collected when required, as it cannot be stored and must be used fresh. The bark is harvested by stripping from the tree.

Yield The latex yield of a scarred tree may be 100–500 g in 2 days.

Handling after harvest An extensive list of traditional preparations and mixtures of 'upas poison' can be made. In general, the latex from the root-bark or bark is mixed with other ingredients such as bark or roots of *Strychnos*, *Derris* and other presumably irritating substances. The mixture is boiled over a fire to obtain a thick paste in which the dart and arrow points are dipped. The time over which the poison retains its potency is rather variable, apparently depending on mixture and method of preparation.

In Malaysia, bark cloth is obtained by shaving off the outer part from bark stripped from the tree, and beating and washing the inner fibrous part. Careful preparation is required, because traces of latex may irritate the skin.

Genetic resources and breeding Genetic erosion of *A. toxicaria* is difficult to assess, as trees are not widely harvested throughout their natural area of distribution, but generally occur at low densities.

Prospects The latex of *A. toxicaria* has been proposed as a medicine for heart diseases. As the crude drug extract varies in concentration and composition of the constituents, and given the extreme toxicity of the latex, it is rather difficult to standardize clinical applications.

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E. Boer, M. Brink & M.S.M. Sosef

Arcangelisia flava (L.) Merr.

Interpr. Herb. amboin.: 222 (1917).

MENISPERMACEAE

$2n$ = unknown

Synonyms *Arcangelisia lemniscata* (Miers) Becc. (1877), *Arcangelisia loureiri* (Pierre) Diels (1910).

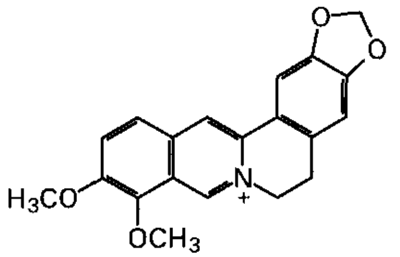
Vernacular names Yellow-fruited moonseed (En). Indonesia: areuy ki koneng (Sundanese), sirawan (Javanese), daun bulan (Moluccas). Malaysia: mengkunyit. Philippines: abutra (Ilokano, Bisaya), suma (Tagalog, Pampango). Thailand: khamin khruea (Chanthaburi), kamphaeng jedchunum. Vietnam: v[arly d[aws]ng.

Origin and geographic distribution *Arcangelisia* consists of only 2 species. Yellow-fruited moonseed is widely distributed from Hainan (China), Indo-China, southern peninsular Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, the Philippines, Sulawesi, the northern Moluccas to New Guinea.

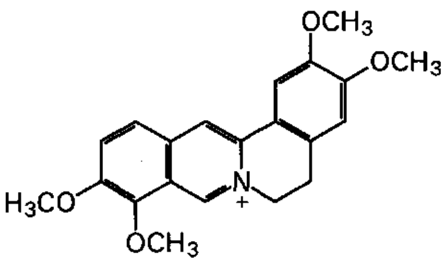
Uses Yellow-fruited moonseed is mainly used medicinally. In Peninsular Malaysia, a decoction of the stem is taken internally for jaundice, worms, indigestion and other intestinal complaints. The smoke from the burning wood is inhaled for troubles of the mucous membrane of the nose and mouth. In the Philippines, yellow-fruited moonseed is a popular antiseptic: a decoction of the wood is used to clean wounds, ulcers and other skin irritations. Traditional applications include the use of a decoction or infusion of the stem as a stomachic, febrifuge, expectorant, tonic, and emmenagogue or abortivum (depending on the quantity administered). In Indonesia, the stems are sold as 'kayu seriawan', meaning 'wood against sprue'. The sap which flows abundantly from cut stems is drunk against fever and sprue. In Thailand, the stems are used against indigestion, as a tonic and emmenagogue; the flowers are used to treat dysentery. In the Philippines, the Moluccas and New Guinea a yellow dye is extracted from the woody stem. The use of the fruits as a fish poison is questionable.

Properties *Menispermaceae* species are well-known to contain mixtures of (bis-)benzylisoquinoline-type alkaloids, which are biosynthetically derived from the amino acids phenylalanine or tyrosine. Alkaloids found in *A. flava* are: berberine, 8-hydroxyberberine, columbamine, jatrorrhizine, palmatine, thalifendine, dehydrocorydalmine, shobakunine (all of the quaternary protoberberine type), and (–)R,R-limacine, (+)R,S-homoaromaline and pycnarrhine (of the bisbenzylisoquinoline type). The pharmacological effects and the yellow colour of the dye extracted from the plant, are largely attributable to berberine, which is present in concentrations of up to 5% in the stem (dry weight).

The pharmacological effects of berberine have been fairly well investigated. Berberine (as the chloride) has been found to be active against a number of gram-positive as well as gram-negative bacteria, such as *Diplococcus pneumoniae*, *Escherichia coli*, *Neisseria gonorrhoeae*, *Salmonella typhosa*, *Shigella dysenteriae*, *Staphylococcus au-*



berberine



palmatine

reus, *S. hemolyticus* and *S. paradysenteria* in different media. It had about the same antibacterial activity as some sulphonamides; berberine also had an effect in broth supplemented with serum, whereas the sulphonamides were antagonized. However, it was found possible for the microorganisms to acquire resistance when left in contact with berberine for a long time.

Berberine (as the sulphate) has been shown to be bactericidal to *Vibrio cholerae* at a concentration of 35 μg/ml and bacteriostatic to *Staphylococcus aureus* at a concentration of 50 μg/ml. In both these organisms berberine at the concentrations mentioned inhibited RNA and protein synthesis almost immediately after addition. Cell-free preparations made from vibrios pretreated with berberine did not produce choleraic symptoms in infant rabbits, suggesting that the toxin was either inactivated or neutralized. Oral administration of berberine to infant rabbits 18–24 h before a single fatal intra-intestinal dose of choleragenic toxin prevented toxin-induced diarrhoea and consequently prolonged survival when compared with untreated choleragenic animals. The quaternary ammonium group in berberine seems necessary for its antibacterial activity. Derivatives without the quaternary ammonium group, such as tetrahydroberberine, showed only little antibacterial effect. Berberine (sulphate) in concentrations of 10–25 mg/ml inhibited the growth of the fungi *Alternaria* spp., *Aspergillus flavus*, *A. fumigatus*, *Candida albicans*, *Curvularia* spp., *Drechslera* spp., *Fusarium* spp., *Mucor* spp., *Penicillium* spp., *Rhizopus oryzae* and *Scopulariopsis* spp. Oral administration of berberine sulphate at doses of 350–700 mg/kg was effective in treating *Candica albicans* infections of the intestine in mice.

Berberine (sulphate) administered to rats at doses of 100 mg/kg body weight, 10 days after experimentally induced intestinal amoebiasis was effective in 80% of the animals. It completely inhibited the growth to trophozoites of *Entamoeba histolytica* at concentrations of 0.5–1 mg/ml in vitro, and was active in vivo against infections with *E. histolytica* in hamsters and rats. Berberine has also been found to be trypanocidal against *Trypanosoma brucei rhodesiense*. In vitro activities with IC_{50} values of 0.4 μg/ml were determined.

Both berberine sulphate (50 μg/ml) and berberine chloride (25 μg/ml) showed growth inhibition of Ehrlich and lymphoma ascites tumour cells. The presence of berberine in granules inside the cells was detected by its fluorescence. The cytotoxic ED_{50} values in HeLa cell cultures were 3.5–30 μg/ml, and in KB cells a 70% inhibition of protein synthesis was found at a concentration of 1 μg/ml. Berberine chloride inhibited the formation of DNA, RNA, proteins and lipids, as well as the oxidation of [^{14}C]glucose to $^{14}CO_2$ when incubated with S180 (Swiss mouse ascites sarcoma) cells in vitro. Protein and RNA syntheses were most sensitive to berberine. However, berberine failed to inhibit the growth of S180 ascites tumours in mice, which may be explained by the effect of different glucose levels in biological fluids. The binding of the alkaloid to DNA was investigated by means of spectroscopy. Calf thymus DNA produced systematic changes in the absorption spectrum of berberine, which suggests that berberine forms a complex with DNA and binds to the extent of one alkaloid molecule per two base pairs. These binding properties seem te be influenced by the presence of charge and the position and type of substituents in the molecule. From other experiments it was also concluded that berberine is a potent activator for macrophages, to induce inhibition of tumour cells in vitro.

Intravenous infusion of berberine sulphate to rats was found to lower the blood pressure in a dose-dependent manner. A significant hypotensive effect was followed by bradycardia. These effects were also observed in bilaterally vagotomized rats. Berberine chloride at doses of 0.5–5.0 mg/kg administered to rabbits anaesthetized with urethane produced a long lasting, dose-related decrease in blood pressure. The berberine induced hypotension seems attributable to α-adrenoceptor blockade, and not to a direct relaxant effect on vascular smooth muscle. Berberine had no direct vasodilatory effects on isolated rabbit pulmonary and cat coronary arteries either, however, the alkaloid reversed vasoconstriction mediated by α-adrenergic agents in both preparations.

Both berberine and palmatine inhibited specific cholinesterase in rabbit spleen and pseudocholinesterase in normal horse serum. Both compounds were less effective inhibitory agents than neostigmine, but palmatine exhibited lower toxicity than berberine. Tetrahydropalmatine and tetrahydroberberine had no anticholinesterase effect, suggesting that the quaternary ammonium group is crucial for the effect of isoquinoline alkaloids on this enzyme.

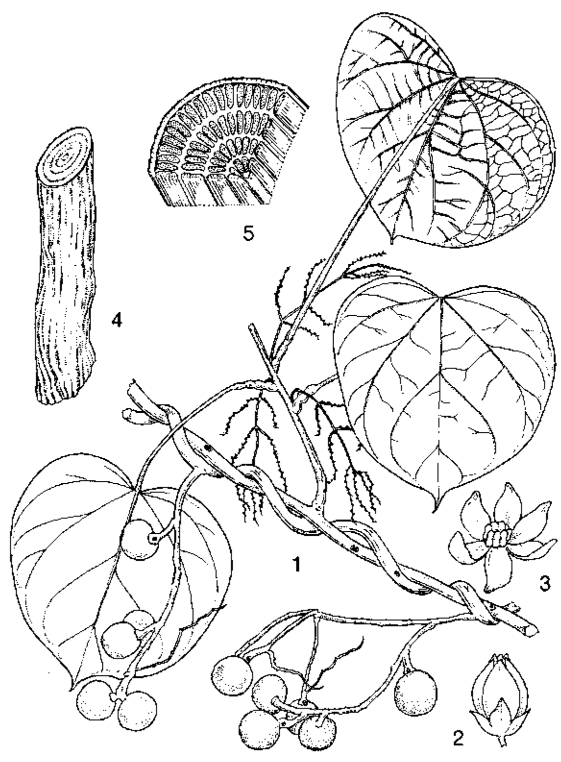
Some metabolic and toxicological data on berberine are available from experiments on rats. The blood level of orally administered [^{3}H]berberine chloride plateaued after 4–24 h, and maximal levels in the liver and muscles were achieved at 12 h. Urinary berberine excretion reached a maximum at 12–24 h. Excretion in the urine and faeces at 48 h amounted to respectively 2.7% and 86% of the administered dose. Faecal elimination as the main excretion route indicates that berberine is not readily absorbed by the gastro-intestinal tract. The biological half-life of berberine chloride was 5.2 h after intraperitoneal administration and 5.4 h after oral administration. Perfusion experiments (in dogs and rabbits) indicated oxidation of berberine chloride in the liver. The LD_{50} value of berberine sulphate was more than 1 g/kg after oral administration in the rat and about 90 mg/kg after intraperitoneal administration. Histopathological examinations revealed no changes in tissues and organs, even in cases when berberine sulphate had been given for 6 weeks at daily doses of 500 mg/kg.

Of the bisbenzylisoquinoline alkaloids investigated, (+)-homoaromaline showed inhibition of the histamine production by RBL-2H3 cells in vitro, and both (+)-homoaromaline and (−)-limacine were capable of inhibiting the growth of cultured *Plasmodium falciparum* strains and tumour cell lines. However, their 'selectivity index' (activity against mammalian cells / activity against cultured *P. falciparum* strains) typically ranges from 2–100; a selectivity index of >1000 appears to indicate that a component merits further investigation as an anti-malarial.

Crude aqueous extracts of *A. flava* showed slight insecticidal activity against cotton bollworm (*Helicoverpa armigera*) in the Philippines. Bollworms fed with treated cotton bolls were significantly smaller and shorter than their controls.

Adulterations and substitutes Several *Menispermaceae*, e.g. *Coscinium fenestratum* (Gaertner) Colebr., *Fibraurea tinctoria* Lour., *Limacia* spp. and *Tinospora* spp. contain berberine or related compounds and are used for similar purposes. *Coptis teeta* Wallich (*Ranunculaceae*) is another species containing berberine and with similar uses. Berberine has been named after the genus *Berberis* (*Berberidaceae*) in which the compound was found first. In India and Vietnam, for example, *Berberis* spp. are used against similar diseases as *A. flava*.

Description A large, woody, glabrous, dioecious liana, up to 20 m long; stem up to 5 cm in diameter, wood yellow, exuding yellow sap when cut. Leaves usually ovate, (10–)12–25 cm × (5.5–)8–19 cm, coriaceous, palmately 5-veined at the base;



Arcangelisia flava (L.) Merr. – 1, intertwining flowering and fruiting stems; 2, closed male flower; 3, opened male flower; 4, part of woody stem; 5, detail of stem in cross and longitudinal section.

petiole (4–)7–15(–20) cm long, swollen at both ends; stipules absent. Inflorescence axillary or cauliflorous, paniculate, slender, 10–50 cm long, lateral branches spicate to subspicate. Flowers unisexual, with 3–4 minute outer sepals and 6 larger inner sepals, petals absent; male flower subsessile, with a sessile, globose cluster of 9–12 anthers; female flower with 3 carpels and a number of staminodes. Fruit a slightly laterally compressed drupe, transversely subovoid, 2–3 cm in diameter, yellow, with a club-shaped stalk; endocarp woody, covered with a dense mat of radial fibres. Seed broadly ellipsoidal, with ruminate endosperm, cotyledons much folded.

Growth and development The fruits are eaten and dispersed by primates such as macaques, gibbons and orang-utans, and probably other arboreal mammals.

Other botanical information Some confusion exists in the literature between *Arcangelisia flava* and *Anamirta cocculus* (L.) Wight & Arnott. *A. flava* has yellow wood and is used predominantly as a medicine, *Anamirta cocculus* has white wood and the fruits are used as a fish poison and an insecticide, while its bark is used as rope. The second *Arcangelisia* species (*A. tympanoda* (Lauterb. & K. Schumann) Diels) is apparently endemic to New Guinea and is poorly known.

Ecology *A. flava* occurs in forests at altitudes up to 1000 m, sometimes near river banks. In Sulawesi, it is reported on limestone.

In vitro production of active compounds In vitro production of berberine is possible. Callus cultures of *A. flava* have been established in Thailand, using revised tobacco medium supplemented with phytohormones (naphtalene acetic acid at 2 mg/l, indole-butyric acid at 2 mg/l and kinetin at 1 mg/l). The production can be increased on media containing coconut milk, casein hydrolysate, tyrosine (a berberine precursor), manganese sulphate and aluminium sulphate. The intensity of the yellow colouration of the callus is an indication of the amount of alkaloid produced.

Harvesting In Indonesia, the stems are cut in the early morning to obtain the sap which is drunk to cure fever and sprue.

Yield In the Philippines, it has been reported that as much as 1 kg of berberine can be obtained from a single plant.

Genetic resources and breeding Yellow-fruited moonseed is widespread and seems not to be easily liable to genetic erosion. There are no known germplasm collections or breeding programmes. Future breeding work may focus on the selection of types with high alkaloid content.

Prospects Yellow-fruited moonseed is considered an interesting medicinal plant and may become important in cancer control. The development of proper biotechnological methods to produce alkaloids in tissue culture might provide the tools for large-scale production of alkaloids from *A. flava*.

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E.H. Mandia, C.E. Ridsdale,
S.F.A.J. Horsten & A.M. Aguinaldo

Aristolochia L.

Sp. pl. 2: 960 (1753); Gen. pl. ed. 5: 410 (1754).
ARISTOLOCHIACEAE
$x = 7$; *A. tagala*: $2n = 14$

Major species *Aristolochia tagala* Cham.

Vernacular names Birthwort, Dutchman's pipe (En). Snakeroot (Am). Aristoloche (Fr).

Origin and geographic distribution *Aristolochia* consists of approximately 300 species and is mainly distributed throughout the tropics, but some species occur in warmer temperate regions. The greatest diversity in species is found in Central and South America. In the Malesian region 28 species have been found; *A. tagala* has the largest area of distribution, occurring from India and China, throughout South-East Asia, to Australia.

Uses *Aristolochia* is not much used in local medicine in South-East Asia. The use of a decoction of the roots as a stomachic, emmenagogue and febrifuge is most common. A poultice of the leaves is sometimes used to treat skin diseases. Some extra-Malesian species are, however, renowned in Chinese, Indian and South American health care systems, and are included in pharmacopoeias.

The Chinese Pharmacopoeia lists e.g. the dry ripe fruits of *A. contorta* Bunge and of *A. debilis* Sieb. & Zucc. which are used in the treatment of respiratory diseases as an antitussive and antiasthmatic. Their dry aerial parts are also used as a diuretic against oedema and as an antirheumatic. The root of *A. fangchi* Y.C. Wu ex L.D. Chou & S.M. Hwang is valued as an antirheumatic and diuretic and the dried vine of *A. mandshuriensis* Kom. is a well-known diuretic and antiphlogistic for treatment of oedema and rheumatic pain. In China and Japan, extracts from the roots of *A. debilis* are furthermore used to treat high blood pressure.

A. bracteolata Lamk (synonym: *A. bracteata* Retz.) and *A. indica* L. have a considerable reputation in India. *A. bracteolata* is reputed for its purgative and anthelmintic properties; a root decoction is employed to expel roundworms, and is known as an emmenagogue. In Africa, *A. bracteolata* has a local reputation as a powerful anthelmintic mostly used in veterinary practice. The dried rhizomes and roots of *A. indica* constitute an important drug in India, much esteemed as a gastric stimulant and bitter tonic and used to treat intermittent fevers. The drug is prescribed as a tincture, and sometimes administered as a powder. The juice of fresh leaves is used to treat coughs, and the seeds to treat inflammations, biliousness and cough. Juice from the leaves is applied to ulcers and, mixed with castor oil, to eczema. *A. indica* is also used in India as an antidote for snakebites and scorpion stings. In traditional Thai medicine, the roots are used as antipyretic, emmenagogue, expectorant and tonic. The leaves are used in the treatment of snakebites. Its roots possess antifertility activity. *A. tagala* roots are considered in India to be tonic, carminative and emmenagogue. They are frequently used there to adulterate *A. indica* for use in medicine. *A. elegans* Masters from tropical America has medicinal and insecticidal properties and is locally cultivated in South-East Asia, e.g. in the Philippines and Thailand. In Vietnam, some species are imported from China to be used in local medicine, e.g. *A. heterophylla* Hemsley and *A. westlandii* Hemsley, which are used as diuretic and prescribed to treat oedema and dysuria. *A. serpentaria* L. is used in local medicine in North America.

Several American species are cultivated as ornamentals for their beautiful flowers. Some species are cultivated as food plants for the larvae of commercially traded swallowtail and birdwing butterflies.

Production and international trade None of the Malesian *Aristolochia* species are traded, but fruits of *A. debilis* are imported from China and sold in Chinese medicine shops in Peninsular Malaysia.

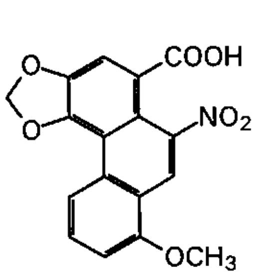
Properties The chemical constituents of *Aristolochia* species can generally be divided into three chemical groups: aristolochic acids (derivatives), alkaloids and sesquiterpenes.

The aristolochic acids are a family of at least 14 closely related structures, derived from the phenanthrene system and bearing a carboxyl function and a nitro substituent. These compounds are intensely bitter, and it is hypothesized that in their biosynthesis oxidative coupling of orientaline gives prestephanine, which is converted into stephanine; oxidative cleavage of stephanine then furnishes aristolochic acids. When the nitro group is replaced biosynthetically by an amino group, the carboxyl group forms a lactam ring, giving a number of aristolactams. Aristolochic acid can furthermore be converted to aristolic acid by a one-step removal of the nitro group.

One of the alkaloids isolated from some *Aristolochia* species is magnoflorine (an aporphine type alkaloid derived from phenylalanine/tyrosine), which is structurally and phylogenetically strongly related to aristolochic acid derivatives. The sesquiterpenes are mainly constituents of the volatile oil.

Not much is known about the properties and chemical constituents of the South-East Asian species, except for some information on *A. tagala* from the root of which aristolochic acid I (= aristolochic acid A), aristolochic acid IIIa (aristolochic acid C), 9-hydroxyaristolochic acid I and allantoine have been isolated. Much more research has been done on some Indian and Chinese species.

Aristolochic acid I (0.1–0.6%) and debilic acid have been isolated from the roots of *A. debilis*, together with 9-hydroxy and 9-methoxyaristolochic acid I, aristolochic acid II, aristolochic acid IIIa, aristolochic acid IV, aristolochic acid IVa (= aristolochic acid D) and some aristolactams. Furthermore isolation of the alkaloidal constituents magnoflorine, cyclanoline, tetrandrine, N-acetyl-nornuciferine and allantoine has been reported. The sesquiterpenes isolated are mainly of the aristolane type: e.g. aristolone (about 0.42%), 9-aristolene, 1(10)-aristolene and debilone. Aristolochic acid I methyl ester, aristolochic acid IV methyl ester and aristolochic acid IVa were isolated from the stems of *A. mandshuriensis*, and magnoflorine detected. In addition, a new glycoside of aristolochic acid D was also isolated and named aristoloside or aristolochin. Phytochemical analysis of the constituents in the roots of *A. fangchi* revealed amongst others the presence of aristolochic acid I, aristolochic acid IVa, aristolochic acid IV methyl ester, magnoflorine, p-coumaric acid and N-(p-hydroxyphenyl)-p-coumaramide in the ethanol extract. Together with aristolochic acid I, magnoflorine and allantoine, a new compound aristolochic acid E was isolated from the root of *A. contorta*. Several aristolochic acids and derivatives (e.g. aristolic acid), sesquiterpenes, alkaloids (e.g. l-curine), steroids, p-coumaric acid and a naphthaquinone (aristolindiquinone) have been identified from the roots of *A. indica*. A phytochemical investigation of the leaves of *A. elegans* indicated the presence of sterols and 5 alkaloids. The steroidal material was isolated and identified as β-sitosterol. The seeds of *A. bracteolata* contain



aristolochic acid I

aristolochic acid and magnoflorine. Aristolochic acid I and IVa, magnoflorine, allantoine and β-sitosterol have been isolated and identified from the roots of *A. heterophylla*.

The biological activities of aristolochic acid I have been studied extensively. A number of gram-positive bacteria (including *Bacillus*, *Diplococus*, *Mycobacterium*, *Sarcina*, *Staphylococcus* and *Streptococcus*) are inhibited by this acid at a concentration of 50–200 μg/ml. A concentration of aristolochic acid I higher than 200 μg/ml was needed to inhibit gram-negative bacteria and fungi. Mice infected with *Diplococcus pneumoniae*, *Staphylococcus aureus* or *Streptococcus pyogenes* were found to be protected from disease by intraperitoneal administration of aristolochic acid I at a dose of 50 μg/kg. The phagocytic activity of peritoneal macrophages of treated mice was markedly stimulated. Some results of studies on the immunostimulating and antitumour activities of aristolochic acid I contradicted each other. It has been reported that the survival time of mice bearing ascitic sarcoma-37 tumours treated with aristolochic acid by intraperitoneal administration at a daily dose of 1–5 mg/kg for 5 days was appreciably prolonged. Growth of mouse sarcoma-37 cells was found to be completely inhibited by incubation with aristolochic acid I. Treating mice with aristolochic acid I at a daily dose of 2.5–5 mg/kg for 3 days after subcutaneous implantation of sarcoma-37 cells resulted in 40–50% inhibition of tumour growth. Aristolochic acid I, administered orally, reduced the number of tumours induced by methylcholanthrene in mice. Aristolochic acid I increased oxygen consumption in a dose-dependent manner in liver cells and splenocytes of mice. The metabolic activity of guinea-pig peritoneal macrophages and human leucocytes was also enhanced by aristolochic acid I, as shown by measuring oxygen consumption. Both aristolochic acid I and II exhibited a stimulation of lucigenine-enhanced, opsonized Zymosan-induced neutrophil chemiluminescence as a sensitive assay for immunomodulating activity. In a leucocyte adherence inhibition test, an activity of aristolochic acid I could also be demonstrated; however, it was weaker than that of prednisolone. Following the administration of aristolochic acid I to guinea-pigs immunized with Q-fever antigen, the antigen-induced decrease in bone marrow lymphocyte count was restored to normal levels much faster than was observed in untreated immunized controls. In contrast to these results, there is also a report that aristolochic acid I did not prolong the survival time of tumour-bearing mice or enhance the immune function of the mouse reticuloendothelial system, or the phagocytic activity of mouse peritoneal macrophages. Aristolochic acid has been shown to be a non-competitive inhibitor of phospholipase A2 from snake venom. It inhibited the oedema-inducing and haemolytic activity of this compound in the venom, but failed in tests to inhibit other pathological activities of the enzyme.

Aristolochic acids are known for their nephrotoxicity in humans and several animal species, and their mutagenic and carcinogenic activities have also been extensively studied. Aristolochic acid I has been proved to be a direct mutagen in *Salmonella typhimurium* strains TA 1537 and TA 100, but had no mutagenic effect on TA 1535, TA 1538 or TA 98. Aristolochic acid II had almost equal mutagenic potency, and the aristolactams were mutagenic in both strains too, when a metabolizing system was present. The mutagenic activity of aristolochic acid I was also tested in the granuloma pouch assay, which detects gene mutations induced in subcutaneous granuloma tissue of rats. After direct exposure of the target tissue, aristolochic acid I induced high frequencies of mutations at a relatively low cytotoxic level. After oral administration of aristolochic acid I to rats, a dose dependent mutagenic activity was registered. The carcinogenic activity of aristolochic acid I has been demonstrated in experimental animals. Male and female rats treated orally with aristolochic acid I at daily doses of 0.1, 1.0 or 10.0 mg/kg developed a high incidence of tumours, dependent on dose and time. Rats treated for 3 months with either 1.0 or 10.0 mg/kg aristolochic acid I developed severe papillomatosis of the forestomach, with occasional signs of malignancy. Without further treatment, the rats developed squamous cell carcinomas in the forestomach 3–6 months later and formation of metastases. For these reasons, many European countries (e.g. Germany and France) have restrictive regulations for preparations containing *Aristolochia*, even including homeopathic preparations with their great dilution.

The alkaloid magnoflorine is a hypotensive principle. In rabbits it decreased arterial blood pressure and induced hypothermia. In anaesthetized cats, intravenous injection of 2 mg/kg magnoflorine produced a prompt and significant fall in blood pressure. Oral administration at a dose of 20–40 mg/kg also resulted in hypotension. The acute LD_{50} of magnoflorine by intravenous injection in mice was 20 mg/kg. Oral administration with a tenfold higher dose daily for 4 weeks did not elicit any toxic symptoms or retard growth.

Aristolic acid (biosynthetically derived from aristolochic acid through removal of the nitro group) obtained from *A. indica* disrupted nidation in mice when administered on the first day of pregnancy. It showed implantation-inhibiting effects. Possibly this compound interferes with steroidal conditioning of the uterus. Furthermore, both aristolochic acid I and magnoflorine induced contractions in isolated pregnant rat uterus and stimulated guinea-pig ileum. p-Coumaric acid isolated from *A. indica* roots is known to be an inhibitor of prolactin secretion.

Ethanol extracts of *A. indica* roots decreased fertility in rats and hamsters. The petroleum ether extract of the roots showed 100% interceptive activity in mice at a single dose of 100 mg/kg. The sesquiterpene (12S)-7,12-secoishwaran-12-ol is reported as another active principle. Other laboratory experiments have failed to demonstrate activity on uterine contraction, and experiments on abortifacient activity have been inconclusive.

Tests on rats with ethanolic extracts of *A. indica* showed no antipyretic activity. The ethanol extract of *A. bracteolata* exhibited uterine stimulant and anthelmintic properties. Aqueous and alcohol extracts of *A. debilis* were found to be highly effective against herpes simplex virus in vitro, and also showed some effect on respiratory syncytial virus and coxsackie virus. Extracts of *A. mandshuriensis* showed significant inhibitory activity on the mutagenicity of 3-amino-1,4-dimethyl-5H-pyrido-(4,3-b)-indole, and anglotensin converting enzyme.

The aristolochic acids extracted from *A. bracteolata* showed chemosterilizing effects on several insect species including mosquitoes. In the Philippines, extracts from *A. tagala* showed insecticidal properties against the yponomeutid crucifer pest *Plutella xylostella*, the maize pest *Ostrinia furnacalis* and the common cutworm (*Spodoptera litura*). A methanolic extract of *A. bracteolata* showed significant inhibitory effect on the aflatoxin production of *Aspergillus flavus*, and the plant may have potential as an antifungal agent.

Adulterations and substitutes There are indications that *Aristolochia* extracts are sometimes mistaken for *Menispermaceae* extracts. Rapidly progressive renal fibrosis has been described in young women who had taken Chinese herbs as part of a slimming regime. Aristolochic acid was suspected as its causal factor, but this compound is not present in the *Stephania* extract, which is one of the ingredients of the drug. Possibly an *Aristolochia* extract and not a *Stephania* extract was used to prepare the drug in question.

Description Woody or herbaceous perennial climbers or erect, scandent to scrambling shrubs often woody at base; tuberous or prostrate rhizomes or rootstocks often present; older woody stems usually with a thick corky and fissured bark. Leaves arranged spirally or alternate, simple, usually entire but sometimes 3-lobed, venation palmate or pinnate, secondary veins often extending obliquely towards the leaf margin; petiole grooved above; stipules absent. Flowers solitary or in fascicles or in cymose, racemose, spicate or paniculate inflorescences, in the axils of leaves or borne on the stems, bisexual, zygomorphic (rarely actinomorphic), bracts usually present and persistent, pedicel usually hardly distinct from the ovary; perianth consisting of 3 parts with a basal inflated part (utricle), a straight or curved cylindrical tube, and the expanded 3(–6)-lobed limb with valvate or induplicate lobes or (usually) 1-lipped; stamens 6(–10), in a single whorl, adnate to the style column to form a gynostemium, anthers extrorse and dehiscing longitudinally; ovary inferior, oblong or elongate, 6-celled, style column 6-lobed. Fruit a 6-celled capsule, dehiscing septicidally, usually basally towards the apex, many-seeded. Seeds ovate, deltoid or triangular, flat, often winged, testa crustaceous or hard, finely verrucose or smooth, funicle often thickened and covering the whole seed, with fleshy and copious albumen and minute embryo. Seedling with epigeal germination; cotyledons rather fleshy; first 2 leaves opposite, subsequent ones alternate.

Growth and development In *Aristolochia* the flowers of an inflorescence open only singly or very few at a time. Their form is related to the fly-trap pollination mechanism. The flowers are insect-pollinated, usually by flies and sometimes by ants attracted by the putrid odour of the flowers and trapped in a kettle-like part (utricle), after having passed a 'slide zone' on the limb. The flower tube in between the limb and utricle is usually provided with retrorse hairs preventing insects from leaving the utricle. The flowers are proterogynous and the ripe stigmas may be pollinated by insects when entering the utricle, where glands provide feed to keep them alive until the stamens have ripened. Mostly flowers open around daybreak and wither after about 24 hours, but sometimes they last longer. After the stamens have shed their pollen, the flower withers, the hairs in the tube lose turgescence, and the insects can leave the utricle and possibly visit another flower, leading to cross-pollination. However, some *Aristolochia* species are not furnished with such specialized systems to promote cross-pollination and are then self-fertilized.

The fleshy funicle of the seed forms an elaiosome which is probably attractive for ants dispersing the seeds. The seed wing present in some *Aristolochia* (e.g. *A. tagala*) may serve wind dispersal.

Other botanical information Flowering material of *Aristolochia* is generally needed for correct identification, but flowers are often scantily represented in herbaria, and are commonly deformed by drying.

Ecology *Aristolochia* usually occurs scattered, often in primary forest, but some species (e.g. those discussed here) are also found in secondary forest and scrub vegetation. Most species are confined to lowland forest, but some occur above 1500 m altitude.

Caterpillars of several butterfly species (particularly swallowtail butterflies of the family *Papilionidae*) are known to feed exclusively on leaves and young shoots of *Aristolochia*. They use chemical compounds in the plants to become poisonous for predators. For instance, it has been shown that aristolochic acid I present in larvae feeding on *A. debilis* deterred feeding of tree sparrows, but also triggered cannibalistic activity of the larvae against eggs and pupae, which also contain the compound. It has also been demonstrated that aristolochic acid induces a significant oviposition response in female swallowtail butterflies.

Propagation and planting In India, *Aristolochia* is usually propagated by seed, which germinates in about 2 weeks. Sometimes it is grown from rhizomes collected from the wild.

Experimental in vitro propagation has been successful for *A. bracteolata* in India. The formation of callus was observed from young leaves and nodes placed on Murashige and Skoog medium supplemented with kinetin, naphthalene acetic acid and indole acetic acid. Roots were initiated from the callus when the concentrations of kinetin and indole acetic acid were increased. From a single nodal segment 1–4 shoots were raised, and shoots grew 5–6 cm tall within 30 days.

Diseases and pests Although caterpillars of various butterfly species feed on the leaves of *Aristolochia*, they are rarely reported to cause extensive defoliation.

Harvesting In India, *A. indica* is allowed to grow for 2 years to yield rootstocks of marketable size.

Yield The yield of *A. indica* rootstocks in India is estimated at 4.5–5.6 t/ha in 2-year-old plantations.

Handling after harvest No information available.

Genetic resources and breeding Most *Aristolochia* species have a limited area of distribution and occur very scattered in lowland forest. This makes them very vulnerable to genetic erosion due to rapid changes in land use. Some species (e.g. *A. indica* in India) have already become rare in the wild because of their popularity for medicinal purposes.

Prospects The medicinal uses of *Aristolochia* are extremely local in South-East Asia and in addition many of them were reported more than 100 years ago. However, *Aristolochia* is widely used medicinally, particularly in China and India, and the activity for several applications has been demonstrated by research. The South-East Asian *Aristolochia* probably have similar properties, but these still have to be confirmed by experiments. A major drawback for use in medicine is the carcinogenic activity of some of the major active compounds, limiting the application in modern medicine. The viricidal, fungicidal and insecticidal properties might offer prospects for wider use.

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Selection of species

Aristolochia philippinensis Warb.

Perkins, Fragm. fl. Philipp.: 170 (1905).

Vernacular names Philippines: barubo (Negrito), puso-pusoan (Tagalog), tambal-balanding (Zambales).

Distribution The Philippines (Luzon, Mindoro, Bancalan Island, Mindanao).

Uses A decoction of the roots is used in traditional medicine in the Philippines as a stomachic and emmenagogue.

Observations An erect shrubby plant up to about 1 m tall, with terete old stems up to 4 cm in diameter, slightly irregularly ridged, and slightly striate branches; leaves elliptical, lanceolate to oblanceolate, 8.5–24 cm × 3.5–8.5 cm, obtuse, sometimes slightly cuneate at base, usually glabrous on both surfaces, with 1 pair of faint basal veins, 5–8 pairs of secondary veins and loosely reticulate tertiary veins; flowers in a spicate or racemose inflorescence, perianth 1-lipped, distinctly veined; fruit subglobose, shortly cylindrical to oblong-ellipsoidal, up to 2.5 cm long; seeds not winged. *A. philippinensis* occurs in thickets and forest up to 900 m altitude.

Selected sources 356, 1126, 1178.

Aristolochia rumphii Kostel.

Allg. med.-pharm. Fl. 2: 465 (1833).

Vernacular names Indonesia: akar pulurun, tuhe tutunu, warosbot (Moluccas).

Distribution The Lesser Sunda Islands, southwestern Sulawesi and the Moluccas.

Uses A decoction of the roots (and sometimes of the twigs but this is less powerful) is used to treat stomach-ache, spasm, constipation and intermittent fever.

Observations A climber, woody at base and with long slender stem; leaves elliptical-oblong or ovate-oblong to narrowly lanceolate, 7–12.5 cm ×

(1–)3–5.5 cm, obtuse, sometimes slightly cuneate at base, minutely hairy beneath, with 1 pair of basal veins, 4–5 pairs of secondary veins and loosely transverse or reticulate tertiary veins; flowers in a short racemose inflorescence, perianth 1-lipped, green with brown limb; fruit short cylindrical, about 2.2 cm long; seeds not winged. *A. rumphii* occurs in open forest, thickets and grassland up to 100 m altitude.

Selected sources 356, 580.

Aristolochia sericea Blanco

Fl. Filip.: 283 (1837).

Synonyms *Aristolochia imbricata* Masters (1875), *Aristolochia membranacea* Merr. (1919).

Vernacular names Philippines: bangisi, pangisi (Iloko).

Distribution The Philippines (Luzon).

Uses Roots are chewed to treat gastralgia, and, macerated in spirituous liquor, the drug is administered as a uterine tonic after childbirth; it is a violent abortive. The entire fresh plant is used as carminative, emmenagogue and febrifuge.

Observations An erect shrubby plant up to about 0.5 m tall, with terete stems about 3 mm in diameter, initially densely pubescent; leaves lanceolate or oblong-lanceolate, 7–15 cm × 2–5 cm, usually shallowly cordate at base, sparsely hairy beneath, with 2 pairs of basal veins and about 5 pairs of faint secondary veins; flowers in a few-flowered and short inflorescence, perianth 1-lipped, with rather distinct reticulation; fruit subglobose, about 1 cm in diameter, initially densely hairy; seeds not winged. *A. sericea* occurs in dry thickets up to 350 m altitude.

Selected sources 190, 356, 1126, 1178.

Aristolochia tagala Cham.

Linnaea 7: 207, t. 5, f. 3 (1832).

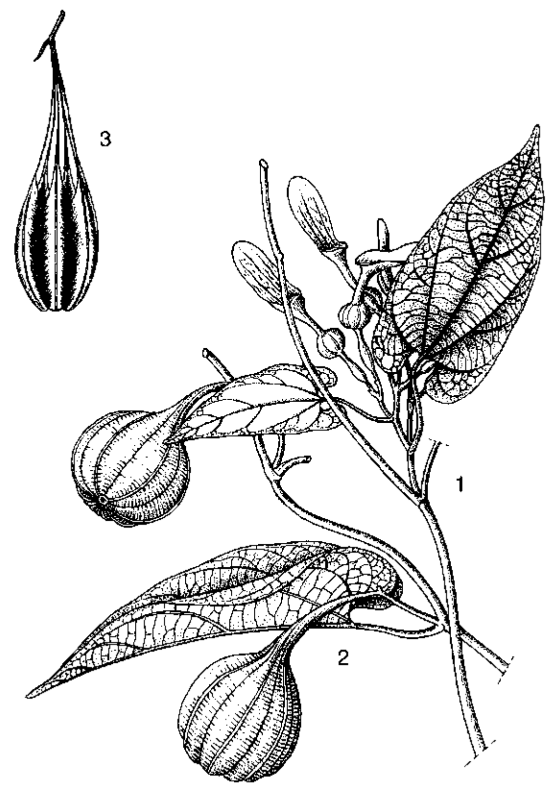
Synonyms *Aristolochia roxburghiana* Klotzsch (1859), *Aristolochia megalophylla* K. Schumann (1889), *Aristolochia mindanaensis* Warb. (1905).

Vernacular names Indonesia: kalayar (Sundanese), puyan (Javanese), kunit (Sulawesi). Malaysia: akar ketola hutan, akar petola hutan (Peninsular). Philippines: timbangan (Tagalog), goan-goan (Bisaya), nagerus (Iloko). Thailand: krachao pheemot, krachao mot (central). Vietnam: ph[of]ng k[yr], d[aa]y kh[oos] r[as]ch.

Distribution From India, Sri Lanka and Bangladesh, through Burma (Myanmar), Indo-China (Cambodia, Vietnam), China and Thailand, to the whole of Malesia, the Solomon Islands and Australia (Queensland).

Uses Powdered roots are used as a tonic, carminative and emmenagogue, and to treat infantile tympanites in the Philippines. In Malaysia, pounded leaves are applied to the head to treat fever. In Papua New Guinea, leaves are rubbed over a patient's head and subsequently mixed with water and given to the patient to drink. In the Moluccas, leaves ground with *Curcuma* are warmed and applied externally to treat swollen limbs, colics and skin diseases.

Observations A climber up to 20 m long, with terete, slightly furrowed branches up to 5 mm in diameter; leaves usually ovate to ovate-oblong, 6–20(–27) cm × 4–10(–16) cm, cordate at base with rounded auricles, sparsely short-haired to subglabrous beneath, with 2 pairs of basal veins, 3–5 pairs of secondary veins and loosely reticulate or crossbar-like tertiary veins; flowers in a racemose or paniculate inflorescence, perianth 1-lipped, with faint venation, pale yellowish or greenish to purplish or dark reddish-brown; fruit subglobose, slightly pyriform or oblong, up to 4 cm long; seeds winged. *A. tagala* occurs in forest and thickets,



Aristolochia tagala Cham. – 1, flowering stem; 2, fruiting stem; 3, dehisced fruit.

usually up to 800 m altitude, but in Thailand up to 1050 m and in New Guinea up to 1350 m.

Selected sources 202, 288, 359, 364, 580, 597, 1126, 1137, 1178.

R. Kiew

Artemisia L.

Sp. pl. 2: 845 (1753); Gen. pl. ed. 5: 367 (1754).

COMPOSITAE

$x = 8, 9$; *A. annua*: $2n = 18$, *A. apiacea*: $2n = 18$, *A. capillaris*: $2n = 18, 36$, *A. vulgaris*: $2n = 16, 18, 24, 54$

Major species *Artemisia annua* L., *A. capillaris* Thunb., *A. vulgaris* L.

Vernacular names Mugwort, wormwood (En).

Origin and geographic distribution *Artemisia* consists of approximately 200 species (some estimates are up to 400 species), most of which are native to dry grassland regions of Eurasia and North America. The regions of central and south-western Asia are particularly rich in species; the genus is thought to have originated here, and to have migrated to North America. Several species have been introduced in the Malesian area, usually as ornamentals; some have naturalized.

Uses *Artemisia* is well known in phytotherapy all over the world. Numerous species are used in local medicine. The rediscovery in the 1970s of *A. annua* as remedy against malaria was spectacular. It had already been used for over 1000 years in China to treat malarial fever, but modern researchers became interested in its properties when the search for new antimalarial medicines started in response to the growing resistance of malaria-causing agents (*Plasmodium* spp.) to the industrial antimalarial drugs currently in use. The active compound, artemisinin (or 'quinghaosu' in China), a sesquiterpene lactone endoperoxide, may be administered in tablets or suppositories. A series of artemisinin derivatives has been semi-synthesized, often with improved pharmacological, pharmaceutical, technological or pharmacokinetic properties; some of them are also used clinically now. The methyl-ether derivative, artemether, and the ethyl-ether derivative artemotil (proposed INN name, previously β-arteether), which are better lipid soluble, are available for intra-muscular injection. The sodium salt of the hemisuccinate ester, also known as (sodium) artesunate is water soluble; it is administered orally or by intravenous injection.

Leaves and flowering tops of *A. vulgaris* are traditionally used to stimulate the appetite, as a sedative and as a vermifuge. However, the use of excessive doses over long periods may lead to digestive and urinary disorders. A gel containing *A. vulgaris* extract is considered a useful skin care product for dry and pruritic skin conditions. *A. vulgaris* (or a related species) is used in local medicine in India to treat rheumatism. Leaves are used in Chinese medicine as a remedy against haemorrhage and diarrhoea. In Vietnam, a decoction is prescribed to treat menorrhagia.

The buds of *A. capillaris* ('Artemisiae Capillaris Flos') have been used since antiquity in Chinese and Japanese medicine, mainly in the treatment of liver and related diseases, e.g. inflammation of the liver, jaundice and cholecystitis. The drug is also applied as cholagogue, anti-inflammatory drug, analgesic, antipyretic and diuretic.

A. absinthium L. is used in traditional medicine in several countries, e.g. in India to treat chronic fever, swellings and inflammation of the liver and as a tonic and stimulant. In Cuba it is applied to treat various diseases caused by parasites, whereas formerly in Europe it was used as a digestive, in the treatment of gastritis, against stomach cramps, stomach and intestinal atony, and as anthelmintic. Formerly it was an ingredient of a popular alcoholic drink in France, but its use in absinthe has been banned because of the suspected neurotoxicity of one of the chemical constituents, i.e. thujone. *A. dracunculus* L. and *A. maritima* L. are used as an aperient, stomachic, stimulant and febrifuge in India. The flowering heads of the latter and *A. cina* Berg ex Poljakov produce santonin, valued as an anthelmintic. In India, *A. nilagirica* (C.B. Clarke) Pampan. is considered an emmenagogue, anthelmintic, stomachic and febrifuge, and is also used to treat skin diseases and ulcers. *A. scoparia* Waldst. & Kit. is a source of scoparone, which exhibits significant hypotensive and tranquilizing activity.

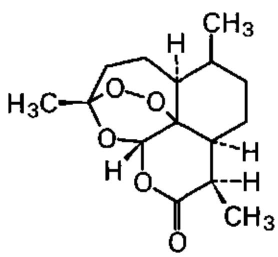
A. vulgaris is sold as a vegetable on markets in Sarawak and Thailand.

Production and international trade Artemisinin and its derivative artemether are produced commercially in several countries. Artemisinin is extracted industrially from cultivated *A. annua* in Vietnam, and pharmaceutical companies in China and France produce artemether industrially. Artemether is, for instance, marketed in ampules of 80 mg/ml in vegetable oil, to be administered by intra-muscular injection. Artemotil (proposed INN name, previously β-arteether) will be commercially available in 1 ml ampules containing 50 mg or 150 mg per ml sesame oil for intra-muscular injection in cases of severe *Plasmodium falciparum* malaria, as soon as marketing authorisation has been obtained in the Netherlands.

Properties Extracts of *A. annua* show antimalarial activity, which can be attributed to the fraction containing sesquiterpene lactones (based on cadinane and closely related carbon frameworks). The most important active compound of *A. annua* against malaria from this fraction is the endoperoxide artemisinin, but some related compounds from *A. annua* and other *Artemisia* species also show some activity, e.g. arteannuin B and other peroxides such as artemisitene and arteinculton. However, artemisinin has significantly greater activity than the other peroxide compounds, having an EC_{50} of 0.01 μg/ml, compared with 1–10 μg/ml for the other compounds.

Artemisinic acid plays a pivotal role in the biosynthetic pathway of artemisinin. Artemisinic acid originates from mevalonic acid and farnesyldiphosphate, yielding a cadinane skeleton as a close precursor of this compound. The arteannuin B formed as a result of various processes, one being lactonization, is considered an intermediate in the bioconversion of artemisinic acid to artemisinin. Artemisinin is too complex to be synthesized on a large scale, and it is generally obtained by isolation from plant material. Leaves originating from the Washington (Virginia, United States) area and Europe contain 0.05–0.1% artemisinin (on dry-weight basis), while leaves originating from southern China and the northern provinces of Vietnam contain up to 1.3% artemisinin (on dry-weight basis). A liquid-liquid extraction technique, that allows the use of recovered solvents, has been developed for large-scale production of artemisinin.

Several analytical methods are in use to assay the biosynthetic precursors and metabolites of artemisinin. A simple TLC method is available for screening. HPLC with electrochemical detection, GC-MS and thermospray LC-MS allow very efficient detection of artemisinin and structurally related compounds.



artemisinin

Clinical tests in China, Cameroon, the Gambia, the Netherlands, Thailand, Vietnam, Zambia and other countries on volunteers and thousands of patients with severe and non-severe *Plasmodium falciparum* malaria indicated that artemisinin and its derivatives are safe and effective.

For instance β-dihydroartemisinin shows a rapid absorption and distribution, and depending on the dosis, blood levels peak in 1–2 hours, while the biological half-life lies between 1–2 hours too. Multiple dose treatment via the intra-muscular route with artemotil (β-arteether) attained a steady state level after 8–14 hours. The half-life varied between 35–45 hours. The artemisinin group of drugs is only valuable to treat cerebral or *Plasmodium falciparum* malaria.

Malaria is caused by a parasitic *Plasmodium* protozoan, which uses mosquitoes of the genus *Anopheles* as an intermediary host. When an infected mosquito bites a person, sporozoites enter the blood, but they disappear rapidly from the circulation to localize in the parenchymal cells of the liver in which they grow and segment to merozoites. This stage of the infection lasts for 5–16 days, depending on the *Plasmodium* species. On reaching maturity these merozoites are released from the liver cells and penetrate erythrocytes where further division and development takes place. When this process is complete, the erythrocytes burst open and the merozoites enter the blood stream. It is this periodic breaking of erythrocytes that causes the chill so characteristic of malaria. The fever following the chill is due to the liberated foreign protein and cell products. Some of the merozoites infect new blood corpuscles, while others develop into the sexual form, called gametes. The gametes can pass to a healthy mosquito when it bites a person suffering from malaria. The gametes conjugate in the mosquito, forming sporozoites, and the circle is complete.

Artemisinin acts as a so-called blood schizonticide on the asexual erythrocytic stage of the parasites. A critical step in the mechanism of action of artemisinin (and related drugs) seems a hemin-catalysed reduction of the peroxide moiety, resulting in more cytotoxic compounds, such as free radicals and reactive aldehydes that subsequently kill malarial parasites. Membrane damage, alkylation and oxidation of proteins, oxidation of fats, inhibition of the protein and nucleic acid synthesis have been found in these parasites, as well as interaction with cytochrome oxidase and with the glutamine transport system. The hemin-rich internal environment of the parasites in the erythrocyte is assumed to be responsible for the apparent selective toxicity of artemisinin towards these organisms. Artemisinin rapidly clears the blood from parasites (elimination and improvement of symptoms occur sooner than with chloroquine, and good results have also been obtained with patients who were no longer responsive to chloroquine), but it is inactive against liver stages of the parasite. Due to this spectrum, the drug should not be used as prophylactic; this also greatly reduces the risk that resistance will develop to this new class of antimalarials. Artemisinin and several derivatives have furthermore been found to kill early stages of gametocytes of *Plasmodium falciparum* too. This gametocidal effect may play a role in the interruption of malaria transmission. There are no reports of serious toxicity in humans. Toxicity to the myocardium in macaques after extreme high doses has been reported, while in a test on dogs the highest dose caused deaths. However, when the latter study was repeated under conditions of good laboratory practice, no mortality occurred, and the no toxic effect level was 3 mg/kg in dogs treated daily during 4 weeks with artemotil.

In addition to the antimalarial activity, some other biological activities of artemisinin (and related structures) and of other *Artemisia*-constituents have also been investigated, e.g. cytotoxicity to Ehrlich ascites tumour cells in vitro. All compounds (including artemisinin, artemether and sodium artesunate) showed cytotoxiticy, with IC_{50} values ranging from 12–30 μM. The variations in effect between the structurally strongly related compounds mostly correlated well with the theoretical capacity of radical formation and stabilization. Artemisinin, artemisinic acid, arteannuin B, a series of friedelane-type triterpenoids, and the flavonoid quercetagetin-6,7,3',4'-tetramethylether showed positive test results for in vitro cytotoxicity in a series of tumour cell lines (P-388 murine lymphocytic leukaemia, A-549 human lung carcinoma, MCF-7 human breast adenocarcinoma, HT-29 human colon adenocarcinoma and KB human nasopharynx carcinoma). Artemisinin and artesunate have been found effective against experimental schistosomiasis in mice and dogs.

Extracts of *A. annua* showed a strong inhibitory effect on tobacco mosaic virus; the inhibitory agents were identified as the sterols sitosterol and stigmasterol. The extracts also showed in vitro anticoccidial effect against *Eimeria tenella*, which causes a serious disease in poultry. Artemisinin has allelopathic activity, and inhibits seed germination, seedling growth and root induction of crops such as lettuce and beans.

An extract of 5 g dry powder of *A. absinthium* in 50 ml water, diluted 1:35, showed 90% growth inhibition of *Plasmodium falciparum* in a test in Cuba. An LD_{50} of 31 μg/ml was detected for the sesquiterpene lactone fraction. The test method available for the evaluation of crude extracts assesses the ability of the extract to inhibit [G-^{3}H]-hypoxanthine uptake into *Plasmodium falciparum*.

A. vulgaris extracts show insecticidal, insect-repellent, antimutagenic and anthelmintic activities; reports on antimalarial activity are contradictory. The efficacy of a gel containing *A. vulgaris* (or a closely related species) extract has been studied in Japan on 56 patients having pruritic skin lesions. Excellent clinical improvement was obtained in 67% of the cases of pruritic dermatitis, in 56% of atopic dermatitis and 73% of senile xerosis; poor response was observed in 2 cases of contact dermatitis. No side effects were observed.

An aqueous extract of *A. vulgaris* markedly inhibited the growth of both gram-positive and gram-negative bacteria in vitro. It inhibited the growth of the cariogenic bacterium *Streptococcus mutans* considerably. The essential oil from fresh leaves tested at 5000 ppm against the storage fungus *Aspergillus flavus* showed 67% growth inhibition. The dehydromatricaria esters present in the plant showed some antifungal activity, but in general their biological activity is slight. Roots of *A. vulgaris* showed mild toxic activity against the oriental fruit fly. An extract of *A. vulgaris* (particularly of young leaves) inhibits germination and seedling growth of other plants, e.g. of lucerne; it showed some retarding effect on the growth of tea, but it increased the growth of the fungus *Pythium myriotylum*.

The essential oil from several species (e.g. *A. annua*, *A. vulgaris*) is suitable for use in the perfume and cosmetics industry. The oil content of dried flowering parts of *A. annua* is approximately 0.6%. However, *A. vulgaris* normally has a low volatile oil content (0.03%), which accounts for its palatability and digestibility for animals as compared with other *Artemisia* species; the protein content is about 32% and the average in vitro digestibility 67%. *A. vulgaris* is, however, suspected of causing bladder cancer in cattle. The oil content can be much higher in certain types, e.g. in the Philippines where a yield of 0.3% from air-dried leaves has been reported. The volatile oil is yellowish-greenish with an intense and persistent fragrance. More than 70 compounds, mainly monoterpenes and sesquiterpenes have been identified structurally from the essential oil from flowering parts of *A. vulgaris*. The oil production is seasonally dependent and chemical composition is highly variable; 1,8-cineole, camphor, terpinen-4-ol, β-pinene, (+)- and (−)-borneol, myrcene and vulgarin are invariably present, but thujones (α- and γ-) are only present in traces or absent. A rather high concentration of thujones is present in oil from *A. absinthium*; habitual use or large doses of absinthe beverages causes absinthism, characterized by neurotoxic symptoms such as restlessness, tremors and convulsions. Whether thujones are the sole cause of these symptoms remains an open question since absinthe formerly also contained cupric sulphate and indigo-based colorants. Almost 50 components were identified in leaves of *A. vulgaris* from Vietnam, the major ones being β-caryophyllene (24%) and β-cubebene (12%).

In *A. capillaris* it is the seed that contains most oil. In the essential oil of *A. capillaris* 25 terpenoids (e.g. β-pinene, limonene and γ-terpinene), 6 phenylacetylenes, 7 phenols and 15 fatty acids have been identified; capillen (a phenylacetylene) is the main component. The main components of drugs prepared from *A. capillaris* are scoparone (6,7-dimethoxycoumarin) and capillarisin. Several other flavonoids and the coumarin 6,7-dimethylesculetin have been identified in the active fraction of the methanol extract. An extract of *A. capillaris* inhibited bovine lens aldose aldehyde reductase and rabbit platelet aggregation; this may be of interest in the prevention of diabetes complications. Scoparone and scopoletin exhibited a potent inhibitory effect on rabbit platelet aggregation, and capillarisin did likewise on bovine lens aldose reductase. Scoparone and capillarisin have choleretic action. The flowers, as one of the ingredients in a herbal medicine, helped change the bile flow to almost normal level in α-naphthyl isothiocyanate-induced cholestasis in rats. In tests with mice, the buds and leaves of *A. capillaris* showed significant protective effect against liver lesions induced by carbon tetrachloride. The active principles were shown to be the flavones eupatolitin and arcapillin. An extract inhibited the adherence of *Streptococcus mutans*, a bacterium which causes dental caries, to teeth surfaces. Tests on isolated rat heart indicate that scoparone possesses anti-anginal action as a vasodilator. Furthermore, kinetic experiments using rabbit thoracic aorta showed that scoparone has a marked inhibitory effect on the contractions induced by norepinephrine (noradrenaline), 5-hydroxytryptamine, histamine and angiotensin II. Like nitroglycerin, scoparone appeared to be a competitive antagonist of norepinephrine.

Polymers of caffeoylquinic acids are the main polyphenolic components in *A. capillaris*; caffeic acid can be produced by partial hydrolysis of these compounds. Extracts containing these 'caffeetannins' and related compounds have protective action against liver damage. Species used as haemostatic generally also contain caffeetannins.

Extracts of *A. capillaris* have been found to be positive in the chromosomal aberration and micronucleus assays in mice. Leaf and stem extracts of *A. capillaris* showed pronounced nematicidal activity against *Bursaphelenchus lignicolus*. The phenylacetylenes capillen (1-phenyl-2,4-hexadiyne) and 2,4-pentadiynylbenzene (1-phenyl-2,4-pentadiyne) have been isolated from *A. capillaris* roots and buds; capillen inhibits the germination of seeds of, for instance, millet, cabbage and carrot, and both compounds have an antifeeding activity on cabbage butterfly (*Pieris rapae*) larvae, as do certain other minor constituents in growing buds such as capillarin, methyleugenol, ar-curcumene and bornyl acetate. A factor promoting root growth, capillarol, has also been isolated from the leaves; it increased root growth of rice by 80%. *A. capillaris* extracts showed antimicrobial action and were effective in suppressing the growth of food-poisoning bacteria, *Lactobacillaceae* and mycotoxigenic moulds. The flavonoid fraction has been patented for anti-acne treatment and the coumaric fraction for use as a hair stimulant.

The aerial parts of *A. cina*, which contain flavonoids (e.g. hispidulin, quercetin, rutin and caffeic acid), phenol acids and coumarins, and certain other *Artemisia* species indigenous in Russia showed anti-tumour activity in animal tests; these species may be useful in the treatment of Ehrlich carcinoma, breast adenocarcinoma, sarcoma and Walker carcinosarcoma. An aqueous extract of flowering parts of *A. cina* was found to be lethal to larvae of the mosquito *Culex pipiens*; it had an EC_{50} value of 4 g/l 24 hours after treatment. At a dose of 40 ppm the extract is able to give a significant control of the root-knot nematode *Meloidogyne incognita*. Twenty components have been identified in *A. cina* oil including α-pinene, β-pinene, myrcene, camphene, β-ocimene, sabinene and limonene.

The large amounts of pollen produced by the wind-pollinated plants can cause allergic reactions in susceptible persons. Contact dermatitis caused by *A. vulgaris* has been reported.

Adulterations and substitutes Synthetic antimalarials derived from quinine are widely used, as are related alkaloids from *Cinchona* spp. The search for new antimalarials in response to the growing resistance of malaria-causing agents to industrial drugs has not only resulted in interest in *A. annua*, but also in interest in certain other promising plant resources used in traditional medicine to treat malaria, e.g. *Azadirachta indica* A.H.L. Juss., *Brucea javanica* (L.) Merr., *Cyclea barbata* Miers and *Dichroa febrifuga* Lour.

Description Erect or ascending aromatic annual or perennial herbs or subshrubs, usually densely hairy. Leaves alternate, usually divided or 1–3-pinnate; stipules absent. Flowering heads numerous and small, in spicate, racemose or paniculate inflorescences or sometimes solitary, usually nodding at anthesis, discoid, greenish or yellowish, rather few-flowered; involucre campanulate or subglobose to ovoid, with bracts imbricate in 1–3 series and scarious at margins, the outer bracts usually smaller; receptacle flat or conical to hemispherical, glabrous or pubescent. Flowers of two types, with 1 series of marginal pistillate ray flowers, and bisexual or functionally male tubular disk flowers in the centre of the head; pappus absent; corolla of ray flowers tubular and 2–3-fid, that of disk flowers tubular and 5-fid; stamens 5, inserted on the corolla, with distinct filaments and connate anthers forming a tube around the style, anthers often tipped with acute appendages; ovary inferior, 1-celled, style bifid and exserted in pistillate flowers and often dilated or penicillate in disk flowers. Fruit an obovoid or oblong, terete achene, rounded and with a disk at the apex, striate or 2-ribbed, glabrous or pubescent.

Growth and development The life cycle of the Chinese-Vietnamese material of *A. annua*, under natural conditions, is completed within 10 months. Seeds germinate in January to March and fruits can be harvested in October-November. The harvest of plants for extraction of artemisinin takes place in July. Initially, growth is slow and seedlings reach a height of about 5 cm after one month and 25–30 cm after 3 months. Growth is much more rapid from the fourth month. The vegetative period lasts 6–8 months. By August, *A. annua* has become strongly branched, and flower buds become visible. The flowers do not secrete nectar and are wind pollinated; they produce pollen abundantly. The life-cycle of European-American material of *A. annua* is completed within 6 months. Germination takes place in May, while seeds can be harvested in November.

Chinese-Vietnamese material grown in Europe in the open cannnot be planted earlier than May-June because of night frost. In October one can observe elongation of stems and small branches as a prelude to flowering. Flowering is in general frustrated by early night frost and bad weather. Under green-house conditions seed can be produced.

A. annua is basically self-fertilizing, but considerable cross-pollination may occur. In some *Artemisia* species, the inner flowers in a flowering head are functionally male and do not set fruit (e.g. in *A. capillaris*). This is also reported for *A. annua*, but in fact the inner flowers do produce seeds, but these are less viable and seedlings often die shortly after germinating.

Other botanical information *Artemisia* is in desperate need of a thorough and complete taxonomical revision. Several closely related (or perhaps conspecific) species are often confused in eastern Asia, particularly in the group *A. campestris* L., *A. capillaris* Thunb. and *A. scoparia* Waldst. & Kit. of the section *Dracunculus*, and in the group of *A. indica* Willd. (synonym: *A. princeps* Pampan.), *A. nilagirica* (C.B. Clarke) Pampan. and *A. vulgaris* L. of the section *Abrotanum*. Consequently, the literature is often difficult to interpret, and information on *A. vulgaris* from eastern Asia probably often refers to other related species. In fact, some authors consider *A. vulgaris* to be a single very variable and widespread species, whereas many others consider it as a complex of up to about 100 closely related species.

A. annua, *A. apiacea* (both of the section *Abrotanum*) and *A. capillaris* are sometimes confused. *A. annua* can be identified by its strongly branched panicle and small, subglobose heads. *A. capillaris* is a subshrub, the other two species are annuals.

A. annua material from European-American and Chinese-Vietnamese origin shows some clear differences. The European-American type has the ability to produce inflorescences 3–4 months after sowing, while the Chinese-Vietnamese type will not do so when planted in Europe in the open. In order to produce seed of the Chinese-Vietnamese type in Europe, one has to grow it under greenhouse conditions. Furthermore, the artemisinin content of the Chinese-Vietnamese type is ten-fold higher compared to the European-American type, also when raised under European conditions.

Ecology *Artemisia* prefers full sunlight. It is often found in roadsides, waste places and fields. *A. vulgaris* is locally a noxious weed, e.g. in tea plantations.

In cultivation, *A. annua* demands fertile and moisture-retentive soils for optimal growth. It does not tolerate dry conditions or waterlogging, and it usually dies within 2–3 days of flooding. It tolerates neutral to slightly acid soils (pH no lower than 5), and is usually cultivated on rich sandy loams or alluvial soils.

Variation in acetylene content has been found in different ecotypes of *A. capillaris*; the phenylacetylenes capillen and capillin were found to be the main constituents in the roots and leaves of plants growing along freshwater rivers, but were only found in the roots of plants growing in a saline environment.

Propagation and planting *A. annua* is propagated by seed. In northern Vietnam, seeds are collected in November and sown in February-April or in July-August (southern Vietnam). One gram contains 20 000–22 000 seeds. Before sowing, seeds are soaked in warm water (45–50°C) for 2–3 hours or in a 0.1% gibberellin solution for 15–20 minutes. Under optimal soil moisture and temperature (20–25°C) conditions pretreated seeds start germinating 4–8 days after planting, untreated seeds 10–20 days after planting. The germination rate is usually 50–60% when fresh seed is sown, but drops to 2–3% after 6 months of storage. The usual rate for broadcasting seed in the field is 300–500 g per ha. About 40–50 days after sowing plants are thinned to 20–40 cm × 20–40 cm. Nowadays, seed is preferably sown in nurseries and when seedlings are 15–20 cm tall they are planted into the field at 20–40 cm × 20–40 cm. The latter method of propagation is preferred to direct seeding because it shortens the crop cycle by about 2 months and secures a better and more uniform stand.

Seedbeds are 1–1.2 m wide and 15–20 cm high and provided with a layer of fine-textured topsoil. The application of 5–10 t/ha of green manure or organic manure before planting is beneficial.

In vitro production of active compounds Callus from *A. annua* seed has been initiated by transfer onto agar containing Murashige and Skoog basal salts with 5% sucrose, 0.1 mg/l kinetin and 1 mg/l 2,4-dichlorophenoxyacetic acid. The callus cultures were maintained at 25°C under constant illumination and subcultured every 4 weeks. After 3 subcultures, the calli were inoculated into liquid medium of the same ingredients (without agar) and maintained under the same conditions on a rotary shaker. The cell suspension culture was used for the isolation of constituents. The cell suspension cultures exhibited antimalarial activity in vitro, both in the n-hexane extract of the plant cell culture medium and in the chloroform extract of the cells. Trace amounts of artemisinin may account for the activity of the n-hexane fraction, but only the methoxylated flavonoids artemetin, chrysoplenetin, chrysoplenol-D and cirsilineol can account for the activity of the chloroform extract. However, the activity of these flavonoids is much lower than for artemisinin.

Husbandry *A. annua* responds well to fertilization. N fertilizers are usually applied twice, each time 90–110 kg/ha, the first time about 2 months after direct sowing in the field or 2 weeks after transplanting from the nursery, the second time one month before harvesting. P and K fertilizer is sometimes also applied. However, the artemisinin content of the plants does not increase under these favourable growth conditions. In Vietnam, it has been reported that the artemisinin content of cultivated *A. annua* plants can be comparable to that in plants growing in the wild.

A. vulgaris has been intercropped successfully with poplar (*Populus* sp.) in India. It responds well to the application of complete fertilizer (10 g/plant).

Diseases and pests Several years of experience with trial plantations of *A. annua* in Vietnam did not reveal serious diseases or pests. Minor pests are ants carrying away seeds after sowing, crickets damaging seedlings, and caterpillars and aphids feeding on the crop.

Weedy *Artemisia* can serve as a host to pathogens and pests that can seriously affect crops. *A. vulgaris*, for instance is a host for cucumber mosaic virus, the worm *Ostrinia nubilalis* and the European corn borer. *A. annua* has been reported as a host of nematodes (*Meloidogyne* spp.).

Harvesting The highest leaf yield and the highest foliar artemisinin content in *A. annua* (up to 0.9%) are obtained when the crop is 5 months old. In Vietnam, the harvest is usually in August in the north and in November in the south. Harvesting should preferably be on dry, sunny days.

In Japan, tests with material of *A. capillaris* harvested on different dates showed considerable variation in activity of the drug and in the content of capillarisin and dimethylesculetin. In that country, the capillarisin and 6,7-dimethylesculetin contents reach maximum levels in leaves just before the appearence of flower buds (end of

July), and one month later in the heads (end of August). The best time for harvesting is between the flower bud stage and early flowering, which is from late August to early September in Japan. The flavonoid content of *A. cina* is low during the vegetative period, increases during bud formation and flowering, and decreases again during fruiting.

Small quantities of *A. vulgaris* are usually collected all year round.

Yield Yields of cultivated *A. annua* in Vietnam range between 25 and 45 t/ha of fresh material. Yields are generally lower in northern Vietnam than in southern Vietnam: 1.5–2.5 t/ha of dried cleaned material (0.5–0.9% artemisinin) in the north, 2–4 t/ha (0.3–0.6% artemisinin) in the south.

Handling after harvest After harvesting, plants are usually sun-dried on brick or cement yards or on asphalt roads for 1–2 days. Broken parts of roots and stems are subsequently separated mechanically, and the remaining material is further dried to below 12% moisture content. Dried leaves of *A. annua* should be stored and packed in jute bags under air conditioning (low relative humidity). In experiments, where the relative moisture of the material varied between 4–16%, the artemisinin content was slightly affected over a period of one year. Material with a moisture content of 16% and stored in jute bags under air conditioning showed a decrease from 5.9–5.2% artemisinin only. Thus, if described storage conditions are maintained, there will be ample time to extract artemisinin before the next crop arrives, while extra electricity costs for air conditioning will be compensated by higher artemisinin extraction yields.

Moreover, there is advantage because of the fact that there is no pressure to extract the crop immediately. As highly volatile extraction solvents are used, chemical extraction can be carried out during the winter season in northern Vietnam and not during summer and autumn when high temperatures complicate cooling of these solvents.

Artemisinin has a low solubility in aqueous and oily solvents, thus causing problems for clinical application. The derivative sodium artesunate is readily water-soluble, and can be processed more easily to medicaments.

Genetic resources and breeding Although *A. capillaris* has for centuries been considered useful as a medicinal plant in China and Japan, it has hardly been cultivated, and the crude drug has been largely derived from wild plants. *A. apiacea* occurs rather scattered and is poorly known. It has been reported that protection of *A. cina* is necessary in parts of Russia because of overcollecting for medicinal purposes. *A. annua* is increasingly being planted for artemisinin production (e.g. in Vietnam and China); in other regions (e.g. Java) it was already being planted for ornamental purposes. *A. vulgaris* is widespread and is not at risk of genetic erosion. There are no records of *Artemisia* species in germplasm banks, and there are no known breeding programmes.

Prospects Interest in *A. annua* as an antimalaria crop is increasing enormously. Tests indicate that artemisinin and its derivatives have a rapid and effective action and low toxicity. To date, no resistance of *Plasmodium* against artemisinin and its active derivatives has been found. It is advisable to control the prescription strictly and not to use these compounds for preventive treatment (which is in any case not self-evident, given that the biological half-life of artemisinin is approximately 4 hours). The therapeutic indications should be provisionally the treatment of severe malaria or when resistance to other antimalarials is suspected. *A. annua* has great prospects in malaria control, and research should continue to optimize its utilization. Artemisinin yields are about 2 kg/ha and should be raised to at least 50 kg/ha to make a cheap antimalarial.

Several other *Artemisia* species have interesting medicinal properties and deserve more research. For instance, *A. capillaris* and *A. vulgaris* are of interest as an anti-inflammatory for treating skin complaints and for the prevention of dental caries, whereas the former species may be useful in the prevention of complications caused by diabetes and for its protective action against liver damage.

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Selection of species

Artemisia annua L.

Sp. pl. 2: 847 (1753).

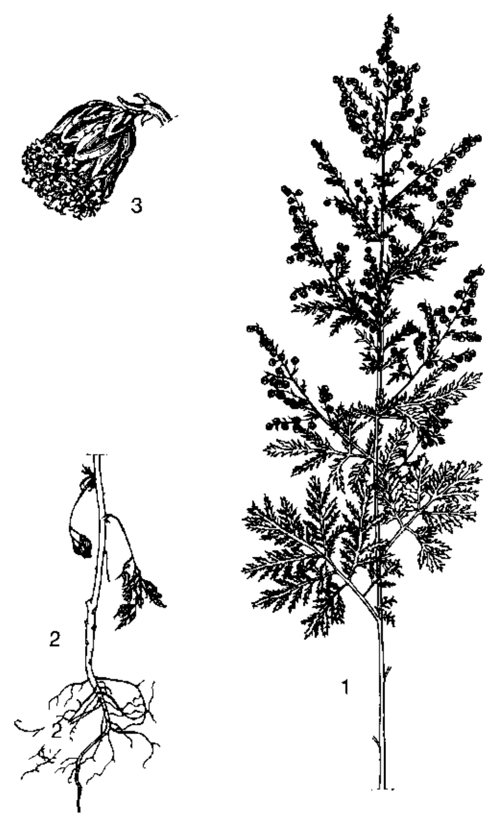
Vernacular names Sweet wormwood (Am). Vietnam: thanh hao, thanh hao hoa v[af]ng, ng[air] si.

Distribution Eastern Europe to India, Indo-China, China and Taiwan, naturalized in Japan and North America, sometimes as an adventive plant in western Europe; locally cultivated as an ornamental in Java, but on a larger scale for medicinal purposes in Vietnam and China.

Uses An extract is highly valued as a cure for malaria; the isolated active compound (artemisinin) is the basis for commercially traded medicaments. The plant is also used in folk medicine to treat jaundice and anorexia. The seeds are used in China to treat flatulence, dyspepsia and tuberculosis, and plants in the bud stage in China and Indo-China as febrifuge and to treat boils and skin diseases.

Observations An annual branched herb up to 150 cm tall (in cultivation sometimes up to 300 cm tall) with ribbed stem; leaves bipinnatifid or tripinnatifid, up to 12 cm long, with linear, 0.3–1 mm wide pectinately dentate segments, glabrous; heads in rather large panicles, 1.5–2.5 mm long, central flowers bisexual, corolla yellowish; fruit obovoid, 0.6–1 mm long and glabrous. *A. annua* is locally a common weed on waste grounds and in fields. It is reported that only plants from southern China (Sichuan Province) and northern Vietnam contain abundant artemisinin. This intraspecific variation ranges up to a ten-fold higher artemisinin content compared to plants from other regions.

Selected sources 10, 11, 12, 38, 39, 97, 193, 246, 361, 394, 724, 748, 872, 878, 903, 1032, 1033, 1035, 1061, 1126, 1130, 1262, 1287, 1585, 1654.



Artemisia annua L. – 1, flowering stem; 2, stem base and roots; 3, flower head.

Artemisia apiacea Hance

Walp., Ann. bot. syst. 2: 895 (1852).

Vernacular names Vietnam: rau bao, thanh cao, th[ar]o cao.

Distribution India, Indo-China, China, Korea, Mongolia and Japan.

Uses In Vietnam and China, the aerial plant parts are considered febrifuge, haemostatic, tonic and stomachic and prescribed to treat tuberculosis, malaria, epistaxis, anorexia and neurasthenia, and externally to treat furuncles, haemorrhoids and dermatosis.

Observations A branched annual or biennial herb up to 150 cm tall; leaves bipinnatifid, up to 15 cm long, with pectinately dentate lanceolate to linear, 1.5–2 mm wide segments, glabrous; heads in panicles, 4–6 mm long, central flowers bisexual, corolla pale yellowish; fruit obovoid, nearly 1 mm long, glabrous. *A. apiacea* is often found along rivers.

Selected sources 1035, 1126, 1130.

Artemisia capillaris Thunb.

Fl. jap.: 309 (1784).

Vernacular names Malaysia: rumput roman (Peninsular). Vietnam: ng[ar]i l[as] kim, nh[aa]n tr[aaf]n b[aws]c.

Distribution India, China, Korea, Mongolia, Japan, the Ryukyu Islands and the Philippines; locally cultivated in gardens in Peninsular Malaysia.

Uses The buds have been used since antiquity in Chinese and Japanese medicine as a cholagogue, anti-inflammatory, antipyretic and diuretic in jaundice, inflammation of the liver and cholecystitis; dried plants are imported by Vietnam from China. It has been reported in Peninsular Malaysia that the leaves used to be applied in poultices to cure headache.

Observations A much-branched subshrub up to 100 cm tall, stem somewhat woody at base, sterile as well as flowering branches present; leaves bipinnate, up to 9 cm long, with linear-filiform, 0.5–2 mm wide segments, initially densely villous but glabrescent; heads in large panicles, 1.5–2 mm long, central flowers male; fruit oblong, about 0.8 mm long and glabrous. *A. capillaris* closely resembles the widely distributed *A. campestris* L. and *A. scoparia* Waldst. & Kit., but these species differ in respectively their larger and smaller heads. It is especially found along seashores and rivers.

Selected sources 202, 645, 737, 743, 744, 745, 959, 1035, 1047, 1075, 1130, 1484, 1606, 1607, 1617, 1618, 1619, 1620.

Artemisia vulgaris L.

Sp. pl. 2: 848 (1753).

Vernacular names Mugwort (En). Indonesia: baru cina (Sumatra), beunghar kucicing (Sundanese), suket ganjahan (Javanese). Malaysia: hiya, bunga ayam hutan bateh, baru cina (Peninsular). Philippines: damong-maria (Tagalog), erbaka (Iloko), gilbas (Cebu-Bisaya). Thailand: kot chulaalamphuaua. Vietnam: ng[ar]i c[uws]u, thu[oos]c c[uws]u.

Distribution Native in Europe, continental Asia and North America, introduced and naturalized locally in South-East Asia, e.g. in Java; locally cultivated, e.g. in Peninsular Malaysia and the Philippines.

Uses Leaves and flowering tops are used traditionally to stimulate the appetite, as a sedative and as a vermifuge. A gel containing the extract is considered a useful skin care product for dry and pruritic skin conditions. In the Philippines, a decoction or infusion of the leaves is used as a vulnerary, expectorant, stomachic and emmenagogue. In Indonesia, the herb is used as a diuretic, to treat haemorrhoids, diarrhoea and (externally) to treat skin diseases and sores. In Malaysia, it is also used to treat sores. In Thailand, the roots are used as anthelmintic, the leaves as an anti-asthma, antipyretic, expectorant, emmenagogue and to cure diarrhoea; the flowers are used as an anti-asthma and expectorant. In Vietnam, it is considered haemostatic, emmenagogue and stomachic, and is used externally for poulticing ulcers and sores. *A. vulgaris* is used in local medicine in India to treat rheumatism. In Chinese medicine the leaves are used as a remedy against haemorrhage and diarrhoea. Leaves are used to flavour food.

Observations A perennial, often ascending and branched herb up to 200 cm tall, with subterranean stolons and grooved stem; leaves pinnatipartite to bipinnate, up to 10.5(–14) cm long, with lanceolate, 1–7 mm wide segments, with dense white lanate-arachnoid hairs beneath; heads in panicles with spiciform branches, 3.5–5 mm long, central flowers bisexual, corolla pale green; fruit glabrous, but not developing in Java. *A. vulgaris* is locally a common weed in open localities, in fields and roadsides, in Java at 250–3000 m altitude. *A. vulgaris* is a complex species that many authors have divided into numerous species, but that others consider to represent a single very variable and widespread species. Information on *A. vulgaris* from eastern Asia probably often refers to other related species (mainly *A. indica*?).

Selected sources 97, 193, 202, 243, 244, 332, 350, 361, 580, 944, 1008, 1035, 1126, 1130, 1178, 1448, 1572.

Nguyen Tien Ban, Vu Xuan Phuong & Charles B. Lugt

Belamcanda chinensis (L.) DC.

Redouté, Liliac. 3: t. 121 (1805).

IRIDACEAE

$n = 16, 64, 2n = 32$

Synonyms *Ixia chinensis* L. (1753), *Belamcanda punctata* Moench (1794), *Pardanthus chinensis* (L.) Ker Gawler (1804), *Gemmingia chinensis* (L.) O. Kuntze (1891).

Vernacular names Blackberry lily, leopard lily, leopard flower (En). Indonesia: brojo lintang, jamaka (Sundanese), semprit (Javanese). Philippines: abaniko (Tagalog), abanico (Spanish), palma (Spanish, Tagalog). Thailand: waan meetyap (northern), waan haangchaang (Bangkok). Vietnam: x[aj] can, r[er] qu[aj]t, la cho.

Origin and geographic distribution *B. chinensis* occurs in northern India, northern Vietnam, eastern China, Korea and southern Japan. It is often planted as an ornamental, and has locally semi-naturalized on a small scale, e.g. in Sumatra, Java, Sulawesi and the Moluccas. It is also planted for ornamental purposes in the Philippines, but has not naturalized there. In China and Japan it is planted as a medicinal plant. It is also locally naturalized in North America.

B. chinensis was introduced as an ornamental from China into Great Britain and continental Europe at the end of the 17th Century or early 18th Century, and to North America in the late 18th Century. Now it is a common garden plant in North America and Japan.

Uses The rhizome of *B. chinensis* is much used against inflammations of the throat and upper respiratory tract such as laryngitis, pharyngitis, tonsillitis, cough and asthma. It is given for purifying the blood and in Vietnam also against swollen liver and spleen, and to treat snake bites. The rhizome is recommended as an expectorant, antitussive, deobstruent and carminative, and is used in tonics and as a purgative. In Vietnam it is also considered diuretic. It is reported as a remedy for gonorrhoea in Malaysia. In Indonesia, it has been reported to be chewed with *Piper betle* L. leaves after childbirth in Sumatra, and to be used as a poultice to treat lumbago; it is also applied as a medicinal plant in northern Sulawesi. Locally in Peninsular Malaysia the rhizome has been used in a medicinal bath after childbirth.

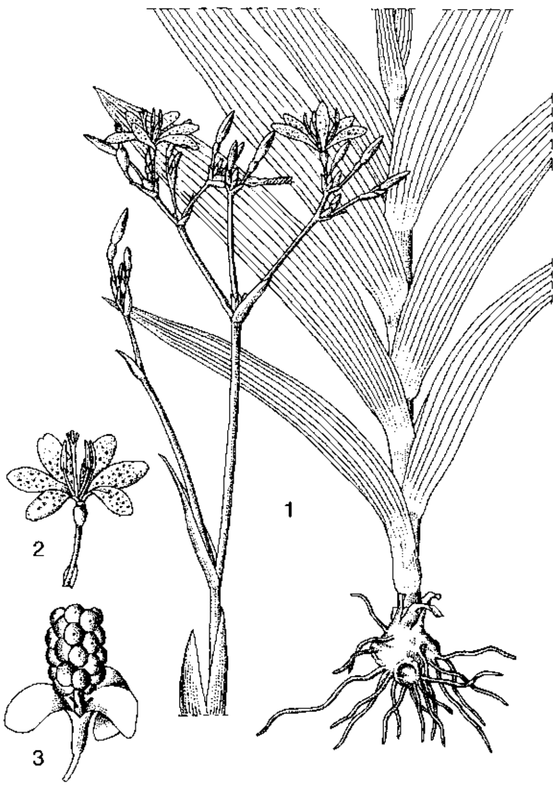
With its attractively blotched orange flowers and its fruits showing the glossy black seeds, blackberry lily is commonly planted as an ornamental in the tropics and in more temperate regions.

Production and international trade The trade in rhizomes of *B. chinensis*, often dried and sliced, is mainly from China, but no statistics are available.

Properties The rhizomes of *B. chinensis* taste bitter and acrid. Several highly oxygenated isoflavonoids have been isolated from the rhizomes, including tectorigenin, irigenin, iristectorigenin, belamcanidin, methyl-irisolidone, irisflorentin and noririsflorentin, which are thought to be responsible for the allergy-inhibiting activity. Furthermore, nine iridals have been isolated, the most important of which is belamcandal (28-acetoxy-14,15-dihydro-26-hydroxy-19-methylidene-spiroirida-15,17-dienal). This compound stimulates the throat membrane, but it is unstable and decomposes during drying processes; no stimulation is thus reported when the dried rhizomes are applied. An aqueous extract of the rhizomes has been screened for possible inhibitory activity against HIV-1 proteases, using a fluorogenic assay. In this test, the effective concentration was found to be 25 μg/ml. The dimeric 1,4-benzoquinones belamcandaquinones A and B have been isolated from the seeds; the first of these compounds showed specific cyclo-oxygenase inhibitory activity. Belamcandol A and B, two alkenyl- (pentadecyl-) phenols and ardisianone A, an alkenyl-1,4-benzoquinone, have also been isolated from the seeds. Using the cytosol of isolated guinea-pig polymorphonuclear leucocytes, belamcandol A and ardisianone A were found to be specific 5-lipoxygenase inhibitors. The belamcandaquinones are probably derived from ardisianone A and belamcandol B.

Adulterations and substitutes The rhizome of *Iris* species, such as *I. japonica* Thunb., also contains iridals, has the same activity on the throat membrane and is used for disorders of the throat.

Description A perennial, erect, glabrous herb, 50–150 cm tall, with short, creeping, stoloniferous rhizome with round scars of old stems, usually without leaf remnants; stem corymbosely branched in the upper part. Most leaves crowded in the lower half of the stem, distichous and folding over, ensiform and obliquely linear-lanceolate, 20–60 cm × 2–4.5 cm, nearly erect, with long spathaceous base and somewhat distinct veins,



Belamcanda chinensis (L.) DC. – 1, flowering plant habit; 2, flower; 3, dehisced fruit showing the seeds.

vivid green to glaucous, pellucid-margined; one short leaf present at the base of each branch of stem. Inflorescence a cyme, only top branches with flowers, each cyme with 2 membranous floral sheaths (spathes), (3–)6–12 flowered. Flowers rather small, shrivelling spirally after flowering; pedicel terete, 2–4 cm long, persistent, with indistinct articulation below the ovary; perianth actinomorphic, tepals short connate at base, oblong, 2–3.5 cm long, outer 3 slightly longer than inner 3, clawed, spreading, yellow outside with orange margins, bright orange with dark red blotches inside, outer tepals with longitudinal dark red nectaries at base of upper side; stamens 3, placed before the outer tepals, 1.5–2 cm long, with free filiform filaments and linear, basifixed anthers; ovary inferior, ovoid and slightly trigonous, 8–10 mm long, 3-celled, short-beaked, style about 15 mm long, orange-yellow, 3-fid with style-arms gradually thickened upwards. Fruit an oblong or obovoid, trigonous capsule with 3 deep longitudinal furrows, 1.5–3 cm long, opening with 3 loculicidal valves, many-seeded. Seeds subglobose, 4–5 mm in diameter, glossy black, remaining attached to the central placenta by the raphe for some time after the fruit opens.

Growth and development After germination, *B. chinensis* grows slowly but steadily, and may flower within one year of sowing the seed. The flowers are open for a few hours only, from dawn to noon, and 1–2 flowers open at a time within one cyme. It has been reported that apomixis may occur in *B. chinensis*. The plant is short-lived.

Other botanical information The monotypic genus *Belamcanda* belongs to the tribe *Irideae*. Morphological, anatomical, cytological and palynological investigations suggest it is particularly closely related to *Iris dichotoma* Pall. An intergeneric hybrid between *B. chinensis* and *I. dichotoma* is available from commercial plant growers; the hybrid is vigorous and partly fertile.

The root tip karyotypes may exhibit inconstancy in their chromosome complement. Cells with $2n$ = 28, 30 and 32 can be present; $2n = 30$ has been reported to be most frequent. This type of polymorphism along with aneusomy within different cells of the same tissue has been attributed to the often vegetative means of propagation; it is thought that cells with altered karyotype enter the growing tips of daughter shoots during propagation.

Ecology In Java, *B. chinensis* is semi-naturalized in forest edges, brushwood and waste places at 750–2100 m altitude. In Vietnam, it is usually found in savannas. It grows well in the full sun, but also in partial shade. It tolerates moderate frost, but should be protected from severe cold (below −15°C). In more temperate regions, *B. chinensis* easily adapts to a wide range of soils.

Propagation and planting *B. chinensis* is usually propagated by dividing the rootstock in spring or early autumn in temperate regions, or from seed. In the United States it was found that after stratifying the seed for 60 days at a temperature of 5°C germination occurred one month later. Controls of seed without stratification failed to germinate. Seed can be sown in an equal mixture of *Sphagnum* moss and quartz sand. Seedlings require little care.

Diseases and pests Tomato spotted wilt virus can attack *B. chinensis* plants. A mosaic virus found on *Iris fulva* Ker Gawler can also infect *B. chinensis*, causing yellowish streaks and sometimes faint general yellowing of leaves and occasionally downward curling or twisting of young leaves and deforming of fruits. *Pestalotiopsis disseminata* has been reported to cause leaf spots in

India, and the leaf miner *Amauromyza belamcandae* has been reported in Japan. Aphid colonies may cluster on the leaves.

Handling after harvest In markets in China rhizomes of *B. chinensis* are sold in hard longitudinal slices which are dark brown outside with transverse markings and a few rootlets, and pale yellowish-brown inside. However, it has been reported that some of the active compounds (e.g. belamcandal) decompose easily on drying and so it is recommended to use fresh rhizomes for medicinal purposes.

Genetic resources and breeding *B. chinensis* is planted widespread as an ornamental and locally also as a medicinal plant. It is assumed that the genetic diversity is not endangered, and germplasm collections are not known to exist.

Prospects The presence of some active compounds in rhizomes and seed of *B. chinensis* makes it an interesting medicinal plant for home-garden use and perhaps also for large-scale planting. Its ornamental value adds to the promising prospects for planting in South-East Asia, where it seems most suited for mountainous regions. The reported inhibitory activity against HIV-1 protease deserves more research.

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Other selected sources 97, 128, 202, 287, 580, 947, 1035, 1178, 1396.

N. Bunyapraphatsara & R.H.M.J. Lemmens

Bidens L.

Sp. pl. 2: 831 (1753); Gen. pl. ed. 5: 362 (1754).

COMPOSITAE

$x = 12$; *B. bipinnata*: $2n = 24, 36, 48, 72$, *B. biternata*: $2n = 24, 48, 72$, *B. pilosa*: $2n = 24, 36, 48, 72$, *B. tripartita*: $2n = 48, 72$

Major species *Bidens pilosa* L.

Vernacular names Beggar-tick, bur-marigold (En). Bident (Fr). Indonesia: hareuga (Sundanese), ketul (Javanese). Thailand: noksai.

Origin and geographic distribution *Bidens* is a large genus of about 200 species and has a worldwide distribution. Its centres of diversity are located in tropical and subtropical regions of North America and Africa. Only 4–5 species are found within the Malesian area.

Uses *Bidens* is widely used in traditional medicine, against numerous complaints, often to soothe pain. Applications may be ascribed to its antiseptic and astringent properties. An infusion or a decoction of roots, leaves or flowers, or the juice of the leaves is used against coughs, headache, fever, constipation, diarrhoea, intestinal worms, stomach-ache, toothache, poisoning, muscular pains and as a bath to treat itching and rheumatic pains. Crushed leaves or flower-heads, sometimes heated over a fire, are applied on the skin to treat inflammations, burns, ulcers, boils or skin affections in general and as a haemostatic on wounds. A decoction of the leaves or the roots is applied on eyelids to treat eye infections. Roots are chewed against toothache, and tinctures of the flowers and leaves are applied as a mouthwash against toothache. Furthermore, the roots and seeds are used as an expectorant, emmenagogue, diuretic, and also against kidney-stones and gall-stones. Seeds are sometimes used as an anaesthetic. An infusion of the leaves of *B. pilosa* is used in diabetes.

In Europe, *B. tripartita* was formerly valued for its diuretic and astringent properties, and used against fevers, gravel stone, bladder and kidney troubles and as a good styptic and remedy for ruptured blood vessels. In North America, the roots and seeds of *B. tripartita* are used as emmenagogue and in laryngeal and bronchial diseases. In Brazil, *B. pilosa* is used in the treatment of malaria.

The flowers of *B. pilosa* are used in the Philippines in the production of a kind of wine called 'sinitsit'. In Mexico, the leaves are used as a substitute for tea as a tonic and stimulant. In Indonesia and in Africa young, 2–5 cm long shoots and young leaves are eaten raw or cooked as a vegetable. They have a bitter astringent taste and are much relished in some regions. *B. pilosa* is readily browsed by domestic livestock, including poultry, and is sometimes used as a fodder. It is said to have a high nutritional value. The flowers are rich in nectar which yields a high-quality, reddish honey. In Thailand, *B. bipinnata* is considered an ornamental. Young shoots of *B. biternata* are eaten raw or steamed. Plants of *B. tripartita* yield a black dye which is used as a hair dye in China.

Production and international trade In most regions *B. pilosa* is available as a weed to meet daily needs. In Indonesia, young shoots are for sale on local markets but no statistics are available.

Properties Extracts of *B. pilosa* show antimalarial activity both in vitro and in vivo. The crude ethanol extract from *B. pilosa* (50 μg/ml) causes up to 90% inhibition of *Plasmodium falciparum* growth in vitro, compared with respectively 86–94% and 68–79% inhibition for the chloroform and butanol fraction (both at 50 μg/ml). In vivo, the crude ethanol extract and the chloroform fraction cause about 40% reduction of *P. berghei* parasitaemia in mice. Phenylacetylenes and flavonoids have been found in the ethanol extract from the leaves and the roots. The major component of the chloroform fractions from the roots was the phenylacetylene 1-phenylhepta-1,3-diyne-5-en-7-ol-acetate. Other *Bidens* species with aliphatic and phenylacetylenes and related compounds (thiophenes) were also found to be very active in vitro: 50 μg/ml of *B. tripartita*, which contains 13 acetylenes, reduced *P. falciparum* growth by 87%, and a similar dose of *B. bipinnata*, which has 9 acetylenes, gave a 70% reduction. However, extracts of *B. biternata* containing only 3 acetylenes showed only 38% inhibition at the same dose. The results indicate that the antimalarial activity of *Bidens* may be attributed to the presence of acetylene compounds. The therapeutic usefulness of these compounds seems limited, since they are easily oxidized by air and light.

Furthermore, acetylenes also have antimicrobial activity. A number of polyacetylenes, e.g. phenylhepta-1,3,5-triyne from petroleum ether and methanol/water extracts of *B. pilosa* are toxic to yeasts and some bacteria. This compound, which can also be isolated from the aqueous methanolic extract of leaves, flowers and achenes of *B. bipinnata* is an active anti-parasitic and exhibited marked insecticidal activity with LC_{50} of 204 ng/cm^2 for the first instar larvae of the fall armyworm (*Spodoptera frugiperda*).

In literature, the polyacetylene 7-phenylhepta-2,4,6-triyne is reported phytotoxic to fibroblast cells. The polyacetylene β-D-glucopyranosyloxy-3-hydroxy-6(E)-tetradecen-8,10,12-triyne from *B. pilosa* shows overgrowing action against normal and transformed human cell lines in culture. Dried leaves of *B. pilosa* have a co-carcinogenic action for oesophageal tumours induced in rats. Consumption of the leaves, as in South Africa, has been found to promote the development of oesophageal cancer.

In addition to the acetylenes, other compounds such as phytosterols (β-sitosterol), triterpenes (friedelin and friedelan-3β-ol) and caffeic acid(s) are also reported from *B. pilosa*. The main flavonoids from leaf extracts of *B. pilosa* are aurones and chalcones. Since friedelin and friedelan-3β-ol, as well as several flavonoids have known anti-inflammatory properties, their detection in extracts from *B. pilosa*, together with the presence of the described acetylenes, may rationalize the use of *B. pilosa* in traditional medicine, especially for treating wounds, against inflammations and against bacterial infections of the gastro-intestinal tract.

The ethanolic extract of *B. pilosa* showed a very high inhibition of prostaglandin synthesis in an in vitro assay for cyclo-oxygenase inhibitors. The methanol extract of *B. pilosa* showed radio-protective activity for bone marrow. Besides the above-mentioned pharmacological activity, antihyperglycaemic, immunomodulator, anti-ulcer and hypotensive activity are reported.

Adulterations and substitutes 1-Phenylhepta-1,3-diyne-5-en-7-ol-acetate has also been isolated from *Coreopsis* species.

Description Annual or perennial, usually erect herbs; stem branched, terete to 4-angled. Leaves opposite or rarely whorled, upper leaves sometimes alternate, simple to deeply 2–3-pinnatisect, margins entire to dentate or serrate or variously incised, sessile or petiolate; stipules absent. Inflorescence a terminal or axillary, capitulam, solitary or arranged in corymbose or panicle-like cymes; receptacle flat to conical, set with scales (paleae); involucre campanulate to hemispherical, 2-seriate, outer involucral bracts often much larger than the inner ones. Ray flowers absent or present, sterile or female, ligulate, yellow, purple to lilac or white; disk flowers bisexual, with yellow to brownish-orange or purple, tubular, 4–5-toothed corolla; stamens 4–5, anthers fused brown to black, caudate to sagittate at base; style bifurcate with short to long arms. Fruit a dorsiventrally compressed or 3–4(–6)-angled achene, linear-oblong to ellipsoidal or broadly obovate, not beaked, margins setulose, thickened or sometimes winged; pappus absent or composed of up to 4(–5) usually barbed bristles. Seedling with epigeal germination; cotyledons free, strap-shaped to spathulate; hypocotyl elongated; leaves opposite.

Growth and development *B. pilosa* produces seed (achenes) abundantly; one infructescence can produce 50–70 seeds, one plant up to 6000. The seed has no dormancy and germinates within 3–4 days. Seed viability is high and even 3–5-year-old seeds still have a viability of 80%. Phytochrome controls germination in *B. pilosa* and seeds germinate in darkness when the level of the pre-existing active form of phytochrome is above a certain threshold. The optimum range in day/night temperatures for germination is 25/20°C–35/30°C at a photoperiod of 12 h. Temperatures below 15/10°C and above 45/40°C influence germination negatively. Flooding following seeding, even for a day, will reduce emergence to about 25%. Seedling emergence decreases further sharply with extended periods of flooding. In some areas 3–4 generations per year are possible, making *B. pilosa* often a noxious weed in cropped land. Flowering starts about 1.5–2 months after sowing; plants are self-fertile and seed is mature 1 month after flowering. Flowering and fruiting is throughout the year. The seed is easily distributed by animals and people because of the barbed bristles of the pappus which adhere to fur or to clothes. The effective way of dispersal has contributed to *B. pilosa* developing into a worldwide weed. Plants have the highest biomass of leaves at about flowering time.

Other botanical information *Bidens* belongs to the tribe *Heliantheae* and is closely related to *Coreopsis*, with which some authors advocate uniting it. The taxonomy of *Bidens* is still unsatisfactory.

Due to its worldwide distribution, *B. pilosa* is a highly variable species: plants are erect or decumbent, leaves are simple to highly dissected with entire to dentate-serrate margins, heads may be discoid or radiate, ray flowers may be yellow, white or pinkish and short to long, the achenes may be awnless or have 2–5 bristles. In the past *B. pilosa* has been subdivided into 7 varieties, some with a number of formae. However, in America and South Africa it has been discovered that most of the taxa distinguished may occur in one population. Subdivision of the species is no longer considered useful, particularly because different ploidy levels seem to play a role in addition to the morphological variation. It is possible that what is now considered to represent *B. pilosa* in South-East Asia in fact consists of several species, as has appeared to be the case in North and Central America, but more biosystematic research is needed.

B. bipinnata closely resembles *B. biternata* and has been confused occasionally in literature because of erroneous identification of the material.

Ecology All South-East Asian *Bidens* species are known as weeds of cropped land and appear also in roadsides, along watercourses, in brushwood and thickets, up to 2500 m altitude. They prefer sunny to slightly shaded places and moist soils. *B. pilosa* is a cosmopolitan weed of more than 30 crops and often becomes dominant after the eradication of perennial grasses. It displays allelopathic effects on a number of crops.

Propagation and planting Optimal emergence occured when planting seeds less than 1 cm deep, with no emergence when planted as deep as 10 cm.

Harvesting Leaves and flower-heads of *Bidens* are simply collected from the wild whenever the need arises. Plants are readily available in the surroundings of human habitation.

Genetic resources and breeding In view of its widespread distribution and weedy nature, *Bidens* occurring in South-East Asia is unlikely to be at risk of genetic erosion.

Prospects The traditional application of *Bidens* for its antiseptic and anti-inflammatory properties will remain of local importance, especially because plants are always readily available. The antimalarial properties deserve further attention.

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Selection of species

Bidens bipinnata L.

Sp. pl. 2: 832 (1753).

Synonyms *Bidens pilosa* L. var. *bipinnata* (L.) Hook.f. (1881).

Vernacular names Spanish needles (En). Bident bipenné (Fr). Vietnam: v[aj]n th[oj] t[aa]y, song nha k[es]p.

Distribution Native to North America and eastern Asia; introduced and occurring as a weed in southern Europe, Central and South America, Africa, Australia and elsewhere in Asia. In Malesia, only known from the Philippines.

Uses The warmed juice of the leaves is used to treat conjunctivitis, against earache and as a styptic on wounds. The roots and seeds are used as an emmenagogue, expectorant, stimulant and antispasmodic, and also to treat asthma. In China, *B. bipinnata* is used to treat stings of insects, snake bites, and unhealthy granulations of wounds. In Taiwan, a decoction of the entire plant is used as an antidiarrhetic.

Observations An annual, erect herb up to 1.5(–2.5) m tall, stem 4-angular, glabrous or minutely hispid in the upper part; leaves opposite, occasionally alternate towards the apex, bipinnatisect with the lower segment often 2–3-cleft or pinnatifid, 11–20 cm long, the segments ovate to deltoid or the terminal one lanceolate, margin crenate-serrate, petiolate; capitula in lax paniculate cymes, radiate, 4–6 mm broad, outer involucral bracts 7–10, 3–5 mm × 0.5 mm, shorter than the inner ones; ray flowers 3–5, corolla 5–6 mm long, yellow, disk flowers with yellow, 4–5 mm long corolla; achene linear-fusiform, 4-angular, 7–18 mm long, with (2–)4 retrorsely barbed bristles of 2–4 mm. *B. bipinnata* is found on roadsides, wasteland, and field margins, up to 1400 m altitude; in the Philippines it has been found on dry slopes at 1300 m.

Selected sources 289, 458, 852, 935, 938, 1126, 1329.

Bidens biternata (Lour.) Merr. & Sherff

Bot. Gaz. 88: 293 (1929).

Synonyms *Coreopsis biternata* Lour. (1790), *Bidens chinensis* Willd. (1804), *Bidens abyssinica* Sch. Bip. (1846).

Vernacular names Indonesia: hareuga (Sundanese), ketul (Javanese), daun jarong (Malay, Moluccas). Thailand: koncham (Nakhon Ratchasima).

Distribution Widely distributed in tropical and subtropical regions of Africa, Asia including the Malesian region, and Australia; introduced and locally naturalized in temperate Europe.

Uses The leaf juice is used to treat eye and ear affections. The rubbed leaves are applied to skin affections in general, as a haemostatic on wounds, and wrapped around the umbilical cord of babies. The seeds are applied as an anthelmintic in animals.

Observations An annual, erect herb up to 1.5(–2) m tall, stem 4-angular, glabrous to pubescent; leaves opposite or rarely alternate towards the apex, pinnately (3–)5–9-lobed, 9–19 cm long, glabrous to densely tomentose, the segments ovate to ovate-lanceolate, the lower ones often pinnatifid, crenate-serrate or rarely lobulate-dentate, petiolate; capitula in lax paniculate cymes, usually radiate, 5–7 mm broad, outer involucral bracts (4–)5–10(–15), (3–)4–7(–12) mm × 0.4–0.7 mm, much narrower than the inner ones; ray flowers (0–)2–5, sterile, corolla 3–6 mm long, yellow, disk flowers with yellow, 3–5.5 mm long corolla; achene linear, 4–8-ribbed, 6–16(–20) mm long, with (2–)3–4(–5) retrorsely barbed bristles of (1–)2–4 mm long. *B. biternata* is common and occurs in fields, gardens, roadsides, thickets, teak forest and along watercourses, up to 2300 m altitude.

Selected sources 97, 202, 289, 580, 852, 937 938, 1126, 1329, 1380.

Bidens pilosa L.

Sp. pl. 2: 832 (1753).

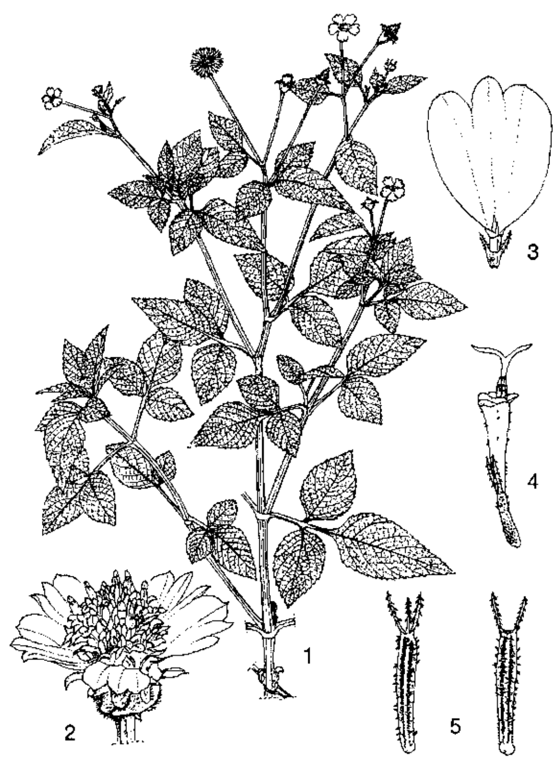
Synonyms *Bidens sundaica* Blume (1826), *Bidens leucorrhiza* (Lour.) DC. (1836), *Bidens pilosa* L. var. *minor* (Blume) Sherff (1925).

Vernacular names Black jack (En). Sornet (Fr). Indonesia: ajeran, hareuga (Sundanese), jaringan, ketul (Javanese). Malaysia: kancing baju, pau-pau pasir, keroten. Papua New Guinea: ivu na mag (Gunantuna, New Britain), rakot (Kurtatchi, Bougainville). Philippines: dadayem (Ibanag), burburtak (Ilocano), pisau-pisau (Bisaya). Thailand: puen noksai (northern), kee nok sai, yaa koncham khaao (central). Vietnam: d[ow]n bu[oos]t, t[uwr] t[oo] hoang, q[ur]y tr[aa]m th[ar]o.

Distribution *B. pilosa* originates from tropical America but is now distributed and naturalized as a weed in most tropical and subtropical regions of the world, even sometimes extending into some temperate areas. In South-East Asia it is common in many places, except in Kalimantan and the Moluccas.

Uses *B. pilosa* is widely used in traditional medicine against numerous complaints, often to soothe pain. An infusion or decoction, or the juice of the leaves is used against coughs, angina, headache, fever, diabetes, constipation, diarrhoea, intestinal worms, stomach-ache, toothache, poisoning, muscular pains and as a bath to treat itching and rheumatic pains. Crushed leaves, sometimes heated over a fire, are applied on the skin to treat inflammations, burns, on wounds to stop bleeding and on ulcers. In Papua New Guinea, crushed flower-heads are often used externally to extract pus from boils. A decoction of the leaves or of the roots is applied on eyelids to treat eye infections. A tincture of the flowers and leaves is used as a mouthwash against toothache. Roots are chewed against toothache. In Indonesia, the Philippines and Africa, young shoots and young leaves are eaten raw or cooked as a vegetable. Leaves as vegetable in the daily diet have been observed to prevent goitre in the Philippines. The plant is sometimes used as fodder.

Observations An annual, usually erect herb up to 1(–2) m tall, stem 4-angled, glabrous or sparsely pubescent; leaves opposite, pinnately 3–5-lobed, occasionally the lower and/or upper leaves simple, up to 15(–20) cm long, glabrous or sparsely pubescent on both surfaces, margin usually serrate or crenate-serrate, the segments ovate to ovate-lanceolate, the terminal one largest, petiolate; capitula solitary or in lax paniculate cymes, usually radiate, 5–12 mm broad, outer involucral bracts 7–10, spathulate, reflexed at anthesis, 3–4 mm × 0.5–0.8 mm, inner ones ovate-lanceolate; ray flowers absent or 4–8, sterile, corolla 7–15 mm long, white to yellow or pinkish, disk flowers with 3.5–5



Bidens pilosa L. – 1, flowering and fruiting plant; 2, flowering head; 3, ray floret; 4, disk floret; 5, achenes.

mm long, yellow corolla; achenes linear, 4–6-ribbed, 4–13 mm long, with 2–3(–5) retrorsely barbed bristles of 2–4 mm long. *B. pilosa* is a very common weed of sunny, often disturbed places like roadsides, fields, thickets and along watercourses, up to 2500 m altitude.

Selected sources 52, 53, 85, 97, 111, 168, 180, 184, 202, 224, 332, 350, 458, 475, 580, 597, 598, 599, 610, 614, 663, 818, 852, 920, 937, 1035, 1124, 1126, 1128, 1178, 1329, 1380, 1386, 1543, 1551, 1572.

Bidens tripartita L.

Sp. pl. 2: 831 (1753).

Vernacular names Trifid bur-marigold, three-lobed butterbur (En). Bident triparti (Fr). Vietnam: th[ur]y song nha.

Distribution From Europe and northern Africa to the Himalayas, China, Japan, Taiwan, Vietnam, the Philippines, West Java and New Guinea (Irian Jaya).

Uses In China, a decoction of *B. tripartita* is recommended in treating chronic dysentery, heart ailments, as a refrigerant and as a wash to treat chronic eczema. The roots and seeds are used as emmenagogue, expectorant, diuretic and also against kidney-stones and gallstones. *B. tripartita* also yields a black dye which is used as a hair dye in China.

Observations An annual, erect herb up to 1(–1.5) m tall, stem 4-angular, glabrous or sparsely pubescent; leaves opposite, the upper ones sometimes alternate, pinnately 3–5-lobed or rarely entire, up to 13 cm long, sparsely pubescent below, margins coarsely serrate, terminal segment larger, sessile or on a short and winged petiole; capitula solitary, not radiate, 10–20 mm broad, outer involucral bracts 5–10, foliaceous, oblanceolate, 10–35(–45) mm long, inner ones ovate-lanceolate, 6–12 mm long; ray flowers absent, disk flowers with 4–4.5 mm long, yellow corolla; achene narrowly obovate, compressed, 6–11 mm long, with 2(–3) retrorsely barbed bristles. *B. tripartita* occurs in moist, open habitats like watersides, swampy pastures and paddy fields, up to 1700 m altitude.

Selected sources 97, 184, 259, 289, 508, 852, 1126, 1329.

D.S. Alonzo & J.W. Hildebrand

Blumea DC.

Guill., Arch. Bot. (Paris) 2: 514 (1833).

COMPOSITAE

$x = 9, 10, 11$; *B. balsamifera*: $2n = 18, 20$, *B. lacera*: $2n = 18, 20, 22, 36$, *B. lanceolaria*: $2n = 18, 20, 54$

Major species *Blumea balsamifera* (L.) DC., *B. lacera* (Burm.f.) DC., *B. lanceolaria* (Roxb.) Druce.

Vernacular names Indonesia: sembung (general), capo (Sulawesi), capa (Sumatra). Malaysia: sembong (general), chapa. Philippines: sambong (Filipino). Laos: 'nat. Thailand: naat.

Origin and geographic distribution *Blumea* comprises about 50 species, most of which are confined to tropical Asia from Sri Lanka to China and the Malesian region, some extending to Africa in the west, Australia in the south, and the Pacific as far as Hawaii in the east. Some of the species reported from Africa may, however, well belong to other related genera. The majority of the species occur in South-East Asia, which seems the most likely centre of origin. *Blumea* is found throughout the Malesian region, with the Philippines being the richest with 19 species (4 endemics), followed by Indonesia with 18 (2 endemics), New Guinea with 13 (2 endemics) and Peninsular Malaysia with 6 species.

Uses A decoction of leaves or flowers of several *Blumea* species is used throughout the Malesian region to treat asthma, bronchitis and catarrhal affections in general. The leaf juice of several *Blumea* species is applied in various countries of the Malesian region to treat sores, boils, aphthae and sore eyes, probably due to its astringent properties. The leaves of *B. balsamifera* have been used in Chinese medicine since ancient times as a carminative, mild stimulant, vermifuge and as topical application for septic ulcers. In South-East Asia it is one of the most common and widely used medicinal plants for a number of ailments, mainly as a stomachic, antispasmodic, vermifuge and sudorific. In the Philippines, a diuretic and kidney-stone medicine is prepared commercially from *B. balsamifera* leaves. In Thailand, cigarettes containing the chopped, dried leaves are smoked to relieve the pain of sinusitis, whereas a decoction of fresh leaves, alone or in combination with other plant preparations, is used as a bath for women after childbirth and also for young children. In northern Vietnam leaves are also used as a medicinal condiment. A decoction of the roots of *B. riparia* is drunk to treat colic and the leaves and roots of *B. arfakiana* are similarly used in the treatment of stomach-ache. Furthermore, *B. lacera* is used in the treatment of haemorrhages and as an anthelmintic, febrifuge, deobstuent, diuretic and stimulant. *B. lanceolaria* is also used as a sudorific and applied externally as a poultice against rheumatism. The young leaves of *B. arfakiana* are eaten to treat anaemia.

B. balsamifera yields a high quality camphor oil, known as 'ngai camphor'. Camphor is used in liniments against rheumatic pains; a 3% ethanol solution is used to sooth itching. *B. lacera* also contains a camphor-like oil which is reputedly stronger than that of *B. balsamifera*. Its leaves can be eaten as a vegetable. *B. lanceolaria* is sometimes cultivated in gardens for culinary purposes as a seasoning.

Properties *B. balsamifera* is well known for its medicinally important essential oil. Plants from the Philippines yield about 0.1–0.4% essential oil, whereas those from Burma (Myanmar) are reported to contain 1.9% oil. The high quality *B. balsamifera* oil ('Ngai camphor') from Chinese sources consists almost entirely of (–)-borneol (l-borneol), that of Burmese origin consists of 75% of (–)-camphor (l-camphor) and 25% of (–)-borneol. These or related compounds can be found in varying concentrations in the essential oils of other *Blumea* species too. *B. lacera* from India yields 0.085% of an essential oil containing 'Blumea-camphor', which is probably a mixture of camphor, borneol and/or related components. The main constituent of *B. lacera* essential oil from Nigeria was thymoquinol-dimethyl-ether. The essential oil of *B. lanceolaria* consists for 95% of methyl-thymol; in another sample, however, p-cymene was identified as the major component (99%).

Phytochemical investigations have furthermore revealed the presence of flavonoids (5-hydroxy-3,6,7,3',4'-pentamethoxyflavone, 5,3',4'-trihydroxy-3,6,7-trimethoxyflavone, and a very small quantity of another flavone) in the leaves of *B. lacera*. Campesterol (a sterol) has also been isolated from the aboveground parts. Two glycosides, the triterpenoid glycoside 19α-hydroxy-urs-12-ene-24,28-dioate-3-O-β-D-xylopyranoside and the phenol glycoside 2-isoprenyl-5-isopropylphenol-4-O-β-D-xylopyranoside have been isolated from the whole plant of *B. lacera*.

The flavonoid blumeatin (5,3',5'-trihydroxy-7-methoxy-dihydro-flavone) has been isolated from *B. balsamifera*. Intraperitoneal injections of this component in CCl_4-intoxicated rats inhibited the increase of serum alanine aminotransferase (ALAT, SGPT), liver triglyceride level and increased serum triglyceride, β-lipoprotein, and liver glycogen content. The histological lesions of the liver of treated rats were less severe than those of their hepatic injury control. After intraperitoneal injection blumeatin also shortened the pentobarbital sleeping time in CCl_4-intoxicated mice. In thioacetamide-intoxicated mice, intraperitoneal injection of the compound inhibited the increase of serum alanine aminotranferase and liver triglyceride. These findings suggest that blumeatin could protect the liver against injury induced by CCl_4 and thioacetamide. Other flavonoids, flavone and quercetin derivatives have been reported in addition to blumeatin. Three sesquiterpene lactones isolated from *B. balsamifera* showed antitumour activity against Yoshida sarcoma cells in tissue culture. An extract from *B. balsamifera* reduced the mutagenicity potential of mitomycin C, dimethylnitrosamine and tetracycline in mice, and exhibited antimutagenic effects.

Other biological activities include antihistamine release properties by *B. balsamifera*, and antifungal activity of the ethanolic extract of *B. balsamifera* against *Epidermophyton floccosum* with a minimum inhibitory concentration of less than 10 mg plant material/ml. Water extracts of the entire plant showed a diuretic activity similar to coffee and tea.

The essential oil of *B. lacera* has a synergistic effect on the insecticidal activity of pyrethrum; the essential oil alone does not have insecticidal activity. *B. balsamifera* has insecticidal properties against the yponomeutid crucifer pest *Plutella xylostella*, but the compound responsible for the insecticidal activity is not known. It also effectively protected stored garlic against a number of insect pests. Moreover, when topically applied its essential oil is toxic to a number of insects and to golden snails (*Pomacea* spp.).

Adulterations and substitutes Essential oils of several other plant groups have similar applications and contain related compounds. Examples for camphor and borneol, without specification of stereo specificity, can be found in *Cinnamomum camphora* (L.) J.S. Presl and in *Compositae* like *Achillea* and *Artemisia*.

Description Herbs or shrubs, up to 4 m tall; stem simple or branched, erect to ascending, sometimes sprawling. Leaves alternate, simple, often pinnately lobed, linear-lanceolate to oblanceolate, margin serrate, dentate or denticulate, base usually rounded to tapering, sessile or shortly petiolate, exstipulate. Inflorescence a discoid capitulum arranged in lax to compact corymbs or panicles or occasionally solitary; receptacle honeycombed, epaleate, glabrous or hairy; involucre campanulate to hemispherical, involucral bracts multiseriate, narrow, pubescent on the back, outer ones much shorter than inner ones. Flowers with a tubular corolla, often yellow, rarely white or pale purple; marginal flowers female, corolla filiform, 2–4-lobed, in several rows; disk flowers bisexual, corolla (4–)5-lobed, stamens (4–)5, alternating with the corolla lobes, tailed at base, ovary inferior, style exserted, bifid. Fruit an oblong achene, terete or obscurely 4-angled, with 5 or 10 ribs; pappus uniseriate, composed of numerous, slender, toothed bristles, white or yellowish-white to red. Seedling with epigeal germination; paracotyledons free, opposite; hypocotyl not elongated; first pair of leaves opposite, subsequent leaves alternate.

Growth and development *B. balsamifera* is evergreen. Pollination is probably by insects. In New Guinea, *B. arfakiana* flowers from March to October, and *B. arnakidophora* from September to January. *B. balsamifera*, *B. lacera* and *B. riparia* flower throughout the year.

Other botanical information *Blumea* belongs to the tribe *Inuleae* and seemed to be closely related to the genera *Laggera* and *Blumeopsis*. It has even been proposed to merge these three genera, but recent studies place the latter two in the tribe *Plucheeae*. There has been considerable confusion about the identity of *B. chinensis* and *B. pubigera*. Most literature on these species pertains to *B. riparia*.

Ecology Most *Blumea* species have a weedy habit and are found in various ruderal and strongly secondarized habitats such as roadsides and fields, in the lowland and mountainous regions up to 3000 m altitude. Most *Blumea* species can tolerate drought and are found in regions with a slight to pronounced dry season. *B. balsamifera* tolerates fire, after which it readily sprouts from underground parts.

Propagation and planting *B. balsamifera* can be propagated by seed and by root or stem cuttings. Cuttings are placed in containers under shade. Water should be given with care, as too much watering is harmful. After about 2 weeks the plants can be transplanted in a place receiving full sunlight. After transplanting into the field, young plantings should be weeded regularly. Other *Blumea* species are usually propagated by seed only. 100 achenes of *B. lacera* weigh 4.8 mg; their germination rate is about 95%, falling to about 10% when stored for 12 months. The optimum temperature for germination is 30°C, but achenes can germinate at 20–50°C.

Husbandry In general, *Blumea* species are considered weeds, so more effort is geared towards eradication rather than towards cropping. Full sunlight is optimal for *B. balsamifera* for growth and for the production of essential oil. In the Philippines it responds well to a fertilizer application of 40 g ammonium sulphate or 100 g solophos (0-18-0) per plant.

Diseases and pests In the Philippines *B. balsamifera* suffers from leaf rust caused by *Endophyllum blumeae*, resulting in premature defoliation when the attack is severe. During the rainy season circular leaf spot caused by *Cercospora* sp. may lead to serious losses. Orange leaf spot also caused by a *Cercospora* sp. occurs occasionally. In Indonesia, *Gloeosporium* sp. has been found to cause anthracnose in *B. balsamifera*. Both *B. balsamifera* and *B. lacera* are occasionally suffering from *Endophyllum blumeae*. *B. balsamifera* is reported to be a host of the mites *Amblyseius* sp., *Brevipalpus obovatus* and *Typhlodromus jackmickleyi*.

Harvesting In gardens, leaves of *B. balsamifera* are collected when required. On a larger scale, either whole plants are harvested or leaves are picked up to four times a year.

Yield In Vietnam yields of 50 t/ha of fresh leaves of *B. balsamifera* have been reported, yielding 50–200 kg borneol.

Handling after harvest For home consumption fresh leaves are washed, finely chopped and given to patients. Commercially, leaves are dried in the shade, in a well ventilated place before use. On distillation the leaves can yield 0.1–0.5% of a yellow oil.

Genetic resources and breeding In view of the weedy nature of most *Blumea*, the risk of genetic erosion appears rather limited. No germplasm collections of *B. balsamifera* are known to be maintained and no breeding work has been done.

Prospects The essential oil contains interesting components such as (–)-borneol and (–)-camphor, which may find use e.g. in perfumery and/or chemical synthesis (due to their more uncommon stereochemical conformation). Furthermore, the presence of flavonoids like blumeatin merits further research for their protective effects on the liver.

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Selection of species

Blumea arfakiana Martelli

Nuov. Giorn. Bot. Ital. 15: 292 (1883).

Synonyms *Blumea balfourii* Hemsl. (1894).

Distribution The Moluccas, New Guinea, the Solomon Islands, Palau and Samoa.

Uses In Papua New Guinea, the young leaves are eaten to treat anaemia, and leaves and roots are used against stomach-ache.

Observations A herb or low shrub up to 2 m tall, stems erect, sparsely pubescent; leaves broadly elliptical to oblanceolate, 6–35 cm × 3–11 cm, long-tapering at base, margin serrate, scabrid above, sparsely pubescent below, sessile or nearly so; capitula in large terminal panicles, 10–14 mm in diameter, peduncle 4–18 mm long, involucre 8-seriate, 9–10 mm long, involucral bracts elliptical-lanceolate, glandular; marginal flowers 8 mm long, disk flowers 2–8, 5–8 mm long; achene 1.5 mm long, ribbed, pilose, pappus 5–6 mm long, whitish to pale red. *B. arfakiana* occurs in open places in forests, along rivers and creeks and in fallow fields, up to 900(–1600) m altitude.

Selected sources 611, 775, 1198.

Blumea arnakidophora Mattf.

Bot. Jahrb. Syst. 69: 286 (1938).

Distribution Borneo (Mt Kinabalu) and New Guinea.

Uses In Papua New Guinea the leaf juice is used to treat boils, sores and sore eyes, whereas in New Britain, the leaves and roots are used against stomach-ache.

Observations A small shrub up to 2 m tall, stems erect, woolly tomentose; leaves lanceolate to oblanceolate, 4–29 cm × 1.5–8 cm, tapering at base, margin mucronulate-serrate, velutinous above, woolly tomentose below, sessile or nearly so; capitula in large terminal panicles, 12–15 mm in diameter, peduncle 2–15 mm long, involucre 9–10 mm long, involucral bracts linear to linear-lanceolate, densely lanuginose; marginal flowers 4.5–6 mm long, disk flowers 7–18, 4.5–6 mm long; achene 1 mm long, ribbed, sparsely pubescent, pappus 4–6 mm long, pale reddish-yellow. *B. arnakidophora* occurs in grassy, secondary growth, forest edges and roadsides, at 1300–2700 m altitude.

Selected sources 597, 610, 755, 1198.

Blumea balsamifera (L.) DC.

Prodr. 5: 447 (1836).

Synonyms *Blumea appendiculata* (Blume) DC. (1836), *Blumea grandis* (Wallich) DC. (1836), *Blumea zollingeriana* C.B. Clarke (1876).

Vernacular names Ngai camphor plant (En). Camphrier (Fr). Indonesia: sembung (general), sembung utan (Sundanese), sembung gantung (Javanese). Malaysia: chapa, chapor, sembong. Philippines: sambong (Tagalog), lakadbulan (Bikol), subsub (Ilocano). Burma (Myanmar): poung-ma-theing. Cambodia: bai mat. Laos: 'nat, phi ma 'sen. Thailand: kam phung (northern), naat yai (central). Vietnam: d[aj]i bi, t[uwf] bi, b[aw]ng phi[ees]n.

Distribution From India, Burma (Myanmar), Indo-China, southern China and Taiwan to Thailand, Malaysia, Indonesia and the Philippines.

Uses In South-East Asia *B. balsamifera* is widely used for a number of ailments, mainly as a stomachic, antispasmodic, vermifuge and sudorific. In the Philippines a diuretic and kidney-stone medicine is prepared commercially from *B. balsamifera*. In Thailand cigarettes containing the chopped, dried leaves are smoked to relieve the pain of sinusitis, whereas a decoction of fresh leaves, alone or in combination with other plant preparations, is used as a bath for women after childbirth and also for young children. In northern Vietnam leaves are also used as a medicinal condiment.

Observations A shrub or sometimes a herb, up to 4 m tall, stems erect, densely woolly-villous; leaves usually narrowly oblong-lanceolate or sometimes oblong-ovate or oblong-obovate, 6–30 cm × 1.5–12 cm, tapering at base, margin entire, serrate, serrulate to pinnately lobed, rugose and pilose above, densely silky-woolly below, sessile to petiolate; capitula in large axillary or terminal panicles, 6–10 mm in diameter, peduncle 3–10 mm long, involucre 7–9 mm long, involucral bracts linear, densely woolly; marginal flowers up to 6 mm long, disk flowers 8–28, 5–7 mm long; achene ribbed, about 1 mm long, pubescent, pappus 4–6 mm long, whitish or reddish-yellow. *B. balsamifera* grows, sometimes gregariously, along roadsides, in fields, grasslands, *Imperata* fields, brushwood and forest, including bamboo and teak forest and sometimes in wet places on river banks, from sea-level up to 2200 m altitude. *B. balsamifera* is very variable in its foliage and degree of pubescence; the flower heads and florets, however, are remarkably uniform in size and morphology throughout its range. Plants growing in montane habitats appear more woolly than those from the lowland.

Selected sources 97, 184, 202, 287, 332, 344, 364, 437, 531, 580, 651, 775, 852, 858, 885, 974, 1035, 1126, 1128, 1178, 1198, 1232, 1261, 1380, 1411, 1503, 1525, 1601.

Blumea lacera (Burm.f.) DC.

Wight, Contr. bot. India: 14 (1834).

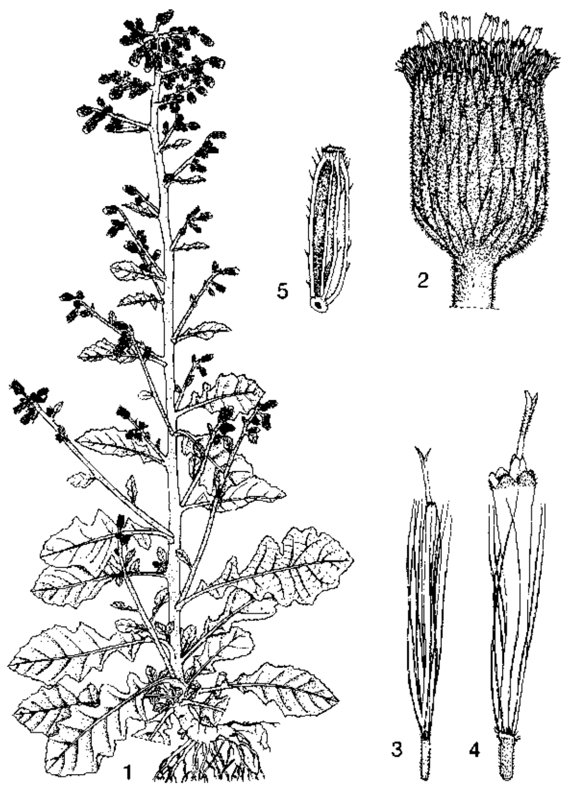
Synonyms *Blumea runcinata* DC. (1836), *Blumea thyrsoidea* Sch. Bip. (1866), *Blumea bodinieri* Vaniot (1903).

Vernacular names Indonesia: batu lincar, sembung lalaki (Sundanese), kremahan (Javanese). Malaysia: lumai hutan (Peninsular). Philippines: damong-mabaho, tubang-kabayo (Tagalog), lamlampaka (Bontoc). Thailand: naat wua. Vietnam: c[ar]i ma, d[aj]i bi r[as]ch.

Distribution The Cape Verde Islands, tropical Africa, Pakistan, India, Sri Lanka, Burma (Myanmar), Indo-China, China, the Ryukyu Islands, Taiwan, Thailand, throughout the Malesian region towards the Marianas (Guam), the Solomon Islands, New Caledonia and Australia.

Uses In the Philippines, a decoction of fresh flowers of *B. lacera* is given before meals to treat bronchitis. Its leaf juice is a useful anthelmintic and is given, mixed with black pepper, for haemorrhages. It is also used as a febrifuge, astringent, deobstruent and stimulant. An astringent eye-lotion has also been prepared from the leaves. Furthermore, it is applied as a diuretic and is useful in several catarrhal afflictions. In Vietnam it is used for its wound-healing properties and in the treatment of sores. The leaves can be eaten as a vegetable. *B. lacera* contains a strong, camphor-like oil.

Observations A herb up to 2.5 m tall, stems erect, tomentose to densely velutinous; leaves elliptical-oblong to oblanceolate or obovate, 3–21 cm × 1–13.5 cm, acute to tapering at base, margin entire to lyrately lobed, coarsely to finely dentate, tomentose to velutinous above, tomentose to woolly below, sessile or shortly petiolate; capitula in axillary and terminal, dense to lax panicles, 5–6.5 mm in diameter, peduncle 2–10 mm long, involucre 4–10 mm long, 5–6-seriate, outer involucral bracts



Blumea lacera (Burm. f.) DC. – 1, plant habit; 2, capitulum; 3, marginal flower; 4, disk flower; 5, achene with pappus removed.

oblanceolate, inner ones linear-lanceolate, all densely velutinous; marginal flowers 3–4 mm long, disk flowers 8–30, 3–4.5 mm long; achene 1–1.3 mm long, ribbed, sparsely pilose, pappus 4–5 mm long, whitish. *B. lacera* is highly variable and occurs in sunny to slightly shaded places in grasslands, fields, roadsides and forest edges, up to 2900 m altitude.

Selected sources 24, 26, 97, 202, 287, 530, 580, 637, 775, 804, 852, 1126, 1128, 1178, 1198, 1199, 1365, 1386, 1398, 1532, 1576.

Blumea lanceolaria (Roxb.) Druce

Rep. Bot. Exch. Club Brit. Isles 4: 609 (1917).

Synonyms *Blumea myriocephala* DC. (1836), *Blumea laxiflora* Elmer (1906), *Blumea conspicua* Hayata (1911).

Vernacular names Malaysia: chapa, kepijit (Peninsular). Vietnam: rau [ax]n g[ox]i, x[uw][ow]ng s[oo]ng.

Distribution From Sri Lanka, India and Bangladesh to Indo-China, China, the Ryukyu Islands, Taiwan, Peninsular Malaysia, Sumatra, Java and the Philippines.

Uses The leaves are sudorific and used against bronchitis, aphthae and asthma. They have also been applied externally as a poultice to treat rheumatism. *B. lanceolaria* is sometimes cultivated for culinary purposes as a seasoning.

Observations A herb or small shrub up to 2 m tall, stems erect, generally unbranched, glabrous though puberulous above; leaves simple, generally elliptical-oblanceolate, 6–35 cm × 1–9 cm, long-tapering at base, margin minutely to coarsely serrate-dentate, rugose and lustrous above, glabrous or puberulous below, sessile; capitula in terminal panicles, 6–11 mm in diameter, almost sessile and clustered on up to 2 cm long peduncles, involucre 8–9 mm long, 4–5-seriate, outer involucral bracts ovate-lanceolate, inner ones narrowly lanceolate, all pubescent on the back; flowers 5–6 mm long; achene ribbed, pubescent, pappus up to 5 mm long, yellowish-white to pale red. *B. lanceolaria* is highly variable and occurs in humid shaded places, along stream banks, up to 1500 m altitude.

Selected sources 97, 202, 384, 852, 1035, 1038, 1126, 1128, 1198, 1397, 1398.

Blumea riparia (Blume) DC.

Prodr. 5: 444 (1836).

Synonyms *Blumea chinensis* auct. non (L.) DC., *Blumea pubigera* auct. non (L.) Merr.

Vernacular names Indonesia: tombak-tombak (Malay), jonge areuy, lalangkapan (Sundanese). Papua New Guinea: mulmul (Wapenamanda, Enga), mungla (Mt Hagen, Western Highlands). Philippines: katarai (Sulu), lankat (Manobo), pagang-pagang (Cebu Bisaya). Laos: phang nhot pang. Thailand: mu masang, kamu maeng.

Distribution From India and Burma (Myanmar) to Indo-China, southern China, Taiwan, Thailand, throughout the Malesian region to the Solomon Islands.

Uses In Peninsular Malaysia, a decoction of the roots is taken to cure colic. In Papua New Guinea, leaf juice is used to treat sores, boils and sore eyes.

Observations A scandent shrub, stems sprawling, glabrous though sparsely puberulous above; leaves simple, narrowly elliptical to narrowly obovate, entire, 2.5–13 cm × 1.3–5 cm, rounded at base, margin mucronulate-denticulate, both surfaces glabrous or with a few hairs, shortly petiolate, petiole up to 8 mm long; capitula in terminal and axillary, few-headed racemes, 8–18 mm in diameter, on up to 2.5 cm long peduncles, involucre 8–10 mm long, 5-seriate, outer involucral bracts narrowly ovate, inner ones linear-lanceolate, all pilose; marginal flowers 4–5.5 mm long, disk flowers 5–8, 5–6 mm long; achene about 1 mm long, prominently ribbed, pubescent, pappus 4–6 mm long, white. *B. riparia* is found in thickets, open grassy places, forest clearings, along streams and rivers and in light rain forest, up to 2000 m altitude.

Selected sources 97, 580, 597, 610, 775, 852, 1126, 1178, 1198, 1525.

D.S. Alonzo

Brucea javanica (L.) Merr.

Journ. Arn. Arb. 9: 3 (1928).

SIMAROUBACEAE

$2n$ = unknown

Synonyms *Brucea sumatrana* Roxb. (1814), *Brucea amarissima* (Lour.) Desv. ex Gomes (1872).

Vernacular names Indonesia: kuwalot (Sundanese, Javanese), malur (Batak), tambara marica (South Sulawesi). Malaysia: embalau padang, kusum, lada pahit (Peninsular). Philippines: balaniog (general), magkapayos (Samar-Leyte Bisaya), manongao-bobi (Cebu Bisaya). Cambodia: damli thnang, pramat monus. Laos: ich kone, kom roi, phia[2] fan. Thailand: ratchadat (peninsular), ka chaplak (northern), dee khon (central). Vietnam: c[aa]y su[oos]t, c[uws]t chu[ooj]t, s[aaf]u d[aa]u.

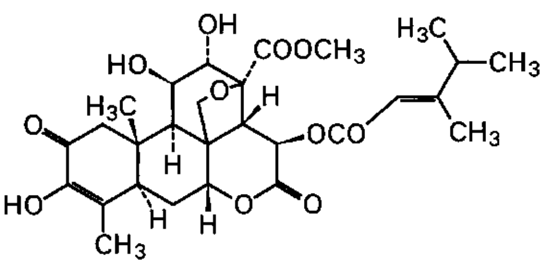
Origin and geographic distribution *B. javanica* is widespread and occurs from Sri Lanka and India towards Indo-China, southern China, Taiwan, Thailand, and although rare in the Moluccas and New Guinea throughout the Malesian region to northern Australia. Its patchy distribution in eastern Malesia suggests that it was introduced here by man long ago. It has certainly been introduced in Micronesia (Ponape) and Fiji.

Uses All parts of *B. javanica*, but most often the pyrenes and roots, are used medicinally, mainly against amoebic dysentery, diarrhoea, malaria and as a febrifuge. It is known in Chinese traditional medicine, where it is additionally applied for the treatment of haemorrhoids, corns, warts, ulcers and cancer. The pyrenes are well-known under the name 'Macassar kernels', and are also applied as an insecticide. The leaves are applied as a poultice against enlarged spleen, scurf, ringworm, boils and centipede bites. A decoction of the roots is also used to treat abdominal pains, coughs and as an important remedy for internal poisoning. In Australia, the bark and roots have been used by Aborigines to treat toothache.

Production and international trade The pyrenes, roots and occasionally other parts of *B. javanica* are traded on local markets, but are not of great commercial importance.

Properties Several quassinoids have been isolated from the fruits of different *Brucea* species. In general, these compounds have been shown to have strong anti-amoebic, antimalarial and/or cytotoxic (anti-cancer) properties.

One of the major quassinoids found in *B. javanica* and *B. antidysenterica* J.F. Miller from Africa is bruceantin. Anti-amoebic, antimalarial and anti-cancer properties of this compound are reported in literature; the antimalarial activity is not simply due to cytotoxic effects. Furthermore, quassinoids (e.g. brusatol) from the fruits, as well as the triterpenoids bruceajavanin A, dihydrobruceajavanin A and bruceajavanin B (from the stems of *B. javanica*) have been shown to inhibit the growth of the chloroquine-resistant strain *Plasmodium falciparum* K1 in vitro. Some of the quassinoids (bruceine A, B and D, brusatol) also showed in vivo activity against *P. bergei* infections in mice after oral dosing. Finally, the quassinoids bruceine A, B and C, present in a chloroform extract of *B. javanica* fruits, had a very potent activity in vitro against a multi-drug resistant *P. falciparum* strain with an ID_{50} of 8.66, 8.15 and 1.95 ng/ml, respectively, in comparison with 6.26 ng/ml for the mefloquine reference.



bruceantin

Quassinoids (e.g. bruceolides, bruceantin and bruceantinol) are reported to show inhibitory action against lymphocytic leukaemia and lung carcinoma. Bruceoside A and B (quassinoids) were found to possess lethal toxicity when the methanol extract of *B. javanica* was administered to mice. Bruceoside C showed potent cytotoxicities against KB, A-549, RPMI and TE-671 tumour cell lines, and bruceosides D, E, and F show selective cytotoxicity in leukaemia and non-small cell lung, colon, central nervous system, melanoma and ovarian cancer cell lines. Other quassinoids found in *B. javanica* with cytotoxic effects and with potential for cancer therapy include e.g. brusatol and the yadanziosides A–H, O and P.

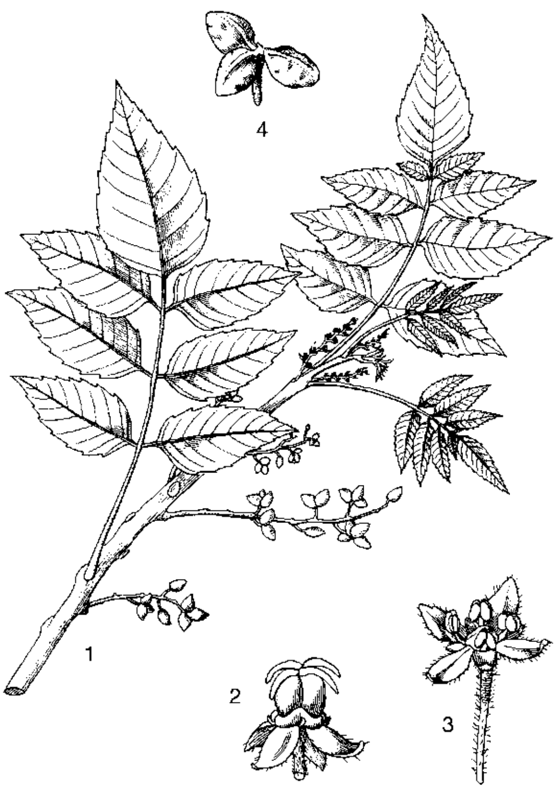
B. antidysenterica also contains quassinoids with similar cytotoxic effects (e.g. bruceanols A, B, D, E, F, G, H, bruceantinosides A–C, yadanziosides G, N, M, P) as well as bruceanic acids (A, the methyl ester of A, B–D). Cytotoxic canthin-6-one alkaloids, biosynthetically derived from tryptophan, are also reported in the literature.

Clinical observations of improvement in clinical manifestations after administering *B. javanica* oil emulsion intravenously to patients with brain metastasis from lung cancer have been experimentally confirmed in rabbits by positive effects on intracranial hypertension.

The crude extract of *B. javanica* has been found to be very effective against the internal parasite *Blastocystis hominis* at an active concentration of 500 μg/ml as compared with 10 μg/ml for metronidazole, the active standard drug for *B. hominis*. Bruceoside D showed in vitro anti-tuberculosis activity. However, the activity on the test organism, Mycobacterium tuberculosis, was low, with 7% inhibition at 12.5 μg/ml.

Adulterations and substitutes The *Cinchona* alkaloid quinine, and the synthetic antimalarials derived from it (e.g. chloroquine) are widely in use for the classical treatment of malaria. Artemisinin (a sesquiterpene lactone from *Artemisia annua* L.) and its synthetic analogues (e.g. β-artemeter and sodium artesunate) comprise a class of new antimalarials, which are of interest, since resistance to the malaria-causing parasites is developing fast. Other *Simaroubaceae* that might be of interest in this respect include *Eurycoma*, *Picrasma* and *Quassia*, whereas *Dichroa* species (*Saxifragaceae*) warrant some atttention as well.

Description A monoecious or dioecious shrub or small tree up to 10 m tall with soft-haired twigs and leaves. Leaves arranged spirally, imparipinnate, 20–50 cm long, exstipulate; leaflets 3–15, opposite, short petiolulate, ovate-oblong to ovate-lanceolate, margin bluntly serrate or crenate, secondary veins unbranched and terminating in a marginal gland. Inflorescence axillary, pubescent, composed of small cymes united into bracteate, raceme-like thyrses. Flowers unisexual, 4-merous, small, greenish-white to greenish-red or purple; sepals connate at base; petals free; disk intrastaminal, thick, 4-lobed; stamens short, vestigial or absent in female flowers; ovaries superior, free, each with a single, pendent ovule, styles free or coherent at base, subulate, bent outwards over the top of the ovary. Fruit consisting of 1–4 hardly fleshy drupelets; drupelet 2-ribbed, dry, purplish-black and 4–5(–7) mm long when mature, pyrene with wrinkled endocarp. Seed ovoid, with thin testa and very thin endosperm. Seedling with epigeal germination; cotyledons emergent, leafy; hypocotyl elongated; first two leaves opposite, subsequent ones arranged spirally; first few leaves 3-foliolate, later ones with increasing number of leaflets.



Brucea javanica (L.) Merr. – 1, twig with flowers and fruits; 2, female flower; 3, male flower; 4, fruit.

Growth and development In a germination test in Peninsular Malaysia fruits of *B. javanica* had a germination rate of about 35% within 11–273 days.

All shoots are orthotropic. Growth is rapid and flowering starts early. Flowering and fruiting can be throughout the year. Pollination is probably by insects. Small fruit bats eat the fruits and thus disperse the seed. However, the life span is only a few years and plants have to be regenerated from seed.

Other botanical information A second Malesian species, *B. mollis* Wallich ex Kurz (synonyms: *B. luzoniensis* S.Vidal, *B. macrobotrys* Merr., *B. acuminata* Li), is found in Indo-China, Thailand and the Philippines and may contain similar medicinally active compounds. The African *B. antidysenterica* is a well-known medicinal plant with similar applications.

Ecology *B. javanica* is very common preferring open localities such as light secondary forest and thickets, forest edges, ridges, and even occurring in sunny places on sandy dunes and on limestone. It grows under both per-humid and seasonal conditions, from sea-level up to 900 m altitude.

In vitro production of active compounds Canthin-6-one alkaloids can be produced by cell suspension cultures of *B. javanica*. The total yield of alkaloids produced in cells and medium is in excess of 2.0 mg/g on a dry weight basis. The major alkaloids produced are canthin-6-one, 11-hydroxycanthin-6-one, 5-methoxycanthin-6-one and 11-methoxycanthin-6-one.

Handling after harvest After the mature fruits have been collected, the fruit pulp is removed. The pyrenes that remain are washed and dried in the sun.

Genetic resources and breeding Since *B. javanica* is common in anthropogenic habitats and has a large area of distribution, the risk of genetic erosion seems limited.

Prospects The various quassinoids found in the seed of *B. javanica* that possess both antimalarial and anti-cancer activity merit further research. Because of the growing resistance of malaria parasites to the well-known, and even newer, antimalarials currently in use, there is a continuous need to develop new compounds to control this almost global infectious disease. The quassinoids and the canthin-6-one alkaloids might also have good potential for the development of a cytostatic drug to treat various cancers.

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Other selected sources 202, 284, 363, 441, 442, 443, 488, 579, 580, 648, 649, 834, 1020, 1035, 1053, 1076, 1077, 1078,1080, 1096, 1126, 1128, 1165, 1178, 1271, 1272, 1273, 1287, 1383, 1473, 1513, 1548, 1571, 1614.

Arbayah H. Siregar

Bryophyllum Salisb.

Parad. Lond.: t. 3 (1805).

CRASSULACEAE

$x = 17, 18$; *B. pinnatum*: $2n = 36, 40$, *B. proliferum*: $2n = 34$

Major species *Bryophyllum pinnatum* (Lamk) Oken.

Vernacular names Indonesia: buntiris (Sundanese). Malaysia: sedingin, seringin (Peninsular).

Origin and geographic distribution *Bryophyllum* comprises about 30 species. Almost all species are restricted to or originate from Madagascar. However, the exact origin of *B. pinnatum* is unknown. In Malesia 2 species are found naturalized.

Uses The main medicinal use of *B. pinnatum* in South-East Asia is in the treatment of boils, wounds, burns and scalds. In Indonesia, pounded leaves are used as a diuretic, and leaves are used externally to treat sores and pain in back and feet; a poultice is sometimes applied on sore eyes or to relieve headache; a decoction is used internally to treat fever and oedema; an extraction of dried pounded leaves in water is used against haemorrhoids. In Malaysia, the crushed leaves are applied to the forehead to treat headache and to the chest to treat coughs and pains. In Brunei, a leaf infusion is drunk as a febrifuge. In the Philippines, the leaves are used as an astringent, antiseptic, and against insect bites. Fresh, pounded leaves are applied to burns and as poultices on boils. Leaf juice is used (mixed with lard) to treat diarrhoea, dysentery, cholera and phthisis. The leaves are also used as topicals to treat dislocations, equimosis and callosities. In Papua New Guinea, young leaves are heated over a fire and placed on sores, or applied as a poultice to boils, sores and swellings. In Vietnam, Cambodia, Laos and Thailand, fresh leaves are applied to burns, scalds, wounds, boils, skin diseases and corns and to treat ophthalmia, phlegm, rheumatism, neuralgia and pain.

The use of *B. pinnatum* for medicinal purposes is also widespread outside South-East Asia. In India, the leaves are applied to wounds, bruises, boils and, in the form of poultice or powder, to ulcers, whereas leaf juice is given to treat bilious diarrhoea and lithiasis. In West Africa, the juice is used as a diuretic and for the treatment of earache and ophthalmia. The leaves are rubbed or tied on the head against headache, and the roots are used to make a cough medicine. In Brazil, the leaves are used as an emollient and refrigerant over a face swollen from neuralgia or tooth trouble, and in Puerto Rico leaf juice is used to treat acute nephritis. *B. pinnatum* is also used as an ornamental plant and in ceremonies.

B. proliferum is sometimes cultivated in South-East Asia as a hedge plant, but there are no reports of medicinal uses.

Properties The leaves of *B. pinnatum* are reported to contain 'bryophyllin', a mixture of bufadienolides, with antibacterial effects on gram-positive and gram-negative bacteria. They are used to treat intestinal problems caused by such bacteria, and also externally. Further phytochemical investigations have revealed the presence of the bufadienolides bryophyllin A (= bryotoxin C), bryophyllin B and bersaldegenin-3-acetate in fresh whole plant material of *B. pinnatum*. Bryophyllin A can be converted into bryophyllin B by the addition of a catalytic amount of acid ((±)-10-camphor sulphonic acid). All 3 compounds have shown strong in vitro cytotoxity against KB-tumour cells; bryophyllin A and bersaldegenin-3-acetate were also cytotoxic to A-549 and HCT-8 cells.

Both *B. pinnatum* and *B. proliferum* can be poisonous to cattle and sheep when eaten in large amounts. The toxic syndrome is known as cotyledonosis (or 'krimpsieke'), a neurotoxic syndrome, which, together with cardiac glycoside poisoning can be caused by *Crassulaceae*-bufadienolides. The bufadienolides bryotoxin A, B and C (= bryophyllin A) have been isolated from different parts of both species. High pressure liquid chromatography (HPLC) analysis has revealed concentrations of 61 mg/kg bryotoxin (total of A, B and C) in the flowerheads of *B. proliferum*, and 24, 52 and 141 mg/kg bryotoxin (total of A, B and C), respectively, in the flowerheads, leaves/stems and roots of *B. pinnatum*. Experiments with the structurally comparable bufadienolides daigremontin and bersaldegenin-1,3,5-orthoacetate (from *B. daigremontianum* (Hamet & Perr.) Berger and *B. tubiflorum* Harv.) showed a pronounced sedative effect in mice at low doses (0.1–0.5 mg/kg; motility test), but a toxic effect at higher concentrations, inducing paralysis and spasmodic muscle contractions. A pronounced positive inotropic activity is also seen on the heart.

Furthermore, methanolic leaf extracts of *B. pinnatum* showed anti-inflammatory activity in rats and mice (carrageenin-induced oedema, cotton pellet granuloma, formaldehyde-induced arthritis, adjuvant-induced arthritis and turpentine-induced joint oedema). It is thought that the active constituents, β-sitosterol and some aliphatic alcohols might contribute to the effects. Methanolic leaf extracts also showed anti-ulcer activity in rats and guinea-pigs by providing protection against gastric lesions induced by e.g. aspirin, indomethacin, serotonin, reserpine, ethanol, histamine, acetic acid or stress. In mice infected with *Leishmania amazoniensis*, oral treatment with an aqueous leaf extract from *B. pinnatum* significantly decreased lesion growth and the number of viable parasites.

Ethyl acetate and petroleum ether extracts of leaves of *B. pinnatum* exhibited potent antimutagenic activities at non-toxic concentrations against reversion mutations induced by ethyl methane-sulphonate in *Salmonella typhimurium* strains TA 100 and TA 102. Further fractionation into non-polar lipid and polar lipid fractions and investigations of these suggest that there may be different types of antimutagenic compounds in *B. pinnatum*.

Besides the bufadienolides mentioned, a variety of other compounds have been found in *B. pinnatum*: sterols (e.g. 24-ethyldesmosterol, sitosterol, clerosterol, isofucosterol), triterpenes (e.g. α-amyrin, β-amyrin, 18α-oleanane, bryophollone, bryophynol, ψ-taraxasterol), phenanthrenes (e.g. 2(9-decenyl) phenanthrene, 2(9-undecenyl)phenanthrene), alkanes (C_{25}–C_{35}, with C_{31} and C_{33} predominating), alkanols (C_{26}–C_{34}, with C_{32} as major component), phenolic compounds (e.g. p-coumaric acid, ferulic acid, syringic acid, caffeic acid, p-hydroxybenzoic acid) and flavonoid glycosides (quercetin-3-di-arabinoside, kaempferol-3-glucoside).

Adulterations and substitutes Other *Crassu-*

laceae, notably *Kalanchoe ceratophylla* Haw. and *K. crenata* (Andrews) Haw., have comparable medicinal uses.

Description Shrubs or shrublets with branches erect, cartilaginous, but usually somewhat woody, rarely regenerating from the base. Leaves opposite, simple or imparipinnate, fleshy, persistent, usually producing pseudobulbils on the margins. Inflorescence terminal or terminal with axillary paniculate cymes; bracts on peduncle distinct, abruptly shorter than leaves. Flowers bisexual, pendulous, 4-merous; calyx with sepals usually fused for more than half the length; corolla fused into a tube longer than the spreading lobes; stamens 8 in 2 whorls, filaments glabrous and fused to corolla tube in lower third, anthers usually protruding, with terminal appendage; ovary superior, consisting of 4 free carpels, abruptly constricted into longer styles. Fruit a many-seeded follicle. Seeds ellipsoid, with a constriction and abruptly widening at the blunt proximal end.

Growth and development The formation of foliar embryos in the notches of the leaf is typical for *Bryophyllum*. Contrary to some other *Bryophyllum* spp., which develop plantlets under long days, foliar embryos in *B. pinnatum* normally develop into plantlets only when the leaf is detached or injured, or when cytokinin is applied to the attached leaf. Inhibition of plantlet formation in intact plants is probably related to high auxin levels. Release from dormancy is also reported to be initiated by external conditions, such as high humidity, absence of light or water stress, but the production of plantlets of *B. pinnatum* is not influenced by photoperiodicity.

The young plants on the leaves fall off after having formed roots and a thin stem with a few leaves. They may be transported by rain-wash. In Malesia, *B. pinnatum* never sets fruit. *B. proliferum* never flowers in lowland Java, and rarely in mountainous regions during the period March-August. It seems that no fruits are produced.

B. pinnatum was the first plant in which Crassulacean Acid Metabolism (CAM) was described. CAM plants are able to fix CO_2 at night and have photosynthesis with closed stomata during the day, to minimize water loss.

Other botanical information *Bryophyllum* is closely related to *Kitchingia* and *Kalanchoe*; sometimes the first two genera are united in *Kalanchoe*. However, several vegetative and floral characters can be used to distinguish *Bryophyllum* from *Kalanchoe*. *Bryophyllum* usually has pendulous flowers, larger, campanulate-globular calyces with fused sepals, corolla tubes constricted above the ovary, stamens inserted at the base of the corolla tube, carpels shorter than the styles, large epigynous scales, foliar embryos on the leaf margins in 50% of the species, a basic chromosome number of 17 for most species and almost all species are from Madagascar.

Ecology *Bryophyllum* is very hardy, and will survive under a low water supply. In South-East Asia, *B. pinnatum* is found up to 1000 m altitude, in sunny or slightly shaded locations. The habitat can be stony, is always dry and never far from human habitation. Naturalized *B. proliferum* is found in Java between 1000 m and 1600 m altitude. It is cultivated at lower elevations as well.

Propagation and planting The easiest way of propagation of *Bryophyllum* is by foliar embryos. When leaves are cut and kept under warm and moist conditions, plantlets soon form. When these have formed roots and a thin stem with a few leaves, they can be separated from the parent leaf and planted. *Bryophyllum* can also be propagated through stem cuttings and seed.

Husbandry *Bryophyllum* species are collected from the wild or grown in small quantities for home use, and information on specific care is absent.

Diseases and pests In India, *B. pinnatum* is reported to be susceptible to the fungi *Alternaria alternata*, *Glomerella cingulata* and *Colletotrichum dematium*.

Harvesting The leaves are simply cut and used fresh.

Genetic resources and breeding *Bryophyllum* species occurring in the Malesian region are widely distributed in other parts of the world. This widespread distribution, the relatively easy propagation and common use as a pot plant limits the risk of extinction. However, as both species are almost exclusively propagated vegetatively, the genetic basis in South-East Asia may be very narrow.

Prospects *Bryophyllum* species will remain of some importance as a readily available traditional antiseptic and counterirritant, and will be collected and/or grown in small quantities for home use. The antimutagenic activity merits further research.

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Selection of species

Bryophyllum pinnatum (Lamk) Oken

Allg. Naturgeschichte Vol. III(3): 1966 (1841).

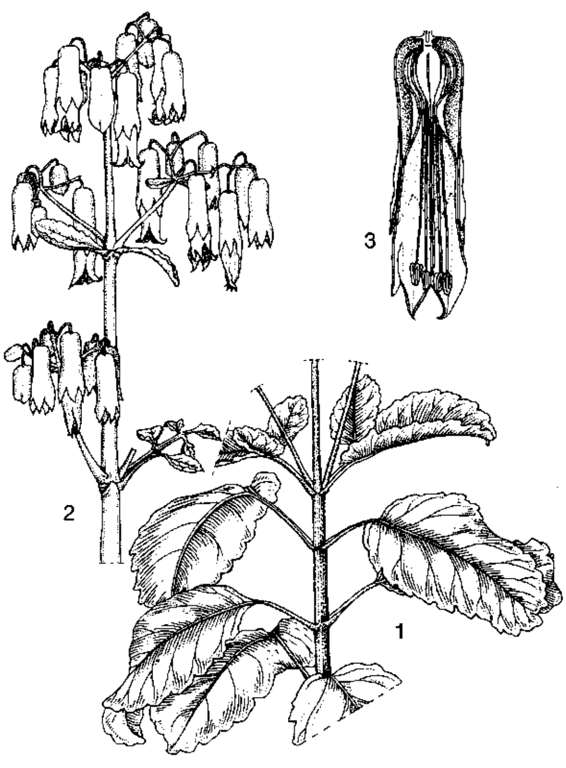
Synonyms *Cotyledon pinnata* Lamk (1786), *Bryophyllum calycinum* Salisb. (1805), *Kalanchoe pinnata* (Lamk) Pers. (1805).

Vernacular names Life plant, floppers (En). Brunei: bendingin, serigen. Indonesia: daun sejuk (Malay, Palembang), buntiris (Sundanese), sosor bebek (Javanese). Malaysia: sedingin, seringin, setawar padang. Philippines: karitana (Bisaya), abisrana (Iloko), katakataka (Tagalog). Burma (Myanmar): yoekiyapinba. Laos: poun tay, poun po. Thailand: benchachat (central), ton tai bai pen, khwum taai ngaai pen. Vietnam: c[aa]y thu[oos]c b[or]ng, c[aa]y tr[uw][owf]ng sinh, l[aj]c d[ij]a sinh c[aw]n.

Distribution *B. pinnatum* has a pantropical distribution. In Malesia it is naturalized throughout the region. In many places it is a weed; on the other hand it is reported to be cultivated in Indonesia, Malaysia, the Philippines and Indo-China.

Uses The fresh leaves are commonly used as a poultice in the treatment of boils, wounds, burns and scalds.

Observations A robust, unbranched herb, 30–200 cm tall, glabrous; leaves fleshy, leathery when older, earlier ones simple, ovate, with cordate or rounded base, upper ones pinnate, 3–5-foliolate, 5–9(–20) cm × 2.5–5 cm, base cuneate, apex obtuse, margin crenate, petiole semi-amplexicaulous; inflorescence a lax terminal cyme, 10–80 cm long; flowers pendulous, with a cylindrical calyx, up to 25 mm × 8 mm, slightly indented at the base, lobes ovate-triangular, 7–12 mm long, very acutely acuminate, corolla tube cylindrical, about 30 mm long, strongly constricted at about 8 mm



Bryophyllum pinnatum (Lamk) Oken – 1, upper part of stem; 2, inflorescence; 3, flower in longitudinal section.

from the base, corolla lobes oblong-ovate, about 6 mm long, abruptly long-acuminate, in lower half green, in upper half red. *B. pinnatum* is found in dry rather sunny locations near human habitation up to 1000 m altitude.

Selected sources 95, 97, 202, 302, 332, 350, 363, 461, 462, 574, 597, 619, 741, 824, 900, 923, 924, 979, 1011, 1035, 1063, 1126, 1128, 1178, 1203, 1346, 1347, 1351, 1569, 1584, 1604, 1605.

Bryophyllum proliferum Bowie

Curtis's Bot. Mag., ser. III, 15: t. 5147 (1859).

Synonyms *Kalanchoe prolifera* (Bowie) Hamet (1908).

Vernacular names Indonesia: buntiris (Sundanese).

Distribution *B. proliferum* is native to Madagascar and was introduced into Java long ago. It is naturalized in mountainous parts of West Java.

Uses The fresh leaves of *B. proliferum* may well be used in a similar way as with *B. pinnatum*. It is sometimes cultivated as a hedge plant.

Observations An erect shrub 50–200 cm tall, quite glabrous; lower and topmost leaves of flowering plants not deeply divided, middle ones deeply pinnatisect with oblong segments, 5–23 cm × 2–8 cm, slightly or rather deeply crenate, very fleshy, petiole robust, semi-amplexicaulous; inflorescence a terminal cyme, 50–80 cm long; flowers pendulous, with broad and cuspidate calyx lobes, corolla tube cylindrical, 2–2.5 cm long, distinctly constricted above the base, shortly 4-lobed, lobes ovate, 3–5 mm long, shortly acuminate, red. *B. proliferum* is found naturalized in hedges, thickets and roadsides between 1000 m and 1600 m in Java.

Selected sources 65, 97, 824, 900, 923, 1536.

Wardah & M. Brink

Cannabis sativa L.

Sp. pl. 2: 1027 (1753).

CANNABACEAE

$2n = 20, 40, 80$

Vernacular names Hemp, Indian hemp, marihuana (En). Chanvre (Fr). Indonesia: ganja (general), ginje jawa (Javanese). Malaysia: ganja. Thailand: kancha, kancha cheen (general), paang (Shan-Mae Hong Son). Vietnam: gai m[ef]o, lanh m[as]n, c[aaf]n xa.

Origin and geographic distribution *C. sativa* is the only species in *Cannabis*. It is a native of the temperate parts of Asia: near the Caspian Sea, in Iran, the Kirghiz steppe, southern Siberia and probably also the Himalayas and northern India. It is one of the oldest of cultivated plants. Hemp was valued by the Chinese 8500 years ago, and it may be one of the oldest non-food crops. It was introduced into western Asia and Egypt, and subsequently Europe during the period 2000–1000 B.C., and cultivation in Europe became widespread from about 500 AD onwards. From Central Asia it spread eastward to China, Indo-China, Thailand and the Malesian region. It might have occurred in Java already 1000 years ago, in Malaysia more than 300 years ago, and in the Philippines more than 200 years ago. It was introduced into South America in 1545 and into North America in 1606. Nowadays, it is cultivated in many parts of the temperate, subtropical and tropical regions. In many countries including those in South-East Asia, however, its cultivation is prohibited by law.

Uses Hemp provides different products: therapeutics and narcotics (flowers and leaves), fibre (stems), oil (seeds) and food for humans and animals (seeds). It was probably first used as a source of fibre: the oldest remains of cloth made from hemp date back 6000 years. The use for seed oil is more recent, but began at least 3000 years ago, and the earliest reference to narcotic use appears to date from 5000 years ago in China. The earliest recorded medicinal use of hemp is found in a Chinese pharmacopoeia of 4700 years old.

All parts of the plant are used in Chinese medicine. The seeds are considered useful as a tonic, alterative, emmenagogue, laxative, demulcent, diuretic, anthelmintic, narcotic and anodyne. They are prescribed in fluxes, post-partum difficulties, obstinate vomiting, and used externally on eruptions, ulcers, wounds and favus. The specially prepared seeds are prescribed for uterine prolapse and to aid parturition, and as a febrifuge. Hemp is a sedative of the stomach, used to treat dyspepsia with painful symptoms, cancers and ulcers. It is also used to treat migraine, neuralgia, tetanus and rheumatism.

In western medicine, hemp preparations were extensively used between the middle of the 19th Century and the Second World War as an anticonvulsant, analgesic, sedative, and soporific, and to treat tetanus, neuralgia, uterine haemorrhage, rheumatism, epilepsy, migraine, convulsions, spasms and miscellaneous pains. It was considered a milder and less dangerous analgesic than opium.

The inconsistency of its therapeutic activity, the poor keepability of its preparations, the difficulty in deciding optimal doses and the emergence of synthetic analgesics and hypnotics led to the use of hemp being gradually abandoned in the first half of the 20th Century, and there is very limited authorized medicinal use today. In recent years, hemp drugs have been advocated as very useful to treat spasm in patients suffering from multiple sclerosis, to treat increased pressure within the eyeball and to treat loss of appetite in AIDS patients. The best known application, however, is its use as a sedative in cancer patients, and to treat side-effects of cancer chemotherapy e.g. nausea, vomiting and convulsions. One of the cannabinoids, Δ^9-tetrahydrocannabinol, the best known active compound of hemp, is marketed as an anti-emetic (sometimes also called dronabinol) e.g. in the United States. Other potential applications of isolated cannabinoids include the use as antiglaucoma, anti-asthmatic, anticonvulsant, spasmolytic and analgesic.

The narcotic use varies between cultures, and many descriptive terms exist. In India, where the use of *Cannabis* as a drug became more important in the last millennium than anywhere else in the world, three types of preparations are distinguished: 'bhang' (dried, powdered plant, made into a drink with milk or water), 'ganja' (dried flowering tips of female plants, usually smoked, sometimes eaten or drunk) and 'charas' (crude resin scraped from the plant, which is smoked, sometimes eaten). In the western world, 'marihuana' usually refers to a preparation comprising crumbled leaves, small twigs and flowering parts of female plants, whereas 'hashish' is a stronger preparation, with more resin and little recognizable plant material. All these drug types contain a resin from the glandular hairs on leaves, stems and inflorescences.

The bast fibres of *C. sativa* are traditionally used to make yarns, twines, ropes, nets and paper, while the wooden core of the stems is normally used as animal bedding or fuel. Hemp yarns are mainly made by wet spinning the long fibres. Improved yarn quality can be obtained by 'cottonization' of hemp, involving the chemical or mechanical rearrangement of bast fibres. This makes it possible to process the fibres on cotton machines. However, the hemp fibres and yarns currently on the market do not meet the requirements of the textile industry with respect to fibre fineness, homogeneity, flexibility and distribution of fibre length. In Malesia, hemp is not important as a fibre crop, but in Thailand its fibres are used to make ropes and textile, especially in the northern part of the country.

Carton can be made from pulp of the different fibre types of hemp. High quality paper (monetary bills) and specialty applications (diapers, bandage) may be envisaged using pulp from bast or core.

Current fibre applications in building and construction materials are fibre and particle boards, panels and inorganic matrix composites (IMC). Boards and panels are mostly used indoors as a non-structural material for insulation. The applications of IMCs include plaster boards, tiles, concrete, mortars and plasters. Important arguments for using plant fibres in IMCs are asbestos substitution, saving of weight, waste management and the good compatability with the matrix due to the hydrophylic properties of plant fibres.

One technologically innovative application of bast fibres of hemp is in fibre reinforced structural materials called composites, where the fibres replace the glass fibres that are normally used. Combined with the application of biodegradable resins such as cellulose, starch or casein, the use of natural fibres in composites has a clear ecological advantage over traditional materials. Markets for these often specialized and costly products are manufacturers of automotive and aircraft interior parts, of machines, of sports and leisure goods and of biomedical aids, and the construction industry.

The oil in the seeds can be used as a substitute for linseed oil in paints and soap. Other applications of the oil are in cosmetics and as surfactants in detergents.

Hemp seed is edible, and used as human food on a limited scale. It is also used as bird and poultry feed. The press cake remaining after oil extraction is used to feed livestock.

Production and international trade The production areas of hemp differ, depending on the product required. Hemp for narcotic properties is mainly grown in warmer climates. It is cultivated for 'ganja' in India (Bengal, Madras and Mysore) by a few licensed growers, and the drug is a monopoly of the Indian Government. In many countries it is grown for narcotics even though this is illegal.

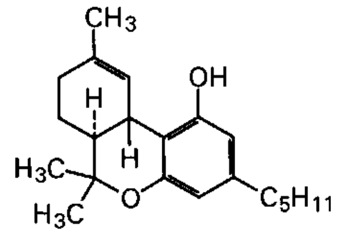
In 1991–1993, the annual world production of hemp fibre and tow was 120 000 t, of which 80 000–90 000 t was produced in Asia, mainly in India (45 000 t) and China (20 000–25 000 t). The annual world production of hemp seed in 1991–1993 was around 40 000 t, of which 22 000–25 000 t was produced in China.

There are no statistics on production in South-East Asia as the cultivation, possession, preservation, distribution, transportation and trade of hemp are forbidden by law e.g. in Singapore since 1870, in Burma (Myanmar) since 1873 and in Indonesia since 1927.

Properties Hundreds of different components have been isolated from hemp, and the amount of literature on their chemistry and biological activity is overwhelming. The most interesting compounds for medicinal purposes are the cannabinoids, which are mainly present in the leaves and flowering tops of female plants, and accumulate in the bracts and resin, but are absent in the seeds and stems.

Cannabinoids are terpenophenolics, classified into several groups on basis of their structures. At present, some 60 of these compounds are known, and the main representatives of each of these groups are: cannabigerol (CBG), cannabidiol (CBD), cannabichromene (CBC), cannabicydol (CBL), cannabielsoin (CBE), cannabinol (CBN), cannabinodiol (CBDL), cannabitriol (CBTL), (–)-Δ^8-trans-tetrahydrocannabinol (Δ^8-THC) and (–)-Δ^9-trans-tetrahydrocannabinol (Δ^9-THC). In the latter compound, Δ^9-THC refers to the more common dibenzopyran system of numbering; when the less common monoterpenoid system of numbering is used, this compound is called Δ^1-THC. In each group, the cannabinoids can be present either as neutral phenolics/phenolmethylethers or as one or more isomeric acidic analogues, differing only in the presence of a carboxyl group (e.g. cannabigerolic acid, cannabidiolic acid, cannabinolic acid). Δ^9-THC has two acidic analogues: Δ^9-tetrahydrocannabinolic acids A (carboxyl group at position 2) and B (carboxyl group at position 4). Acidic cannabinoids are regarded as the genuine compounds; the carboxylic group, however, is very unstable: decarboxylation readily occurs, e.g. during growth of the plant, storage of plant products or upon analysis.

The biosynthesis of the cannabinoids starts with the condensation of geranylpyrophosphate and olivetolic acid (a polyketo-acid) into cannabigerolic acid. Cannabigerolic acid is an intermediate of major importance in the formation of several types of cannabinoids e.g. CBC and CBD. The latter undergoes a second cyclization to yield Δ^9-THC-acid; decarboxylation finally gives Δ^9-THC. Δ^9-THC itself is not quite stable either: e.g. on prolonged storage the compound is converted into CBN via formation of an additional aromatic structure.



Δ^9-tetrahydrocannabinol

Besides the cannabinoids, the presence of various other components in *C. sativa* is documented: flavonoids (e.g. canniflavon-1, canniflavon-2), phenolic spiroindanes, dihydrostilbenes, dihydrophenanthrenes and spermidine alkaloids (cannabisativin, anhydrocannabisativin in the leaves, stems and roots). *C. sativa* contains an essential oil whose main components are β-caryophyllene, humulene, α-pinene, β-pinene, limonene, myrcene and cis-β-ocimene.

The pharmacological activity of *C. sativa* is mainly based on Δ^9-tetrahydrocannabinol; other cannabinoids seem to have less, if any biological activity, although many of them have never been studied well. Of the two major *Cannabis* products, good quality marihuana contains 0.1–2.7% Δ^9-THC and hashish 4–10% Δ^9-THC. CBD and cannabidiolic acid are the main components of the glandular hairs (up to 15%); the remaining cannabinoids occur in smaller amounts.

Various preparations of *Cannabis* or Δ^9-THC have traditionally been used for their psychological manifestations. The predominant central-nervous-system (CNS) response to Δ^9-THC in humans include analgesia and anti-emesis, as well as a 'psychological high' state with alterations in cognition and memory, and a decrement in psychomotor performance. The acute toxicity of Δ^9-THC is reported to be very low (e.g. 128 mg/kg intravenous in the monkey); there are no documented cases of human death caused by this component or hemp. The initial effects caused by a common 'dose' of inhaling one cigarette with 2% Δ^9-THC, or by an oral application of 20 mg of the purified compound are described as a feeling of well-being, euphoria and relaxation, and effects on the sensorium, sense of time, short-term memory and motivation. Higher doses may induce anxiety which may become panic, dysphoria and hallucinations. Tolerance to many of these effects has been found in test animals: use in humans also led to rapid development of tolerance. Chronic use of hemp leads to a weak physical dependence, but psychological dependence is substantial and dependent on the user's history. Chronic use may also lead to paranoid psychosis. An overdose is mainly marked by a psychotic state (anxiety, suicidal tendencies, deep mental confusion) which may last for a week. Interruption of drug intake in chronic users may cause withdrawal syndrome which subsides rapidly in 3–4 days. Since the 1970s, many studies have been carried out to determine the impact of the use of hemp on health, but the long-term effects are still not well known.

Studies on the relations between the structure and activity of cannabinoids have shown that prerequisites for the psychotropic activity are the pyran structure, a stereochemical (–)-configuration, a trans configuration of the Δ^9-bond and a free phenolic group. This might explain why both Δ^9-THC and its metabolites formed by hydroxylation (e.g. 11-hydroxy-Δ^9-THC) are active, whereas CBG, CBD and CBC are inactive. At present, the exact action of cannabinoid drugs in the brain is still poorly understood. Very little is known yet about the neuroanatomical location of the cells responsible, or the cellular mechanisms involved. Cannabinoid drugs have been found to inhibit adenylate cyclase activity in a model neuronal system; this ability was furthermore related to the ability of these compounds to produce effects on the central nervous system. These results led to the identification of the presence of a specialized cannabinoid receptor in brain homoginates of the rat.

Besides the psychological effects, a vast array of other effects is known from the cannabinoids affecting e.g. the immune system, the hormonal system, cell growth and cell structures.

The effects on the immune system have been studied in mice, using sheep red blood cells (SRBC) as the antigen. Animals treated with Δ^9-THC (10 and 15 mg/kg) during the primary immunization period exhibited a suppression of the primary humoral immune response. Mice treated with Δ^9-THC during the secondary immunization period showed no measurable suppression of the secondary humoral immune response to SRBC. However, when mice were given Δ^9-THC (10 and 15 mg/kg) during primary immunization, the secondary humoral was suppressed (existence of a memory aspect). In all experiments CBD or CBN were inactive (10 and 25 mg/kg).

When effects of cannabinoids on the hypothalamic-pituitary axis were studied in vivo in the rat, Δ^9-THC and CBN both produced an acute suppression of plasma luteinizing hormone (LH), plasma testosterone and hypothalamic noradrenaline (norepinefrine) metabolism. There were no effects on plasma follicle-stimulating hormone or hypothalamic LH-releasing hormone (LHRH). These results therefore suggest that decrease of LH secretion is due to reductions in noradrenaline stimulated LHRH release (hypothalamic level), rather than to changes in LHRH synthesis or pituitary LHRH response.

Cannabinoids have been found to affect the growth, proliferation and division of a variety of cell types. Reduction of cell growth and division has been observed in protozoans. Other cell systems sensitive to cannabinoid-induced effects on cell growth include HeLa cervical carcinoma cells (Δ^9-THC, Δ^8-THC, 11-hydroxy-Δ^9-THC and CBN), Lewis lung carcinoma cells (Δ^9-THC, Δ^8-THC and CBN; but CBD appeared to stimulate growth) and B103 neuroblastoma cells (Δ^9-THC).

Cannabinoids furthermore are highly lipophilic molecules. This property can lead e.g. to cannabinoids partitioning into the lipid phase of biological membranes. Interaction has been shown with subcellular structures such as mitochondria, lysosomes and the mitotic apparatus. A reorganization of microtubules, microfilaments and neurofilaments was reported in B103 neuroblastoma cells, following treatment with Δ^9-THC (1–100 μM). On B103 cells, the change in cytoskeleton corresponded with changes to the overall morphology of the cells.

Numerous investigations are also available on the application of *Cannabis* or cannabinoids as drugs. The licensed medicinal use of Δ^9-THC (dronabinol) in e.g. the United States and the United Kingdom is for prevention of nausea and vomiting in patients undergoing cancer chemotherapy. The effects of *Cannabis* on the gastro-intestinal propulsion and motility have been studied in detail in rodents. In mice and rats, intravenous injection of Δ^9-THC slowed the rate of gastric emptying and small intestine transit. In the rat, the substance inhibited gastric emptying and small intestinal transit more than large bowel transit, indicating a selectivity for the more proximal sections of the gut. A decrease in frequency of both gastric and intestinal contractions without altering the intraluminal pressure was also found. Such changes probably reflect a decrease in propulsive activity, without changes in basal tone. CBD had no effect on gastric emptying or intestinal transit. In patients, cannabinoids as anti-emetics are as effective as the well known phenothiazines. Side-effects are relatively common. In some studies a third of patients experienced dysphoria, and up to 80% had somnolence. It was also found that Δ^9-THC is more rapidly and reliably absorbed from the lungs than from the gut, and patients taking the drug by smoking can thus titrate their own dose.

Cannabis has been reported to reduce muscle spasm and tremors in patients suffering from cerebral palsy or multiple sclerosis (MS). On the other hand, it has also been found to impair posture and balance in patients with spastic MS. There have been 3 trials with oral Δ^9-THC in patients with multiple sclerosis. In a placebo controlled study of 9 patients, doses of 5 or 10 mg Δ^9-THC improved spasticity compared with the placebo. Four patients exhibited an objectively measured benefit, described as substantial, 2 patients also claimed subjective improvement of symptoms. One further patient claimed subjective improvement, but this was not confirmed objectively. In a second study 2 out of 8 patients receiving doses of 5–15 mg Δ^9-THC experienced both subjective and objective improvement in tremor. A further 5 claimed mild subjective improvement in tremor and general well-being, but this was not confirmed objectively. The third study included 13 patients with multiple sclerosis spasticity that proved untreatable with standard muscle relaxants. Using doses of 2.5–15 mg Δ^9-THC in a double blind, placebo controlled trial, patients considered that spasticity had improved; however, neurologists blinded to the treatments could not differentiate between Δ^9-THC and placebo. Furthermore, doses over 7.5 mg were relatively poorly tolerated, with symptoms of weakness or psychoactive effects.

In one experiment CBD was given orally to 5 patients with dystonic movement disorders. A dose-related improvement in dystonia, ranging from 20–50% was observed in all patients. In 2 patients, however, the higher doses worsened co-existing parkinsonism. CBD also appeared promising as an anticonvulsant in epilepsy. In a controlled study, adding this cannabinoid to the prescribed anticonvulsants produced improvement in 7 patients with grand mal; 3 of them showing substantial improvement.

Cannabis has been reported to cause bronchodilation, so *Cannabis* derivatives have therefore been tested as anti-asthma drugs. There has been preliminary research on Δ^9-THC in the form of an aerosol spray, but other cannabinoids may also be of interest. One interesting finding for future research is that cannabinoids may affect the bronchi by a mechanism differing from that of the more familiar anti-asthmatic drugs.

Cannabinoids might be used to treat wide-angle glaucoma, which is a major cause of blindness. In a number of patients, *Cannabis* caused a dose-related, clinically significant decrease in intra-ocular pressure, lasting several hours. Though it does not cure the disease, *Cannabis* can slow down the progressive loss of sight when conventional medicines fail and surgery is too risky. CBN and CBG have been administered to cats, topically or chronically. Whereas CBN had a modest effect on intraocular pressure after a single dose, it caused a more significant reduction in ocular tension during chronic administration. CBG had similar effects, but its chronic administration induced a larger response. CBN caused ocular toxicity (conjunctival erythema and hyperaemia). CBG, however, lacked these toxicities; its ocular hypotensive effect, therefore, is most interesting.

Finally, *Cannabis* and/or Δ^9-THC may help to increase food intake and slow weight loss in e.g. cancer and AIDS patients. Preliminary clinical trials on this are showing promising results.

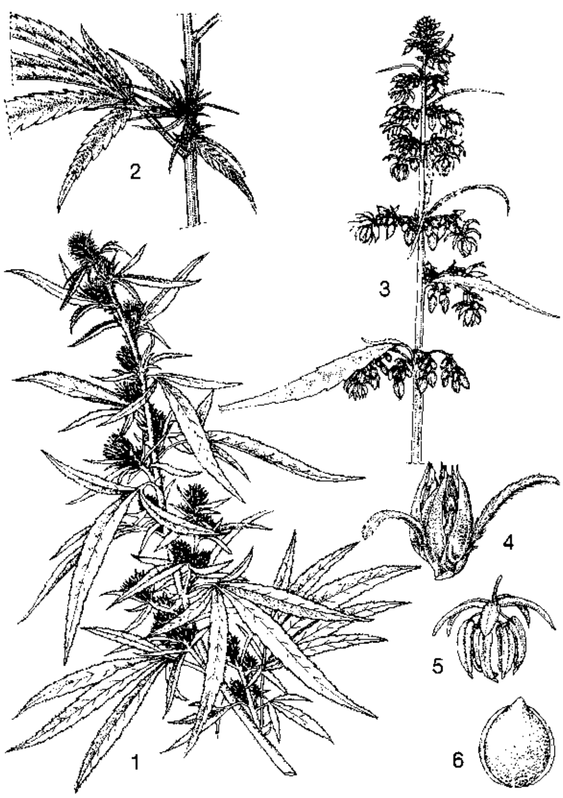
Aqueous extracts of hemp seeds have furthermore showed strong nematicidal activity on the larvae, eggs and cysts of the nematode *Heterodera schachtii*. An aqueous extract from the flowers had less activity, and extracts from leaves, stems and roots showed no activity. The nematicidal activity is probably due to the compounds 7-methyl-1,2,3,4-tetrahydroxy-phenazine and 3-acetyl-4-hydroxy-6-methyl-2-pyridone.

The bast of the plant cultivated for fibre contains primary and secondary bast fibres rich in cellulose but low in hemicellulose and lignin. Today, lines are available containing 67% of cellulose, 13% of hemicellulose and 4% of lignin. Primary bast fibres are 5–40 mm long and heterogenous, secondary bast fibres are smaller and more uniform with an average length of 2 mm. The woody core contains parenchyma, vessels and libriform short fibres with an average length of 0.55 mm. The chemical composition of the core fibres resembles that of hardboard with typical values of 40% cellulose, 20% hemicellulose and 20% lignin.

The seeds of hemp contain 29–35% oil, 20–24% protein and 20–30% carbohydrates. The dry seed contains up to 15% fibre, 4–6% minerals and about 6% water. No narcotically active compounds accumulate in the seed, but contamination may occur due to contact with the glands of flower bracts and leaves containing cannabinoids. Washing is sufficient to remove contamination. The most abundant fatty acid in the seed is omega 6 linoleic acid; it comprises 54–70% of total fatty acids present.

Adulterations and substitutes Because the most important compounds, the cannabinoids, have not been found in plant genera other than *Cannabis*, there are no natural adulterations and substitutes. Synthetic analogues of Δ^9-tetrahydrocannabinol have been developed, notably nabilone and levonantradol. They have undergone successful clinical trials, but still have considerable side-effects.

Description An annual, tall (generally 1–1.5 m tall, sometimes much taller) erect herb, usually branched, dioecious or sometimes monoecious, rather densely appressed-pubescent when young. Leaves opposite near base of stem, arranged spirally higher up, palmately compound, long-petioled; stipules free, filiform or narrowly subulate, about 0.5 cm long; leaflets (3–)5–7(–11), upper leaves often with only 1 leaflet, lanceolate from a narrowed base, 6–14 cm × 0.3–1.5 cm, sessile, long-acuminate, coarsely serrate, on the upper surface very scabrid with short stiff hairs, on the lower surface appressed-pubescent, rather densely beset with sessile glands. Flowers unisexual; male flowers in short, dense cymes, united into foliate, terminal panicles, very shortly pedicelled, with 5 free tepals, oblong, about 5 mm long, membranous, imbricate, finely appressed-pubescent, greenish-white with pellucid white margins, stamens 5, epitepalous, with erect linear filaments and comparatively large 3–4 mm long, basifixed, 2-celled, yellow anthers; female flowers solitary in the axil of a small, primary, membranous, entire bract enveloping the ovary, each enveloped by a spathaceous, conspicuous, acuminate secondary bract, perianth absent, ovary sessile, 1-celled with a solitary pendulous ovule, style central, stigmas 2, up to 7.5 mm long, filiform, caducous. Fruit a broadly oval, much compressed achene, 4–5 mm long, with a concave rimmed base, faintly keeled on the lateral margins, smooth, shiny, yellowish or brown, closely enveloped by the secondary bract; pericarp hard, crustaceous, easily splitting into 2 halves. Seed with unilateral, scanty and fleshy albumen; embryo large, horseshoe-shaped, cotyledons large, radicle long. Seedling with epigeal germination.



Cannabis sativa L. – 1, branch of female plant; 2, part of branch with female inflorescence; 3, part of branch of male plant; 4, female flower; 5, male flower; 6, fruit.

Growth and development Hemp is normally dioecious, but monoecious cultivars have been bred; the two sexes are normally indistinguishable before flowering. In a dioecious crop, male and female plants are generally present in similar numbers, but, depending on cultivar and growing conditions, there may be up to 50% more female than male plants. Male plants die soon after anthesis, whereas female plants live 3 to 5 weeks longer than male plants, until the seed is ripe. The flowers are wind-pollinated. The total growth duration of hemp strongly depends on photoperiod and temperature. The sensitivity to photoperiod starts after formation of a few pairs of leaves and after a certain amount of heat has been received. In practice this means that the optimal production of fibre hemp is limited to regions with relatively long days, in which hemp is able to extend its vegetative growth phase sufficiently to produce long stems. The length of the flowering phase of hemp also depends on photoperiod and temperature. Between plants and in individual plants, flowering is more synchronized at shorter daylength and higher temperatures. The relatively expensive metabolites like cannabinoids and oil formed during and after flowering, may lead to a reduction of the amount of dry mass formed per unit of intercepted radiation. The degree of branching depends on propagation methods and conditions of cultivation.

Other botanical information Great variation exists in hemp as a result of selection for fibre, oilseed and/or resin. This variation is further enhanced by the ease of crossing between these plant types. The widespread intergrading between different types makes all classifications inexact. A geographical classification is in use for cultivated hemp, in which North European, Central Russian, Mediterranean and Asiatic types are distinguished. The North European hemp is characterized by a short stem (< 1.5 m) and a premature flowering. Fibre and seed yields are generally low. Central-Russian hemp is cultivated in Europe and Asia between 50–60° latitude. Total growth duration is 90–110 days, with stems reaching 1.3–3 m height. Fibre yields of these types are average, but high seed yields may be obtained. Mediterranean hemp is normally cultivated south of 50° latitude in Europe, although very high fibre production may be obtained by growing these types further north. The total growth duration is 130–150 days, with stems reaching 2.5–4.5 m. Hence, fibre production can be high and of good quality. Seed yields are average because of their relatively long vegetative growth phase. Asiatic type hemp plants form branched stems of 2.5–3 m with short internodes. Growth duration is 150–170 days, but may vary considerably between populations. For practical purposes, three types can be distinguished, based on the concentrations of Δ^9-tetrahydrocannabinol and cannabidiol: the drug (resin) type, with high Δ^9-tetrahydrocannabinol concentration (> 1%) and no cannabidiol; the hemp (fibre) type with very low Δ^9-tetrahydrocannabinol content (< 0.3%) and high cannabidiol concentration; and the intermediate type, with high concentrations of both compounds. However, concentrations may change during the growing season, and other components may also play a role.

Ecology Hemp can be grown over a great range of altitudes, climates and soils. It requires humid tropical climates to produce narcotic resin. For the production of fibre, climates of the temperate regions with temperatures of 15–27°C during the growing season are optimal. Hemp thrives on moderately to very fertile soils provided there is enough water. It is suitable for alluvial soils along streams or loamy soils with rather high rainfall. The only reliable ecological data available is for European hemp cultivated for fibre. For these cultivars, the temperature requirement to reach the onset of photoperiod-sensitive phase has been quantified at 482 C°d from sowing on, and critical daylengths of 14–14.5 h have been established. Daylengths longer than the critical one extend the length of the photoperiod-sensitive phase, prolonging the vegetative growth phase. For the lower latitudes in the northern hemisphere, this sensitivity to short days limits the potential yield of hemp, while at higher latitudes low temperatures in spring are the main constraint to yield. Hemp has relatively horizontally oriented leaves, resulting in a high degree of light interception by the top of the canopy. This leads to intense shading. Although this has the advantage that weeds are suppressed, it reduces overall photosynthesis of the crop. When oil and resins are also being formed during the reproductive phase, radiation use efficiency may drop significantly. The optimal soils for hemp are sandy loams high in organic matter, with a pH around 6.

Propagation and planting Hemp is usually raised from seed. The seed germinates at low temperatures, but not below 1°C. Soil temperatures of 10–12°C are required for optimal crop establishment. Emergence is seriously hampered by unfavourable conditions such as soil compaction and waterlogging. Healthy seed should give 90% germination, and if properly stored it will remain viable for up to 2 years. Vegetative propagation using cuttings has been successful. However, there are morphological and biochemical differences between plants derived from seed and vegetative propagules. Vegetative propagules have higher concentrations of Δ^9-tetrahydrocannabinol than plants raised from seed, and better developed lateral branches.

The agronomic methods depend on the product desired. For 'ganja' production in India, seed is sown in rows 1.2 m apart at a seed rate of 3–5 kg/ha, followed by a thinning when the plants are 20 cm tall. For fibre production, seed is sown densely at a rate of 30–40 kg/ha, either broadcast or in drills. Optimal plant densities of 90–120 plants/m^2 with row distances of 12–20 cm seem optimal, but row distances of more than 1 m and inter-plant distances between 15–50 cm are used for seed production. In China seed plants are sometimes sown in clusters.

Husbandry Weeding is rarely necessary because the dense canopy shades out weeds. However, weeds may be a problem in the establishing crop and in gaps. Practical experience with fibre hemp on optimal soils has shown that for the production of 1000 kg stem material an annual fertilization of 15–20 kg N, 4–5 kg P_2O_5 and 15–20 kg K_2O is required. The need for nitrogen is highest during the vegetative growth phase in which green leaf material is produced. Requirements for phosphorus and potassium increase gradually during vegetative growth, peaking around flowering before slowly declining again. In an increasing order and within certain limits, fibre quality is improved by the nitrogen, phosphorus and potassium contents of the hemp plant. Hemp is a suitable crop for rotation with almost any crop, though some problems may occur in rotations with beets, because of nematode infestations. Hemp suppresses weeds and loosens the soil for the following crops. Moreover, root and leaf material may be left in the field to serve as organic material for the next crop. The male plants produce the best fibre and are sometimes harvested first; the female plants are sometimes allowed to stand to set seed for oil production. The Asian practice of removing male plants is not because of their lower content of Δ^9-tetrahydrocannabinol, but to prevent seed production in female plants, which would reduce resin production.

Diseases and pests Diseases and pests in hemp may be plant specific or general. Reported damage by hemp-specific organisms are from *Grapholitha delineana*, *Melaspora cannabina*, *Phorodon cannabis*, *Psylliodes attenuata* and *Septoria cannabis*. Seeds of hemp may be infected by the parasitic *Orobanche racemosa* L. or hemp killer. The most important non-specific diseases and pests in hemp are: *Botrytis cinerea*, *Ostrinia nubilalis* and *Sclerotinia sclerotiorum*. Yield may also be depressed by *Cuscuta europaea* L., *Fusarium* spp., *Ditylenchus dipsaci*, *Tetranychus urticae*, some insects of the *Noctuidae* and larvae of *Agriotes lineata*, *Melolontha melolontha* and *Tipula paludosa*. Hemp may also suffer from nematodes such as *Meloidogyne hapla* in northern Europe and, in northern India *Neottolenchus clarus* and *Quinsulcius similis*. The role played by essential terpenoid substances in repelling insects and exudates of cannabinoids (as antibiotics) has been neglected and deserves investigation. Another of hemp's natural defence mechanisms - its covering of non-glandular trichomes - might serve as a mechanical defence against predators.

Harvesting How hemp is harvested depends on the product. For 'ganja' production, male plants are pulled out as soon as they are recognized and before the pollen is shed. Unfertilized female plants are left, and harvested when flower stalks begin to turn yellow, at about 5 months after sowing. For the production of 'charas', the resin is collected by men who run through the plantings clad in leather garments. The resin sticks to the garments and is then scraped off. Another method is to collect the resin by squeezing plant tops between the palms of the hand. Plants are harvested for fibre manually or by machinery. In China, manual harvest is by cutting the stems; the branched plants are left on the edges of the field and their seed is harvested for sowing.

Yield The average yield of 'ganja' in India is about 280 kg/ha. Stem yields (yielding approximately 25–35% fibre) are usually between 3–8 t/ha, with a potential of 20 t/ha. When hemp is grown solely for seed production, yields of 1300–1700 kg seed per ha may be obtained.

Handling after harvest For the production of 'ganja', harvested inflorescences are trodden and pressed into flat cakes. For fibre production the cut stems are graded by pulling out the longest and medium stems, respectively. The short and twisted stems are for local use. Leaves are stripped off with a knife. The stems are then dried on the field for 2–4 days. About 200 stems are then bundled and immersed in water for a 3-day retting. After retting, another 2–3 days are used for field drying. Depending on the degree of retting, a second retting is carried out or stems are allowed to dry further in the field, this time in bundles. Fibre bundles are subsequently stripped off by hand from the partly wet stems and dried on lines before marketing. Another method to obtain the fibres is to dry the stems completely before breaking and to comb them. The yield of ribbon with this dry method is slightly higher than with the semi-wet method; 10% versus 6% relative to dry stem mass. In Europe, hemp is harvested mechanically by cutting, drying in swathes on the field for a few weeks, and subsequently pressing and baling in one operation. The yield of ribbon is on average 15%. The centres for commercial production of sowing seed for fibre hemp are in France, Hungary and Poland. The fineness and coarseness of the fibre and cleanness or degree of retting are decisive for traditional processing of ropes and textiles. Sometimes, male and female plants are therefore separated and processed differently. The stems are also graded during harvest. On modern spinning machines, in which production speeds are the determining factor, fibre length may be a limitation to the use of bast fibre. Parallel processing of the fibrous raw material is required, to prevent entanglement; this adds substantially to the costs of the fabrics. Hemp fibres may easily be used for paper production in which the chemical content of the fibres mainly determines the quality of the pulp. The drainability and bleachability of the pulp and sheet forming are among the many factors that determine the applicability of the pulp. For the application of fibre in composite material the following properties are of interest: high tensile strength, rigidity, impact resistance, small volume shrinkage during curing, resistance to corrosion, low density, nontoxic, recyclability, ease of disposal and economic price. These quality characteristics are partly inherent to the natural fibre, but those like tensile strength and rigidity are determined by cultivar choice, growing conditions, environment, mechanization and processing.

Genetic resources and breeding There has been limited preservation of germplasm of *C. sativa* in gene banks because of its bad image as a narcotic. Together with the declining interest in breeding and maintaining of cultivars, this has led to an impoverishment of germplasm resources. However, a large reservoir of natural variation is maintained by wild forms.

The difference in timing of anthesis of male and female plants promotes outbreeding. Production of large amounts of pollen and wind pollination tend to lead to extensive genetic exchange between different domesticated forms and between domesticated and wild plants. Breeding has mostly focused on the creation of monoecious varieties. In Europe, breeding and selection work is directed at obtaining hemp types with a bast fibre content higher than 30% and Δ^9-tetrahydrocannabinol levels below 0.3%.

Prospects Although the resin present in hemp has been recognized to have therapeutic value, the use of hemp as a medicinal plant is limited. This is mainly because the cultivation, possession, preservation, transportation and trade of hemp is prohibited in most countries. However, research is increasingly being initiated on hemp drugs for relieving patients suffering from diseases such as multiple sclerosis, cancer, AIDS and glaucoma. Since many young people in big cities smoke 'ganja' or 'marihuana', the drug is probably being smuggled into South-East Asia, and illegal cultivation of hemp in remote areas may still be found. Hemp grown for fibre has a long history and still has very good prospects. The plant fibre products have major advantages in various branches of industry. They are biocompatable and biodegradable, thereby reducing the environmental burden caused by consumer goods and disposables, building and construction material and civil engineering. The research priorities include: determining optimal primary production techniques, developing field fibre extraction techniques, quantifying the relationships between primary production conditions, processing and fibre quality, and optimizing the management of production chains to best use all components of hemp.

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N. Wulijarni-Soetjipto, Anas Subarnas,
S.F.A.J. Horsten & N.C. Stutterheim

Cardiospermum halicacabum L.

Sp. pl. 1: 366 (1753).
SAPINDACEAE
$2n = 22$

Synonyms *Cardiospermum corindum* L. (1762), *Cardiospermum microcarpum* Humb., Bonpl. & Kunth (1841), *Cardiospermum luridum* Blume (1847).

Vernacular names Balloon vine, heart pea (En). Coeur des Indes, pois de coeur (Fr). Indonesia: ketipes (Javanese), paria gunung (Sundanese), cenet (Malay, Western Sumatra). Malaysia: peria bulan, uban kayu, bintang berahi. Philippines: parol-parolan (Tagalog), kana (Cebu Bisaya), paria-aso (Iloko). Thailand: kok kra om (central), pho om (Pattani), luupleep khruea (northern). Vietnam: t[aaf]m phong, ch[uf]m phong.

Origin and geographic distribution *C. halicacabum* probably originates from the New World tropics. At present, it is a common weed in tropical and subtropical regions throughout the world, and is common throughout Malesia. It is reported to be cultivated in the Philippines and Burma (Myanmar).

Uses The root is the most important plant part used for medicinal purposes. In South-East Asia it is considered to be diaphoretic, diuretic, emetic, antipyretic and purgative. The roots are reported to be used in Indonesia and the Philippines against catarrh of the bladder and urinary tract. The leaves are considered antirheumatic in the Philippines, where they are either taken internally or applied externally. In Indonesia, the bruised leaves are used as a cooling compress for nervous headaches. The leaves are reported to be used to treat eye problems in Malaysia, Thailand and Vietnam.
In India, the root is considered diuretic, diaphoretic, emetic, laxative, emmenagogic and rubefacient and is sometimes used to treat rheumatism, lumbago and nervous diseases. The leaves are reported to be rubefacient and useful as a poultice to treat rheumatism, and the leaf juice to be a cure for earache. In Bangladesh, pills made from a paste of the whole plant are used to treat asthma. In China, a decoction of the plant is used as a post-surgery wash, and a tea of the leaves is rubbed on itching skin. In Taiwan, leaves are applied to swellings, together with salt. In southern Africa an infusion of the leaves and stalk is applied as an enema to cure diarrhoea and dysentery; a similar method has been reported for Indonesia. The vapour of the crushed leaves is inhaled to relieve headache.
Apart from its medicinal uses, *C. halicacabum* is eaten as a vegetable, the stems serve to make baskets and the seeds are used as beads. The leaves are reported to be used for washing clothes and the head. An edible oil can be obtained from the seed.

Properties The seeds contain about 30% oil, consisting of the glycerides of arachidic, lignoceric, stearic, oleic and linoleic acids and glycerol. Furthermore, the seed oil has been found to contain large amounts (55%) of cyanolipids (e.g. cardiospermin) and to consist for a large part (45%) of C_{20} acids. Cyanolipids have not been found in families other than the *Sapindaceae*. Together with cyanogenous glycosides, these compounds provide plants with the ability to produce hydrocyanic acid, often through the use of enzymes that are activated when plant tissue is damaged. The extremely poisonous nature of hydrocyanic acid can thus protect plants, for instance against damage by insects. Hydrocyanic acid is also dangerous to man; cyanide acts by inhibiting the cytochrome oxidase system for oxygen utilization in cells. Other respiratory enzymes are also inhibited, but to a lesser degree. However, large amounts of plant material often have to be consumed to achieve dangerous concentrations (0.5–3.5 g/kg).
The unsaponifiable fraction of the pericarp is reported to contain pigments and flavones, whereas that of the inner parts of the seeds is characterized by triterpenoids and steroids. The latter fraction showed anti-inflammatory activity in rats.
An ethanolic extract of the aerial parts of *C. halicacabum* has shown anti-inflammatory activity in rats using the carrageenin-induced rat paw oedema test. The mechanism of action is most probably either the inhibition of phospholipase-II activity, resulting in reduced availability of arachidonic acid, or the stabilization of the lysosomal membrane system. An ethanolic leaf extract produced depression of the central nervous system, fall in blood pressure and bradycardia in isolated organ preparations and in vivo. The fall in blood pressure was partly antagonized by atropine and antihistaminics. A possible mechanism may be the inhibition of angiotensin-converting enzyme. On the guinea-pig ileum preparation, the extracts produced a strong contraction, which could also be partly antagonized by atropine and antihistaminics.
Another pharmacological experiment was an in vivo test in rats, in which an extract produced mild

analgesia and showed proconvulsant and anti-inflammatory activity as tested by the granuloma pouch and cotton pellet implantation test. The essential oil and the water-soluble fraction of a dried alcoholic leaf extract gave an immediate fall of blood pressure in anaesthetized dogs; this hypotensive action was not affected by atropine. Furthermore, the water-soluble fraction of a dried alcoholic extract of the seeds produced an initial depression, followed by a marked stimulation of isolated frog heart. Finally, methanolic extracts of dried plants have shown antisickling and anticrenation activity of erythrocytes, with observed reversals being more potent than the effect of testosterone propionate.

In addition to the above-mentioned cyanolipids and cyanogenic glycosides, phytochemical investigations of *C. halicacabum* have revealed a variety of compounds: quebrachitol, steroids (stigmasterol, β-sitosterol), flavonoids (apigenin and acacetin), phenolic acids (p-hydroxybenzoic acid, vanillic acid, melilotic acid, p-coumaric acid and ferulic acid), alkaloids, tannins, proanthocyanidins, aromatic nitrosulfones and saponins. The saponins may account for the diuretic properties and make external preparations slimy for poulticing. Furthermore, saponins characteristically form foamy solutions in water, and saponin-containing seeds are often used as detergents. Most saponins have haemolytic properties, and thus are toxic to cold-blooded animals, hence employed as a fish poison. They are usually only weakly toxic for warm-blooded species when taken orally, but more dangerous when given parenterally, because of their direct haemolytic action.

Cardiospermum halicacabum L. – 1, plant habit; 2, male flower with sepals and petals removed; 3, pistillode of male flower; 4, female flower with sepals and petals removed; 5, pistil of female flower; 6, fruit; 7, seed.

Description An annual or perennial climbing herb or subshrub, up to 3 m tall, often much branched, especially near the base; stems deeply 5-grooved, slender, glabrous to sparsely hairy. Leaves alternate, compound, biternate, 5–8 cm × 5–8 cm, petiole 1.5–3 cm long, grooved, slender, with minute stipules at the base; leaflets mostly 3-partite and pinnately lobed, lobes and apex aristulate, subglabrous to sparsely covered with short appressed hairs, petiolules narrowly winged, petiolule of terminal leaflet about 1 cm long, those of lateral ones about 0.5 cm. Inflorescence thyrsoid, axillary, 5–14 cm long, patent, sparsely short-hairy, with a pair of tendrils, peduncle 7–10 cm long, slender, slightly above the tendrils terminated by a pseudo-whorl of 3 uniparous, helicoid cymes, which are bracteate, spreading, long-stalked and few-flowered; bracts lanceolate to elliptical, 1–2 mm long. Flowers unisexual, 2–3.5 cm long, obliquely zygomorphic, with slender pedicel; sepals 4, broadly ovate to broadly elliptical, 1–2.5 mm × 1.2–2 mm, free, imbricate, green, tinged red with white margins, subglabrous; petals 4, obovate-cuneate to orbicular, 1.5–2.5 mm × 1–2 mm, with a scale inside above the base of each petal, white to creamish with yellowish margin, almost glabrous; stamens 8, slightly curved upwards, unequal, filaments 0.8–2.5 mm long, only slightly reduced in female flowers, slightly hairy, anthers 0.5 mm long; ovary superior, obovoid, 2–3 mm long, 3-angled, 3-celled, with 1 ovule per cell, variously pubescent, with a short columnar style and 3-lobed stigma, in male flowers pistil strongly reduced. Fruit a globular capsule, inflated, 1.5–4 cm in diameter, 3-lobed, 3-celled, green, reddish at base or with reddish veins, papyraceous. Seeds subglobular, about 4 mm in diameter, dull-black, smooth, glabrous, hilum prominent, white, cordate, rather large.

Growth and development *C. halicacabum* can be found flowering and fruiting throughout the year, except for prolonged periods of drought. The first flower in every cyme is usually female, all others male. Fruits are dispersed by water currents, over short distances by wind but mainly as a result of human activities.

Other botanical information *C. halicacabum* belongs to a genus of about 12 species, most of them restricted to tropical and subtropical America. *C. grandiflorum* Swartz, found in Africa and the Americas, is cultivated as an ornamental in Malesia and sometimes naturalized. It also contains cyanogenic compounds in its leaves.

Ecology *C. halicacabum* is found under a wide range of ecological conditions: in everwet or seasonal climates, on acid and basic soils, and in dry, marshy or periodically flooded places. It prefers sunny places, such as wasteland, roadsides, grassland, scrub, hedges and forest edges, at altitudes up to 1500 m.

Propagation and planting *C. halicacabum* can be propagated by seed and softwood cuttings. Seeds germinate at temperatures from 15–40°C with an optimum of 35°C, and taking about 3 weeks. Scarification with concentrated sulphuric acid may facilitate germination.

Diseases and pests Balloon vine is a major problem in soya bean cropping in the United States. The size and shape of the seeds is very similar to those of soya bean seeds, which makes mechanical separation of the two very difficult.

Harvesting *C. halicacabum* is mostly collected from the wild.

Genetic resources and breeding As *C. halicacabum* is a common weed throughout the tropics and subtropics, the risk of genetic erosion appears limited.

Prospects Because *C. halicacabum* contains potentially toxic compounds such as saponins, cyanolipids and cyanogenic glycosides, it seems advisable to carry out research on its toxicity for humans before promoting its use for medicinal purposes.

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J.P. Rojo & F.C. Pitargue

Carmona retusa (Vahl) Masam.

Trans. Nat. Hist. Soc. Formosa 30: 61 (1940).

BORAGINACEAE

$2n = 32$

Synonyms *Ehretia microphylla* Lamk (1792), *Ehretia buxifolia* Roxb. (1796), *Carmona microphylla* (Lamk) G. Don (1837).

Vernacular names Indonesia: kinangan, serut lanang (Javanese), pinaan (Madurese). Philippines: putputai (Bikol), alangit (Bisaya), tsaang gubat (Tagalog). Thailand: khoi cheen (Bangkok), chaa yeepun (central), chaa (Chiang Mai). Vietnam: kim li[ee]n, c[uf]m r[uj]n, b[uf]m r[uj]n.

Origin and geographic distribution *Carmona* is a monotypic genus. The only species *C. retusa* is found from India eastward to southern China, Taiwan and Japan, and further south throughout Malesia to New Guinea and the Solomon Islands. It is often grown as an ornamental.

Uses In the Philippines an infusion of the leaves of *C. retusa* is taken as a substitute for tea. It is considered stomachic, antidiarrhoeal and as a remedy for dysentery and cough. In Ternate an infusion of the leaves is taken as a febrifuge. A decoction of the leaves is taken against stomach troubles and cough in the Philippines. In Madura the roots are reported to be ingested to clean the body after childbirth. In India, the plant is considered an antidote against plant-based poisoning and an alterative in cachexia and syphilis. Furthermore, it is traditionally used to stop the haemorrhaging resulting from the bite of the viper *Echis carinatus*.

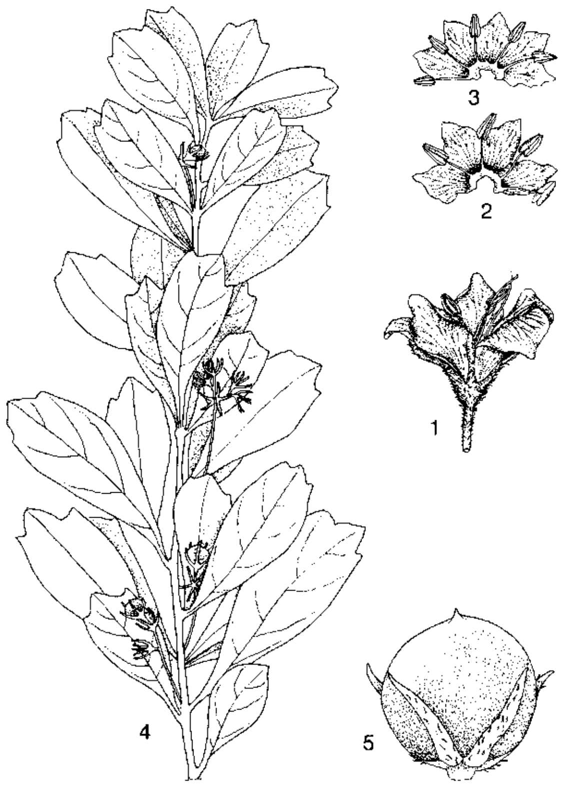
Properties *Boraginaceae* commonly contain pyrrolizidine alkaloids, biosynthesized from the amino acid ornithine, and quinoid or phenolic compounds, derived from C-prenylated, C-geranylated or C-farnesylated 4-hydroxybenzoic acid. The isomeric red pigments alkannin and shikonin are the best known representatives of such hydroxybenzoic acid derivatives.

The portion of the methanol extract of the aerial parts of *C. retusa* that is soluble in ethyl acetate has shown inhibitory activity on exocytosis of hexosaminidase in antigen-stimulated rat basophils. Activity guided studies have shown 5 dimeric prenylbenzoquinones as active compounds: microphyllone (4a,5,8,8a-tetrahydro-11,14-dihydroxy-7-methyl-4a-(3-methyl-2-butenyl)-5,8a-o-benzo-1,4-naphthoquinone) and 4 closely related components. Furthermore, the methanol extract of the leaves showed strong antihistamine release properties. Rosmarinic acid, a phenylacrylic acid derivative, which is a known inhibitor of histamine release, has been isolated as an active constituent. Astragalin, nicotoflorin (both flavonoid glycosides), and α-amyrin, β-amyrin and baurenol (triterpenoids) were also isolated.

Ehretianone, a quinonoid xanthene, (7-hydroxy-9a-α-(3-methylbut-2-enyl)-4a,α9-α-(2-methylprop-2-enyl)-4a,9a-dihydro-1,4-dioxoxanthene) was isolated from a methanol extract of the root bark of *C. retusa*. The compound, administered before and after administration of *Echis carinatus* venom, was shown to protect mice against the action of the snake venom.

Finally, both microphyllone and ehretianone isolated from root-bark material showed antibacterial activity against a panel of bacteria. In an experiment in the Philippines, tablets from the dried leaves reduced the formation of micronucleated polychromatic erythrocytes induced by mitomycin C, tetracycline, and dimethylnitrosamine. This suggests that these tablets possess antimutagenic activity.

Description A shrub or much-branched small tree, 1–4(–10) m tall; young branches hispid, with buds or short shoots producing clusters of leaves and inflorescences. Leaves simple, alternate, obovate to spatulate, 1–6(–10) cm × 0.5–2.5(–4) cm, thick, gradually narrowing towards base, toothed or crenate towards apex, with short rigid hairs, lateral veins about 5, arching; petiole 0.1–0.5(–1) cm long, stipules absent. Inflorescence in axil of leaves or on apex of short shoots, flowers in fascicles of 2–6 or in a cyme. Flowers actinomorphic, bisexual, (4–)5-merous, pedicelled; calyx 3–6 mm long, with (4–)5 linear lobes, densely hairy inside;



Carmona retusa (Vahl) Masam. – 1, flower; 2, 4-merous corolla; 3, 5-merous corolla; 4, fruiting twig; 5, fruit.

corolla sub-rotate, white, 6–9 mm in diameter, tube about 2 mm long, widening, lobes spreading, 2.5–4.5 mm long; stamens (4–)5 with filaments 2.5–3.5 mm long and anthers oblong; ovary superior, globose, about 1 mm in diameter, style deeply bifid, 4.5–6 mm long. Fruit drupaceous, globose, 5–6 mm in diameter, red or yellow, with 1–4 seeds, not breaking up into pyrenes. Seeds with a straight or slightly curved embryo, embedded in thin albumen. Seedling with epigeal germination; cotyledons leafy, green, hypocotyl elongated.

Growth and development Branch shoots are developed at every node, but are of two types: short shoots that do not elongate and long shoots that resemble the leader shoot. The fruits are reported to be dispersed by birds.

Other botanical information In the view of most authors, the *Boraginaceae* family can be divided into five subfamilies. *Carmona* belongs to the subfamily *Ehretioideae*. Together with the other Malesian representatives of this subfamily (*Coldenia*, *Ehretia* and *Rotula*) and with the subfamily *Cordioideae* (represented by *Cordia* in Malesia) *Carmona* is sometimes placed in the family *Cordiaceae*. Most authors have included *Carmona* in *Ehretia*. However, *Carmona* can be distinguished by the undivided, short-beaked endocarp, and its distinctive growth habit and general appearance.

Ecology *C. retusa* is a rare or locally common species found in open, dry, sunny habitats, such as thickets, shrub vegetation and teak forest at low and moderate elevations.

Propagation and planting *C. retusa* can be propagated by cuttings, preferably top shoots or young leafy shoots. Roots develop slowly (1–2 months). Planting is at 1 m intervals with 2 m between rows.

In vitro production of active compounds Using leaf tissue of *C. retusa* as explant, callus growth can be observed after 2 days. The callus contains alkaloids.

Harvesting Mature leaves of *C. retusa* are harvested and senescent leaves discarded.

Handling after harvest In the Philippines, leaves of *C. retusa* are air-dried for 4–5 days in shallow containers with screened bases. Containers are kept in well-ventilated rooms. The dried leaves are powdered and processed into pills.

Genetic resources and breeding *C. retusa* is a widespread species, and there are no reports of overexploitation. The risk of genetic erosion seems to be limited, and in addition it is cultivated as a garden ornamental.

Prospects *C. retusa* ranks among the top 10 of medicinal plants with potential in the Philippines, and thus a small-scale industry has developed. Its constituents, e.g. microphyllone and ehretianone show interesting biological activities, which merit further research. Furthermore, alkannin esters of various organic acids have recently been introduced in therapy for their wound-healing properties.

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A.P. Guevara

Cassia L.

Sp. pl. 1: 376 (1753); Gen. pl. ed. 5: 178 (1754).
LEGUMINOSAE
$x = 12, 14$; *C. fistula*: $2n = 24, 28$, *C. grandis*: $2n = 28$

Major species *Cassia fistula* L., *C. grandis* L.f.

Origin and geographic distribution *Cassia* comprises about 30 species and is pantropical. There is probably only one indigenous species in Malesia (*C. javanica*) and three other species have been introduced from mainland Asia or South America, originally for ornamental purposes: *C. bakeriana* Craib, *C. fistula* and *C. grandis*. The medicinal use of *C. fistula* dates from ancient times and has been the main factor in its spread.

Uses The ripe pods and seeds of *C. fistula*, *C. grandis* and *C. javanica* are used as a laxative. Other plant parts (root-bark, leaves, flowers) of *C. fistula* also have purgative properties, but to a lesser extent. A decoction of the roots may be used to purify wounds and ulcers. The bark of the trunk is reported to be used in Java and India to treat skin problems, whereas in the Philippines the leaves are applied on fungal skin infections. In India, the roots are used to treat fever. Fresh juice of the leaves of *C. grandis* is used externally in the treatment of ringworm. Leaf decoctions are also used as laxative and to treat lumbago. In Panama, *C. fistula* is used in folk medicine for the treatment of diabetes.

In modern medicine, the pulp of *C. fistula* is sometimes used as a mild laxative in pediatrics. However, laxative drugs of this type should be used with caution, because daily and prolonged use may lead to dependence and 'cathartic colon'.

Apart from its medicinal properties, *Cassia* has many other uses. *C. bakeriana*, *C. fistula*, *C. grandis* and *C. javanica* are all planted as ornamentals. The latter three species and especially *C. javanica* provide hard multipurpose timber. In Thailand, the heartwood of *C. fistula* is used as a masticatory. The bark of *C. fistula* and *C. javanica* is also used for tanning, but the latter species is less valued. The seeds of *C. fistula*, *C. grandis* and *C. javanica* are a potential commercial source of gums. Seed gum is a potential binder for the pharmaceutical industry.

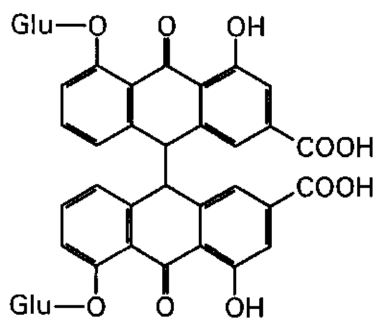
Production and international trade Although *C. fistula* pods have been traded to Europe for centuries, no recent trade information is available.

Properties The fruit pulp of *C. fistula* is rich in pectins and mucilages. Furthermore, the laxative properties of fruit pulp and leaves are mainly due to the content of anthraquinone derivatives (about 2%), e.g. rhein (an anthraquinone), the sennidins (dianthrones) and the sennosides (the corresponding dianthrone-glycosides). In a study in Mexico, sennoside contents were found up to 1.5% in the leaves, and up to 1.9% in the fruits. Anthraquinone drugs are used as laxatives. The sugar moiety in the glycosides increases water solubility of the molecule, and thus facilitates transport to the site of action: the colon. In the colon, bacteria hydrolyse the glycosides and dianthrones to anthraquinones, a reaction which is immediately followed by the local reduction of the anthraquinones to their corresponding anthrones. The latter compounds act directly on the large intestine, to stimulate peristalsis. Anthraquinones are also found in *C. javanica* (anthraquinone glycosides) and *C. grandis* (aloe-emodin).

In an Indian study, fatty acids in *C. fistula* were found to consist mainly of linoleic acid (52.5%), oleic acid (18.1%) and palmitic acid (16%). Other fatty acids were: vernolic acid (6.1%), stearic acid (3.4%), sterculic acid (2%) malvalic acid (1.5%) and myristic acid (0.4%).

Compounds isolated from *C. grandis* include centaureidine, catechin, myristicin, 2,4-dihydroxybenzaldehyde, 3,4,5-trimethoxybenzaldehyde, 2,4,6-trimethoxybenzaldehyde, β-sitosterol, kokusaginine (6,7-dimethoxyfuroquinoline) and fabioline (1,1'-bipiperidine).

In vitro and in vivo tests showed that seed powder of ripe *C. fistula* fruits has amoebicidal and cysticidal properties against *Entamoeba histolytica* and that it could cure intestinal and hepatic



sennoside A (Glu = glucose)

amoebiasis of laboratory animals and intestinal amoebiasis of humans. *C. fistula* also exhibits further anti-amoebic, insecticide and anthelmintic activities.

The hypocholesterolaemic effect of *C. fistula* has been investigated using hypercholesterolaemic male albino rats. Hypercholesterolaemia was induced by feeding on a mixture of cholesterol plus cholic acid for a 12-week period. Hypercholesterolaemia was characterized by significant increase in the average levels of total lipids, total cholesterol and triglycerides, and significant decrease in phospholipid content. Administration of *C. fistula* significantly reduced blood and liver total lipids. Brain, spleen, kidneys and heart followed nearly the same trend but with moderate effect. Blood, liver, kidneys, spleen and heart total cholesterol were significantly reduced, while that of the brain was not affected. The level of triglycerides was markedly improved. There was a moderate rise, however, in phospholipid content in all organs studied; that is, there was marked progress in the correction of lipid metabolism. Administration of *C. fistula* also induced a significant decrease in the high activities of serum GOT, GPT, alkaline and acid phosphatase; the values nearly returned to the initial values. Total serum protein, albumin (A), globulin (G), A/G, free amino acids, uric acid and creatinine were also determined. Their values were improved and nearly attained the normal values of the control group.

The aqueous fraction of *C. fistula* produced a significant decrease in glycaemia in mice ($p < 0.001$) at 4 and 24 hours with doses of 300 and 500 mg/kg, and at 1 and 4 hours after the dose of 1000 mg/kg ($p < 0.001$). In the glucose tolerance test, the aqueous fraction of *C. fistula* produced a significant decrease ($p < 0.05$) in glucose tolerance at a dose of 500 mg/kg, but a significant increase ($p < 0.001$) at a dose of 1000 mg/kg.

The ethanol extract of the leaves and bark of *C. grandis* showed in vitro antifungal activity against *Epidermophyton floccosum*, *Microsporum gypseum* and *Trichophyton rubrum* in pure culture at a minimal inhibitory concentration of 50 μg/ml.

Adulterations and substitutes Anthraquinone glycosides and sennosides are also found in *Senna* species, which are also used for their laxative and purgative properties.

Description Large shrubs or small to medium-sized trees up to 30(–40) m tall; bole up to 60 cm in diameter. Leaves arranged spirally, often distichous, paripinnate, without extrafloral nectaries; stipules present. Inflorescence terminal on main shoots or short side shoots or axillary, racemose. Flowers having pedicels with 2 bracteoles at or just above the base; hypanthium present but variable; calyx 5-merous, sepals reflexed at anthesis; corolla 5-merous, zygomorphic; androecium zygomorphic, 10-merous, filaments of 3 abaxial stamens sigmoidally curved, generally longer than their anthers, the other 7 filaments straight and short; ovary superior, style variable. Fruit an elongated pod, cylindrical or compressed, indehiscent, many-seeded. Seeds 1- or 2-seriate, funicle filiform. Seedling with epigeal germination; cotyledons emergent, semi-fleshy.

Growth and development *C. fistula* is a slow growing, deciduous tree. Generally, it takes 8–10 years from sowing to flowering. This can be reduced by vegetative propagation. In Singapore, *C. fistula* sheds its leaves at 9–10 months' intervals and the inflorescences develop with the new leaves. At the beginning of flowering, the whole crown is covered with flowers; sporadic flowering continues up to 3 months. Experiments have shown that pollen is still viable after 4 weeks of storage.

Seedling development in *C. grandis* is initially rapid, but slows down after 2 months. It is reported evergreen in Java and deciduous in northern Malaysia and Indo-China, where the leaves fall at the beginning of the dry season. The tree flowers before new leaves appear. In Costa Rica, fruit takes 10–12 months to mature.

The roots of *C. fistula* and *C. javanica* lack nodulating ability, but for *C. grandis* this is not clear. The concentration of sennoside in the leaves of *C. fistula* was highest soon after the onset of the rainy season, when new leaves had appeared and flowering started. The sennoside content of the pods was highest at the midstage of fruit maturation, when the pods were pale brown.

Other botanical information Until the beginning of the 1980s *Cassia* was considered to be a very large genus of over 500 species, but then it was split into 3 genera: *Cassia* sensu stricto, *Senna* and *Chamaecrista*. *Cassia* now has only about 30 species, whereas *Senna* and *Chamaecrista* comprise about equal numbers of species (about 260 and 270 respectively). *C. fistula* is able to hybridize with *C. javanica*.

Ecology *Cassia* is found in forests at low altitudes. *C. fistula* occurs in Java in light forest below 400 m altitude, in the Philippines in open grasslands at low and medium altitudes. It seems to favour calcareous and red, volcanic soils, but in

Thailand it is also found on sandy and loamy soils. *C. javanica* occurs in moist evergreen forest, deciduous monsoon forest and in more open or even savanna-like habitats. The various subspecies of *C. javanica* show preferences for either dry or moist habitats on a wide variety of soils.

Propagation and planting *C. fistula*, *C. grandis* and *C. javanica* can be propagated by seed and vegetatively through cuttings and layering. They have a hard seed-coat and germination is improved considerably by mechanical scarification or treatment with concentrated sulphuric acid for at least 45 minutes. Seed can be stored for prolonged periods without loss of viability. *C. fistula* seed should be sown in full light, and adequate water supply is required for optimal germination. The seed can increase three times in weight by absorbing water. Direct sowing is practised in Asia, but preliminary weeding is important. In Costa Rica, *C. grandis* is propagated by means of large cuttings ('apicormic shoots'). Vertical shoots of 15 cm in diameter are cut, trimmed to a length of 2.5 m. These are laid out in the shade for a week and then stacked vertically for three weeks. Then they are planted, with the lower ends buried 50 cm deep. *C. javanica* is usually propagated by seed, with 50% of the seed producing healthy plants.

Diseases and pests *Colletotrichum gloeosporioides* causes brown pinhead spot disease in *C. fistula* in Malaysia. In the Philippines, *C. fistula* is attacked by the psyllid *Heteropsylla cubana*. Symptoms include leaf curling, defoliation, stunted shoot growth and death.

Harvesting Pods of *Cassia* are harvested when mature, and in general simply collected from the ground.

Handling after harvest For domestic use of *C. fistula*, the pulp is scraped from the fresh pods. Pods intended for trade are dried. Prolonged boiling of the pulp leads to loss of the purgative properties.

Genetic resources and breeding In view of their wide distribution *C. fistula*, *C. grandis* and *C. javanica* are not endangered or liable to genetic erosion.

Prospects *C. fistula*, *C. grandis* and *C. javanica* may be interesting multipurpose trees for South-East Asian farmers, and have a high ornamental value. With regard to the frequent use of *Cassia* as laxative, caution seems to be justified. The hypocholesterolaemic, antifungal and anti-amoebic properties warrant further research.

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Selection of species

Cassia fistula L.

Sp. pl. 1: 377 (1753).

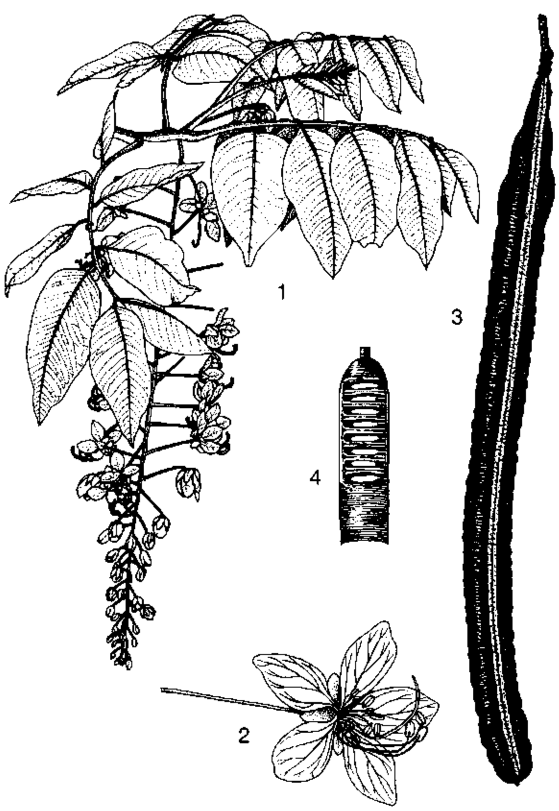
Vernacular names Golden shower, Indian laburnum (En). Caneficier (Fr). Indonesia: trengguli (Javanese), bobondelan (Sundanese), klobop (Madurese). Malaysia: bereksa, tengguli, rajah kayu. Philippines: fistula (Tagalog, Cebu Bisaya), kana-pistula (Tagalog), bitsula (Cebu Bisaya). Cambodia: reach, reach speu, reach chhpoeus. Laos: khoun (general). Thailand: khuun (central, northern), lom laeng (northern), ratchaphruek (central). Vietnam: c[aa]y b[of] c[aj]p n[uw][ows]c, mu[oof]ng ho[af]ng y[ees]n.

Distribution Widespread in the tropics; in Java often cultivated as an ornamental, in the Philippines planted as a medicinal or ornamental plant, cultivated throughout New Guinea.

Uses Since ancient times *C. fistula* has been used as a laxative throughout the tropics. In Papua New Guinea, Central Province, broken bones and tropical ulcers are bandaged with bark scrapings and leaf sap. In Thailand, the heartwood is traditionally applied as an anthelmintic. The wood is occasionally used e.g. for posts, carts and agricultural implements. The bark is used for tanning and as an ingredient in betel paste.

Observations A small to medium-sized tree, 10–15 m tall or sometimes more, deciduous or semi-deciduous, branches spreading, young twigs glabrous; leaves with 3–7 pairs of leaflets, petiole 5–8 cm long, terete, leaflets ovate-oblong, 7–12 cm × 4–8 cm, subcoriaceous, base broadly cuneate, apex acute, with shiny upper surface, glabrous when mature; inflorescence an axillary, pendulous, lax raceme, 20–40(–60) cm long, many-flowered; flowers fragrant, sepals 7–10 mm long, petals broadly ovate, golden-yellow, stamens 10, 3 long with filaments 3–4 cm long, 4 shorter with filaments 6–10 mm long, 3 reduced with filaments 3–4 mm long and minute anthers; fruit pendent, terete, 20–60 cm long, 1.5–2 cm in diameter, black, glabrous, indehiscent; seeds numerous, separated by papery septa and embedded in black, glutinous pulp. *C. fistula* occurs in open forest and grassland at lower altitudes.

Selected sources 91, 97, 133, 181, 190, 284, 319, 332, 336, 357, 402, 409, 580, 653, 692, 726, 817, 846, 973, 1023, 1128, 1178, 1277, 1287, 1343, 1520.



Cassia fistula L. – 1, branch with inflorescence; 2, flower; 3, mature pod; 4, section of pod showing seeds.

Cassia grandis L.f.

Suppl.: 230 (1781).

Synonyms *Cassia pachycarpa* de Wit (1956).

Vernacular names Horse cassia, pink shower (En). Malaysia: kotek, kotek mamak. Cambodia: sac phle, kreete. Laos: brai xiem, may khoum. Thailand: kanpaphruek (Bangkok). Vietnam: b[oof] c[aj]p d[or], [oo] m[oo]i.

Distribution Originating from tropical America, but introduced throughout the tropics; abundant in Cambodia and southern Vietnam, common as an ornamental and escape in Malaysia, Java and New Guinea.

Uses The fruit pulp is used as a laxative similar to *C. fistula* and reported to be more powerful. A decoction of the leaves is used as a laxative and in the treatment of lumbago. *C. grandis* is also reported to give strong multipurpose wood.

Observations A medium-sized tree, up to 20(–30) m tall, semi-deciduous, young branches and inflorescence covered with rusty lanate indumentum; leaves with 10–20 pairs of leaflets, petiole 2–3 cm long, lanate, leaflets subsessile, elliptical-oblong, 3–5 cm × 1–2 cm, subcoriaceous, rounded at both ends; inflorescence a lateral raceme, 10–20 cm long, 20–40-flowered; flowers with sepals 5–8 mm long, petals initially red, fading to pink and later orange, the median one red with a yellow patch, stamens 10 with hirsute anthers, 3 long ones with filaments up to 30 mm and anthers 2–3 mm long, 5 short ones with filaments 7–9 mm and anthers 1–1.5 mm long, 2 reduced ones with filaments about 2 mm long; fruit pendent, compressed, 20–40(–60) cm long, 3–5 cm in diameter, blackish, glabrous, woody, rugose; seeds 20–40 per pod, surrounded by sweetish pulp. *C. grandis* is a common ornamental in villages at lower altitude.

Selected sources 97, 284, 336, 357, 409, 416, 653, 688, 817, 1035, 1493.

Cassia javanica L.

Sp. pl. 1: 379 (1753).

Synonyms *Cassia nodosa* Roxb. (1832), *Cassia bartonii* F.M. Bailey (1901), *Cassia agnes* (de Wit) Brenan (1958).

Vernacular names Indonesia: bobondelan (Sundanese), boking-boking (Sumatra), trengguli (Javanese). Malaysia: bebusok, busok-busok (Peninsular). Philippines: pink shower (En), antsoan (Bikol). Cambodia: bô prùk'. Laos: khoun loy². Thailand: chaiaphruk (central), kalalphruk (central, northern), lak khoei lak kluea (Trang). Vietnam: b[uf] c[aj]p, mu[oof]ng b[of] c[aj]p.

Distribution Widespread in the Malesian area, wild and cultivated. Widely cultivated all over tropical Asia. The various subspecies are geographically confined to parts of the Malesian area, though sometimes cultivated outside their original area of distribution.

Uses The ripe pods and seeds are used as a traditional laxative throughout the Malesian area. In Thailand, bark and seeds are also used as antipyretics. However, it was noted that emesis may be observed. The bark is used for tanning leather. *C. javanica*, in particular subsp. *agnes* (de Wit) K. Larsen and subsp. *nodosa* (Roxb.) K. & S.S. Larsen, is also widely planted as an ornamental. The wood is used for general construction, furniture and cabinet making.

Description A small to medium-sized tree up to 25(–40) m tall, deciduous or semi-deciduous, trunk of young trees either smooth or armed with stump-remnants of branches; leaves with 5–15(–20) pairs of leaflets, petiole 1.5–4 cm long, leaflets elliptical-ovate to oblong, 2.5–5 cm × 1.5–2.5 cm, base broadly rounded, apex acute or rounded to obtuse; inflorescence a raceme or panicle, terminal on leafy shoots or lateral on short side branches, up to 16 cm long, many-flowered; flowers with sepals 4–10 mm long, green to dark red, petals 15–35 mm long, whitish to reddish or buff, stamens 10, 3 longer ones with filaments 2 cm long, 4 shorter with filaments about 1 cm long and 3 reduced wih filaments about 1 cm long and minute anthers; fruit pendent, terete, 20–60 cm long, 1–1.5(–2.5) cm in diameter, indehiscent; seeds numerous, embedded in a flat disk. *C. javanica* is a very polymorphic species and several subspecies are distinguished. It has a wide ecological amplitude and is generally found at lower elevations.

Selected sources 97, 202, 284, 336, 357, 580, 640, 653, 817, 1520, 1564.

Anny Victor Toruan-Purba

Catharanthus roseus (L.) G. Don

Gen. hist. 4(1): 95 (1837).

APOCYNACEAE

$2n = 16$

Synonyms *Vinca rosea* L. (1759), *Lochnera rosea* (L.) Reichenb. ex Endl. (1838).

Vernacular names Madagascar periwinkle (En). Indonesia: bunga serdadu, kembang tembaga, tapak dara (general). Malaysia: kemunting china, rumput jalang, tahi ayam (Peninsular). Philippines: chichirica (Sp), kantotai, amnias (Tagalog). Thailand: nom in (Surat Thani), phakpot bok (northern), phaengphuai bok (Bangkok). Vietnam: c[aa]y b[oo]ng d[uwf]a, d[uwf]a c[aj]n, hoa h[ar]i d[awf]ng.

Origin and geographic distribution *C. roseus* belongs to a small genus of 8 species, all originating from Madagascar except for *C. pusillus* (Murr.) G. Don, which is restricted to India and Sri Lanka. For centuries, Madagascar periwinkle has been cultivated as an ornamental throughout the tropics and occasionally in the subtropics; it has become naturalized in many regions. It was brought into cultivation in the first half of the 18th Century in Paris, from seeds collected in Madagascar, and was later distributed from European botanical gardens to the tropics as an ornamental.

Uses In traditional medicine, a decoction of all parts of the plant is used to treat malaria, diarrhoea, diabetes, cancer and skin diseases. Madagascar periwinkle is well known as an oral hypoglycaemic agent. Extracts prepared from the leaves have been used as an antiseptic agent for the healing of wounds, against haemorrhage and as a mouthwash to treat toothache. Madagascar periwinkle is also considered to be a diaphoretic and diuretic and is used to relieve indigestion, dyspepsia, dysentery, toothache and wasp stings, and as a vomitive, purgative, vermifuge, depurative and haemostatic.

The aerial parts of the plant are used for alkaloid extraction (vincristine, vinblastine, vindesine, vinorelbine). The alkaloids are prescribed in anticancer chemotherapy, usually as part of complex chemotherapy protocols. They are administered intravenously, via injection or infusion. Vincristine (sulphate) is indicated in the treatment of acute leukaemia, Hodgkin's disease, non-Hodgkin's lymphoma, small-cell bronchial cancer, neuro and nephroblastomas, metastasized breast cancer and various sarcomas (especially rhabdomyosarcoma). A normal dose for adults is 1–1.4 mg/m^2 of body surface area, usually at a frequency of once a week, or once monthly in combination chemotherapy. The indications for vinblastine (sulphate) are Hodgkin's disease, non-Hodgkin's lymphoma, advanced testicular cancer, Kaposi's sarcoma, and sometimes choriocarcinomas and some cases of histiocytosis (especially the Lettere-Siwe syndrome). A normal dose for adults is 4–6 mg/m^2 of body surface area weekly. Vindesine, a semisynthetic derivative of vinblastine, is indicated in the treatment of acute lymphatic leukaemia (especially in children) and refractory lymphomas and melanomas. When used alone, a normal dose of vindesine is 3 mg/m^2 of body surface area every 7–10 days for one month, and then at intervals of 15 days. Combination chemotherapy protocols often allow lower doses. The semisynthetized vinorelbine has breast cancer and bronchial cancer as current indications, and is often administered to adults in a dose of 25–30 mg/m^2 of body surface area in monotherapy, and in lower doses in combination chemotherapy protocols. The major toxic side effect of vinblastine is myelosuppression, especially leukopenia. Neurotoxicity is the dose-limiting toxicity of vincristine. Both neurotoxicity and myelosuppression are observed after administration of vindesine, but they are less severe than with vincristine and vinblastine. All four agents may induce thrombocytopaenia and alopecia.

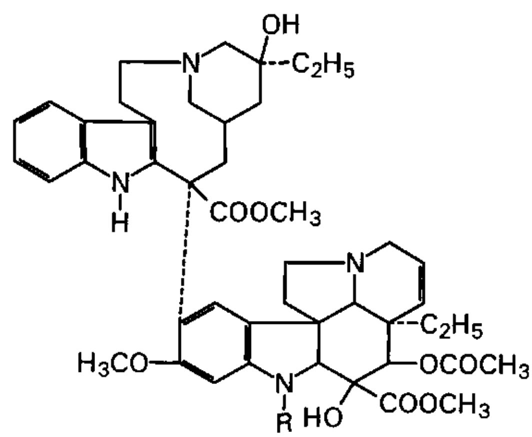
The dried root is an industrial source of ajmalicine (raubasine), which increases the blood flow in the brain and peripheral parts of the body. Preparations of it are used to treat the psychological and behavioural problems of senility, sensory problems (dizziness, tinnitus), cerebrovascular accidents, cranial traumas and their neurological sequelae.

Madagascar periwinkle is a popular garden ornamental, grown as a perennial in tropical regions and as an annual in temperate regions. It is valued for its bushy habit and large flowers carried above dark green foliage.

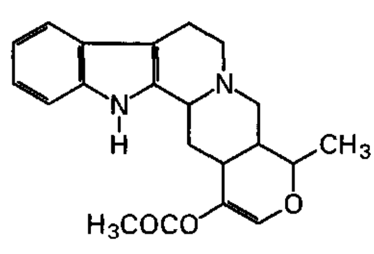
Production and international trade The dimeric alkaloids extracted from the aerial parts of Madagascar periwinkle are marketed as a lyophilisate or a solution of a salt designed for the sole intravenous route (direct intravenous or through infusion tubing). Vindesine and vinorelbine, which are semisynthetized derivatives of vinblastine, are marketed as a sulphate and a bitartrate, respectively, for injectable solutions. All these drugs are prescription drugs that pharmacists in western countries cannot issue without the direct authorization of a physician.

The price of vincristine was reported to be over US$ 200 000/kg in 1993; the world market consumes 250–300 kg annually with a value of US$ 50–80 million.

Properties Madagascar periwinkle has been found to contain as many as about 100 constituents with an indole or dihydroindole structure. The principal constituent is vindoline (up to 0.5%); other major compounds are serpentine, catharanthine, ajmalicine (raubasine), akuammine, lochnerine and tetrahydroalstonine. Ajmalicine and serpentine are essentially present in the roots, whereas catharanthine and vindoline accumulate in aerial parts. The aerial parts contain 0.2–1% alkaloids.



vinblastine (R = CH_3) and vincristine (R = CHO)



ajmalicine

The substances of pharmacological interest are the dimeric alkaloids which show a coupling of an indole and a dihydroindole. Of the separate parts, the indole/dihydroindole moiety is derived from the amino acid tryptophan, which is coupled to a monoterpene residue. Several of these dimeric alkaloids have cytostatic properties, but they occur in very small amounts: vincristine (= leurocristine) in up to 3 g/t of dried drug, and vinblastine (= vincaleucoblastine) in a slightly larger amount. Other active compounds are leurosidine (= 20'-epivinblastine) and leurosine (= 15',20'-epoxyvinblastine).

Vincristine and vinblastine are antimitotics. They bind to tubulin and prevent the formation of microtubules that assist in the formation of the mitotic spindle; in this way, they block mitosis in the metaphase. These compounds have a non-trivial toxicity; they both have neurotoxic activity (especially vincristine) because the microtubule assembly also plays a role in neurotransmission. Their peripheral neurotoxic effects are neuralgia, myalgia, paresthesia, loss of the tendon reflexes, depression and headache, and their central neurotoxic effects are convulsive episodes and respiratory difficulties. Other side-effects are multiple and include alopecia, gastro-intestinal distress including constipation, buccal ulcerations, amenorrhoea and azoospermia. As vinblastine is highly leucopenic, its dosage must be carefully controlled. The alkaloids are very irritating; if extravasation accidentally occurs there is a risk of tissue necrosis. It is possible to limit the side-effects by carefully guiding the dose and administration, and intensively monitoring the treatment. In common with all teratogenic chemotherapeutics, pregnancy and breast-feeding are strictly contra-indicated. Semisynthetic derivatives whose structure is closely related to that of the naturally occurring dimeric alkaloids are also used as anti-cancer drugs. Vindesine can be prepared from vinblastine, and it is also a potent antimitotic. Its side-effects include a transient granulocytopaenia and effects comparable to those caused by vincristine and vinblastine, although the neurological symptoms are less obvious. Vinorelbine (= noranhydrovinblastine) is obtained from anhydrovinblastine. It acts preferentially on mitotic microtubules and not so much on neuronal microtubules, and consequently its neurological toxicity is limited. However, its haematotoxic actovity is substantial, so its dosage must be carefully controlled.

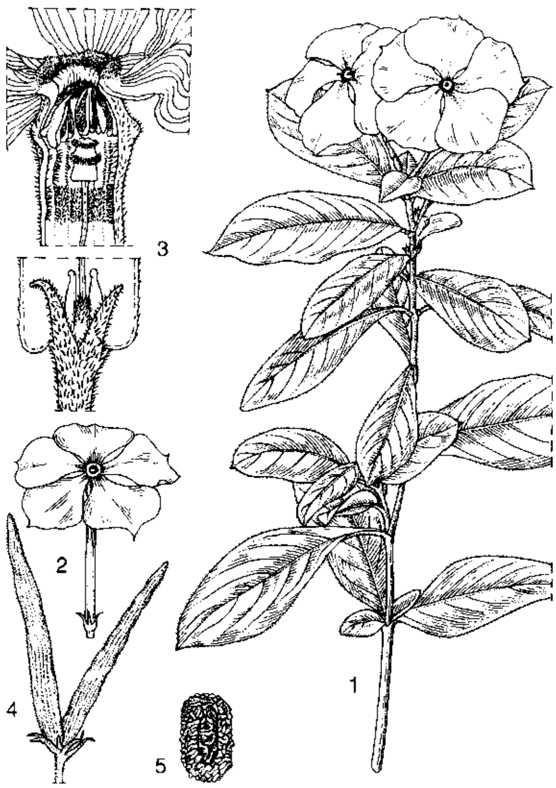
Some of the alkaloids (e.g. leurosine and vindoline) exhibit a moderate hypoglycaemic action. However, most experiments to confirm the reputed positive effect on diabetes have had disappointing results. Vinblastine markedly inhibited in vitro the reproduction of *Trypanosoma cruzi*, the organism responsible for Chagas' disease, which is a major health problem in Central and South America.

Roots to be used in pharmacy must contain at least 0.4% ajmalicine and serpentine (the quaternary base corresponding to ajmalicine; ajmalicine can be derived from it). These compounds can easily be characterized and quantified by two thin-layer chromatography analyses. Ajmalicine is an α-adrenergic blocking spasmolytic, which at high doses reverses the effects of adrenaline and moderates the activity of the vasomotor centres, especially in the brain stem. It temporarily increases the blood flow to the brain.

Antiviral activity has been reported in vitro for some *Catharanthus* alkaloids. Extracts showed fungicidal activity (e.g. against *Fusarium solani* that causes wilt in aubergine and *Sclerotium rolfsii* that causes damping-off disease in tomato) and nematicidal activity (e.g. against *Meloidogyne incognita* and *M. javanica*).

Adulterations and substitutes Ajmalicine and derivatives are also found in other *Apocynaceae*, such as *Rauvolfia* spp.

Description An erect or decumbent, deciduous undershrub up to 100(–200) cm tall, usually with white latex; roots up to 70 cm long; stems often woody at base. Leaves decussate, simple, elliptical to obovate or narrowly obovate, (3–)4–9 cm × (1–)1.5–3.5 cm, herbaceous to thinly leathery, cuneate and sometimes oblique at base, obtuse or acute at apex with a mucronate tip, entire, glossy green above and pale green below, laxly pubescent to glabrous on both sides, secondary veins 7–11 on both sides of midrib and more or less conspicuous, tertiary venation inconspicuous; petiole (0.1–)0.3–1 cm long, with a fringe of colleters in the axil; true stipules absent. Inflorescence terminal, but apparently lateral because of alternating development of one of the axillary buds of the apical leaf-pair, 1–2-flowered. Flowers actinomorphic, bisexual, 5-merous, subsessile; sepals slightly connate at base, (2–)3–5 mm × 1–1.5 mm, green; corolla salver-shaped, pink, rose-purple or white with a purple, red, pink, pale yellow or white centre, tube 2–3 cm long and widening near the top, laxly puberulous to glabrescent outside, with a densely strigose ring of hairs in the throat and with a sericeous ring of hairs lower down the tube, lobes broadly obovate, 1–2(–3) cm long, mucronate



Catharanthus roseus (L.) G. Don – 1, flowering twig; 2, flower; 3, base and top of corolla tube in longitudinal section; 4, fruit; 5, seed.

at apex, glabrous, spreading, in bud overlapping to the left; stamens included in the corolla tube, inserted just below the corolla throat, filaments very short, anthers free, introrse; ovary superior, consisting of 2 very narrowly oblong carpels coherent at base, style filiform, with a cylindrical pistil head provided at base with a reflexed hyaline frill ('petticoat') and with rings of woolly hairs at base and apex, stigma glabrous; disk composed of 2 glands, often longer than ovary. Fruit composed of 2 cylindrical and acute follicles 1–4 cm long, striate, laxly puberulous to glabrous, green, dehiscent at adaxial side, many-seeded. Seeds oblong, 1–2 mm long, with rugose testa and lateral hilum, black; cotyledons flat, slightly shorter than radicle; endosperm scanty.

Growth and development Madagascar periwinkle is self-incompatible. The seeds usually fall close to the mother plant, but are sometimes transported by ants.

Other botanical information *Catharanthus* is very closely related to *Vinca* but differs in general appearance (*Vinca* produces trailing or floppy, long-lived stems with persistent, leathery leaves) and in flower characteristics (flowers in *Vinca* solitary, corolla infundibular, stamens with long filaments, glands at base of ovary small, pistil head without 'petticoat').

The flower types present in Madagascar periwinkle differ in whether the corolla is pink, rose-purple, white, or white but red-eyed. Usually, no qualitative differences have been found in alkaloid composition between these flower types, but tests in the Philippines showed that plants with rose-purple flowers had a higher alkaloid production than white-flowered plants. Likewise, tests in Thailand revealed the white red-eyed plants to produce the highest yields of alkaloids and vinblastine. Nowadays, these types are usually classified as cultivars, e.g. cv. Albus.

C. lanceus (Bojer ex A.DC.) Pichon is used medicinally in Madagascar and South Africa; the leaves are used as astringent and emetic, the aerial parts as galactagogue and vomitive, and the roots as purgative. The alkaloid fractions of *C. lanceus* have shown hypotensive activity (mainly caused by yohimbine, a potent α-adrenergic blocker). A lyophilized aqueous extract was found to show anti-tumour activity (leurosine is most potent), whereas some alkaloids have a hypoglycaemic effect.

Ecology Madagascar periwinkle often occurs in sandy locations along the coast, but also inland on river banks, in savanna vegetation and in dry waste places and roadsides, sometimes in open forest or scrub, usually on sandy soils, but sometimes also on rocky soils. It is highly salt-tolerant, and is mostly found near sea-level, but occasionally up to 1500 m altitude. It can stand drought well, but not severe heat. Under severe water stress the alkaloid content of mature leaves was found to double, but it did not change in stems and immature leaves and it decreased in roots.

Propagation and planting Madagascar periwinkle is usually propagated by seed. Seed may remain dormant for several weeks after maturity. The optimum temperature for germination is about 25°C. The germination rate of fresh seed is reported as 40%, but pretreatment with chemical stimulants like a potassium nitrate solution may enhance it to 90%. Madagascar periwinkle can also be propagated vegetatively by greenwood or semi-ripe cuttings rooted in a closed container with bottom heat.

In vitro production of active compounds Callus tissue of Madagascar periwinkle can be cultured on supplemented White's medium or supplemented Heller's medium, usually solidified with agar. Tests in Thailand showed that the best callus initiation and greatest weight of callus from stem explants was obtained in a Murashige and Skoog basal medium supplemented with 0.5 mg/l 2,4-D and 1 mg/l kinetin. In the Philippines, successful trials have been carried out using floral explants.

Cell suspension cultures are grown in Gamborg's B5 medium or in LS medium containing 2 mg/l naphthalene acetic acid, 0.2 mg/l kinetin and 30 g/l sucrose, under constant light at 25°C and constant shaking. Cell cultures of Madagascar periwinkle produce a variety of monoterpenoid alkaloids. The alkaloid spectra of root and shoot cultures are similar to those of roots and aerial parts, respectively, of whole plants. Ajmalicine, serpentine and catharanthine are usually the major constituents. Much higher yields of serpentine and ajmalicine, the hypotensive agents, can be produced in cell cultures than in whole plants: up to 2% on dry weight basis versus 0.3% in whole plants. The dimeric anti-cancer alkaloids vinblastine and vincristine are almost undetectable in cultured cells, so attention has turned to the production of catharanthine and vindoline, which can be used as precursors for their synthesis. However, in experiments the production of vindoline appeared not to be stable in cell culture. The lack of vindoline accumulation in cell suspension cultures has been correlated with the lack of expression of the enzymes which catalyse the last steps of vindoline biosynthesis. These enzymes are considered to express only at later development stages and occur in above-ground plant parts; the last steps in biosynthesis only occur in seedlings grown in light.

Multiple shoot cultures induced from seedlings produce vindoline and catharanthine in rather higher levels. Murashige and Skoog medium supplemented with 7 mg/l benzyladenine and 1 mg/l α-naphthalene acetic acid strongly stimulates the formation of shoots, whereas medium supplemented with 2,4-dichlorophenoxyacetic acid suppresses the formation of shoots.

Another possible method of vindoline production is by cultures of selected hairy roots. These can be established by infecting seedlings with *Agrobacterium rhizogenes*. Some clones not only showed levels of ajmalicine, serpentine and catharanthine comparable to those of cell suspension cultures, but also about 3 times more vindoline than usually found in cell cultures.

Husbandry In South-East Asia, Madagascar periwinkle is usually cultivated as an ornamental; there are no records of large-scale cultivation for medicinal purposes. It responds well to N fertilizers, but can also grow and persist on poor soils.

In India, Madagascar periwinkle is largely cultivated as a 200-day crop for its leaves (for the extraction of vinblastine and vincristine) and its roots (for the extraction of ajmalicine). The crop needs little irrigation and fertilizer.

Diseases and pests In Malaysia, Madagascar periwinkle has been reported to be infected with so-called Malaysian periwinkle yellow. Symptoms include excessive yellowing of foliage, virescence, phyllody, bunchy top and stunted flowers and leaves, suggesting infection by a mycoplasm-like organism. Similar diseases have been reported from China, Taiwan, North America and Europe. Mycoplasm-like organisms can be transferred to Madagascar periwinkle by parasitic plants of the genus *Cuscuta*, and perhaps also by leafhoppers. Container-grown plants in the United States cultivated as ornamentals have been reported susceptible to *Phytophthora parasitica* that causes root and stem rot.

Yield The alkaloids in Madagascar periwinkle used in cancer chemotherapy occur in very small amounts: vincristine in an amount of up to 3 g/t of dried drug, and vinblastine in a slightly larger amount. These dimeric alkaloids are almost undetectable in cultured cells. The serpentine and ajmalicine production can be much higher in cell cultures than in whole plants: 1.3% on a dry weight basis versus 0.3% in whole plants.

Handling after harvest The aerial parts of Madagascar periwinkle are separated from the roots; both are dried at low temperatures, then packed for shipment. Potted plants for use as ornamentals are usually traded in sealed packages. They are marketable in this condition for 18 days, and do not require watering during this period.

Genetic resources and breeding Although Madagascar periwinkle probably originated from a limited area in south-eastern Madagascar, it is now widely planted and naturalized in all tropical areas, and is certainly not endangered. However, protection of the wild populations in Madagascar is desirable to ensure the conservation of the genetic diversity, which might be of interest for breeding purposes in the future.

Tetraploid plants, induced with colchicine, have been found to have a much higher alkaloid content than diploid plants, but the doubling of chromosomes was found to result in reduced pollen fertility and poor seed set.

C. roseus has been successfully crossed with *C. trichophyllus* (Baker) Pichon, with the F_1 having a high seed set and good viability when *C. trichophyllus* was the female parent. The alkaloid profiles of the two species are different, and alkaloid production seems to be higher in hybrids than in the parent species. A possible strategy for improving alkaloid production in *Catharanthus* could be to breed for hybrids with a high alkaloid content.

Prospects The possibility of accessing active dimeric alkaloids by biomimetic synthesis has recently attracted much attention. It is now conceivable that vinblastine could be obtained from starting materials such as catharanthine and vindoline that are neither rare nor too expensive. These latter two compounds can be produced in sufficient amounts in in vitro cultures of Madagascar periwinkle. Studies on analogues of the well-known alkaloids suggest good prospects for new developments vis-à-vis *Catharanthus* alkaloids.

Madagascar periwinkle may have some prospects as a protectant of stored grain, since tests in the Philippines have demonstrated that its use results in improved germination of treated maize kernels and in vigorous seedlings. Corn weevil and flour beetle infestation were also reduced. However, possible toxicity and teratogenicity of residues could be a serious drawback.

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H. Sutarno & Rudjiman

Centella asiatica (L.) Urb.

Mart., Fl. bras. 11, 1: 287, pl. 78, fig. 1 (1879).
UMBELLIFERAE
$2n = 18$

Synonyms *Hydrocotyle asiatica* L. (1753).

Vernacular names Asiatic pennywort, Indian pennywort, gotu-cola (En). Hydrocotyle asiatique (Fr). Brunei: pegaga. Indonesia: daun kaki kuda, pegagan (general), antanan gede (Sundanese). Malaysia: pegaga (general). Philippines: takip-kohol, tapingan-daga (Tagalog), hahang-halo (Bisaya). Singapore: pegaga. Burma (Myanmar): min-kuabin. Cambodia: trachiek kranh. Laos: phak nok. Thailand: bua bok (central), pa-na-e khaa-doh (Karen, Mae Hong Son), phak waen (peninsular). Vietnam: rau m[as], t[is]ch tuy[ees]t th[ar]o.

Origin and geographic distribution *Centella* comprises approximately 40 species with an amazing diversity in South Africa, where all species are confined except *C. asiatica* which has a pantropical distribution including South-East Asia and extending into some subtropical regions.

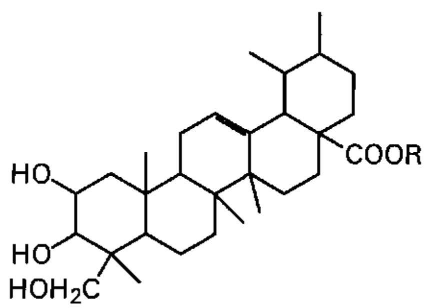
Uses Asiatic pennywort has been used in southern Asia, India and China since prehistoric times for a wide range of complaints. In China, it has been known for many centuries as a medicinal plant with tonic and cooling properties, and (together with *Hydrocotyle* spp.) is known in pharmacology as 'Folia Hydrocotyles'.

The most important use of the whole plant is in skin-related diseases. Fresh leaves, fresh juice, a decoction or an extract are applied, depending on the complaints. Several over-the-counter prepara-

tions recommended for skin care are available, containing various extracts of the plant or one of its constituents asiatocoside. Extracts are applied topically in the adjunct treatment of surgical wounds and minor burns. The extract is used effectively in the treatment of keloids, leg ulcers, phlebitis, slow-healing wounds, scleroderma, lupus, leprosy, surgical lesions, striae distensae, cellulitis and aphthae. Purified extracts are known to accelerate cicatrizing and skin grafting.
Orally, the extract is indicated to relieve the symptoms of venous and lymphatic vessel insufficiency, and used to treat atonic wounds and for hypertrophic healing. The direct application of Asiatic pennywort as a drug is only rarely prescribed in Western medicine. More frequently, standardized extracts are utilized; these are applied orally, intramuscularly or subcutaneously. Asiatic pennywort has a considerable reputation for treating epilepsy. In Ayurvedic medicine in India, it is one of the ingredients of a non-alcoholic anti-epileptic syrup which showed significant anti-epileptic activity in tests with rats. It is also used in India and Thailand as a tonic and to treat dysentery. In Sri Lanka, an extract is used in traditional medicine as a galactagogue. Dry leaves are one of the ingredients of pills taken in Vietnam against senility, and are also used successfully in a complex preparation against acute infective hepatitis.
Asiatic pennywort is a relished vegetable in many South-East Asian countries (with the exception of the Philippines) and also in Sri Lanka. The slightly bitter leaves are eaten raw or cooked. In Thailand, Vietnam, Cambodia and Laos a softdrink is made from the juice of the leaves; the juice is diluted with water and some sugar is added. The popularity of Asiatic pennywort as a vegetable and soft drink is certainly related to its medicinal properties.

Production and international trade The reported quantities of dried plants used by traditional drug manufacturers in Indonesia in the period 1991 to 1994 vary between 19–125 t/year. Most of Asiatic pennywort for commercial medicinal preparations comes from Madagascar. From 1979 to 1988, 26–96 t/year was exported from this country to all parts of the world for pharmaceutical use.
Fresh Asiatic pennywort is a common product on vegetable markets in South-East Asia. Usually plants are gathered from the wild, but it is cultivated commercially in Sri Lanka. No statistics are available. In Thailand a locally produced soft drink made from Asiatic pennywort is sold canned in supermarkets.

Properties Several triterpenoid compounds have been isolated from Asiatic pennywort, the most important ones being asiaticoside, madecassoside, asiatic acid and madecassic acid. These are considered the pharmacologically active principles. In ethanolic extracts compounds such as β-sitosterol and stigmasterol have been demonstrated.
Several animal tests have confirmed that extracts have a wound-healing effect, and this activity has also been reported from clinical studies with humans. Patients with burns, cellulitis, leprotic infections and skin ulcers have been treated successfully in controlled studies. Asiatic acid, madecassic acid and asiaticoside have been tested separately and in combination on skin human fibroblast collagen I synthesis in vitro. The mixture as well as each individual component stimulated collagen I synthesis to a similar extent. Collagen I is involved in wound healing. A mixture of brahmoside and brahminoside exhibits antispasmodic, antipyretic, central nervous system-depressant and hypotensive activity.
Asiatic pennywort has shown promising narcotic analgesic activity mediated through opiodergic receptors. The ethanolic extract exhibited anti-stress activity and activity against stress-induced gastric ulcer formation in rats, comparable to that of diazepam. In a clinical test in Italy, patients with chronic venous insufficiency of various etiology were treated with Asiatic pennywort at a dose of 60 mg/day during 4 months. For most patients the drug was effective against the subjective symptoms, but did not show significant changes in conjunctival capillaroscopy. In a multicentre, double-blind placebo-controlled study in France with patients suffering from venous insufficiency of the lower limbs, a significant difference was found in favour of a titrated extract of Asiatic pennywort



asiaticoside (R = glucose-glucose-rhamnose) for the symptoms of heaviness in the lower limbs and oedema. The venous distensibility was improved by the extract. The triterpene fraction of Asiatic pennywort has an effect on the metabolism in the connective tissue of the vascular wall and on the microcirculation. Treatment with the triterpene fraction for 3 weeks caused a significant reduction in the number of circulating endothelial cells in patients with post-phlebitic syndrome.

An aqueous extract of Asiatic pennywort showed activity against the herpes simplex II virus. The recovery of guinea-pigs with experimentally induced tuberculosis was hastened by treatment with asiaticoside. This compound promotes healing through bacteriostatic activity and stimulation of the reticuloendothelium.

The anti-tumour effect of the crude extract of Asiatic pennywort and of partially purified fractions has been studied by in vitro short and long term chemosensitivity and by in vivo tumour model test systems. The proliferation of transformed cell lines was inhibited more by the partially purified fractions than by the crude extract. The 50% effective doses on 3-hour exposure to the fractions were 17 μg/ml for Ehrlich ascites tumour cells and 22 μg/ml for Dalton's lymphoma ascites tumour cells. Hardly any toxic effects were detected in normal human lymphocytes. At a concentration of 8 μg/ml the partially purified fractions also significantly suppressed the multiplication of mouse lung fibroblast cells. Oral administration of the extracts retarded the development of solid and ascites tumours and increased the lifespan of these tumour-bearing mice.

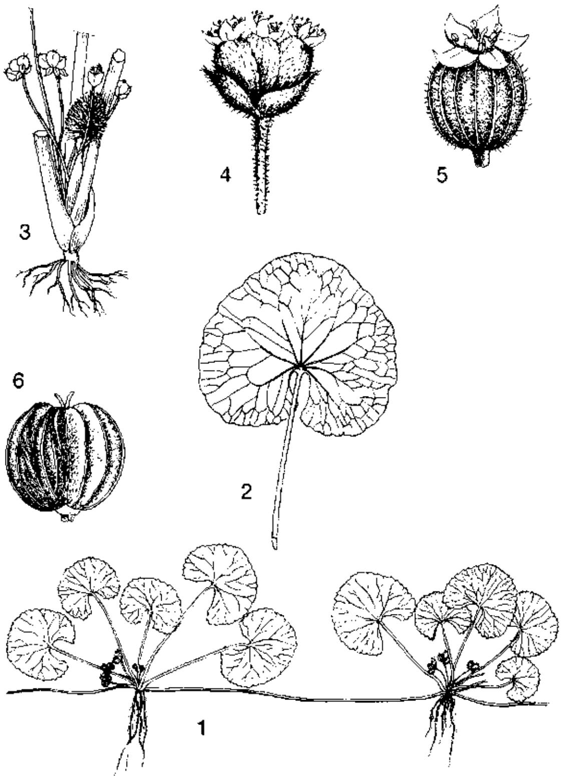
The sensitizing capacity of the raw extract and its triterpenic constituents asiaticoside, asiatic acid, madecassoside and madecassic acid has been studied in guinea-pigs. All were found to be very weak sensitizers; although applied frequently to damaged skin, the risk of acquiring contact sensitivity is low. The toxic dose of asiaticoside by intramuscular application to mice and rabbits is reported to be 40–50 mg/kg body weight. In oral applications, 1 g of asiaticoside per kg body weight has not proved toxic in rats. Asiatic pennywort is toxic in large overdose or as a result of long-term application. It can produce narcotic effects, headache, vertigo, and, occasionally in sensitive individuals, it may even lead to coma. Contra-indications include patients with cardiovascular disorders and internal bleeding. Besides the above activities, anti-amoebic and immunostimulant activity are also reported. Asiaticoside is related to chemical compounds with known oncogenic activity and it has been found to exhibit slight tumour-producing properties in experimental animals, but possible carcinogenic effects have not yet been investigated thoroughly. Reduction of fertility in female mice has also been reported for asiaticoside.

In the essential oil isolated by steam distillation from the aerial parts of Malaysian plants 41 compounds have been identified, with the sesquiterpenoids (80%) as the major category and β-caryophyllene (27%), α-humulene (34%) and germacrene-D (10%) as the most abundant. The major components in the essential oil from plants collected in Sri Lanka were α-copaene (14%), β-caryophyllene (12%), trans-β-farnesene (5%) and α-humulene (9%).

Per 100 g edible portion fresh leaves contain: water 88 g, protein 2 g, fat 0.2 g, carbohydrates 7 g, fibre 1.6 g, Ca 170 mg, P 32 mg, Fe 6 mg, provitamin A 4.5 mg and vitamin C 49 mg.

Adulterations and substitutes Asiatic acid and asiaticoside have also been demonstrated in the bark of *Schefflera heptaphylla* (L.) Frodin (syn. *S. octophylla* (Lour.) Harms), which is used in Vietnamese traditional medicine as a tonic and to treat rheumatism. Asiatic acid has also been found in ether extracts of the wood of *Terminalia brassii* Exell and *T. complanata* K. Schumann.

Description A small perennial herb, creeping with long stolons (up to 2.5 m long), rooting at the nodes; young parts more or less puberulous. Leaves in rosettes, simple, lamina orbicular-reniform, 1–7 cm in diameter, regularly crenate or crenate-dentate, palmately veined, subglabrous; petiole 1–40(–50) cm long, glabrous to puberulous, broadened at the base into a leaf-sheath; stipules absent. Inflorescence an axillary simple umbel, (1–)3(–7)-flowered with middle flower sessile and lateral flowers with a short pedicel and with involucre of 2 ovate bracts, 0.5–5 cm long peduncled, 1–5 together; scale-like leaves at base of peduncles about 3 mm long. Flowers bisexual, 5-merous; calyx obsolete; petals roundish to broadly obovate, 1–1.5 mm long, entire, greenish, pinkish or reddish; stamens alternate with the petals; disk 2-lobed, plane with elevated margin; ovary inferior, 2-celled, styles 2. Fruit consisting of 2 one-seeded mericarps connected by a narrow junction, separating when mature, oblate-rounded, strongly laterally compressed, 3 mm × 3–4 mm, mericarps distinctly 7–9-ribbed, ribs connected by veins, pubescent when young but often glabrescent. Seed laterally compressed. Seedling with epigeal germination; hypocotyl 2–4 mm long, glabrous; cotyledons



Centella asiatica (L.) Urb. – 1, plant habit; 2, leaf; 3, stem base with young leaf, flowers and fruits; 4, inflorescence; 5, flower; 6, fruit.

broadly ovate to elliptical, shallowly emarginate at apex, glabrous; epicotyl absent.

Growth and development Asiatic pennywort grows and flowers year round. In the Philippines, it is reported to be one of the main pollen sources for honeybees.

Other botanical information *C. asiatica* seems related to *Hydrocotyle* species, but there is morphological, anatomical, palynological and phytochemical evidence for retaining it in *Centella*. Morphologically, *Hydrocotyle* differs particularly in its 3-ribbed mericarps, its free stipules at the base of the petiole, and its peltate or reniform leaves, in the latter case with lobed margins.

In Sri Lanka, where Asiatic pennywort is cultivated as a vegetable, two cultivars are distinguished: a small creeping form, and an erect bushy form with large leaves and petioles. The latter cultivar is most popular.

Ecology Asiatic pennywort occurs in sunny or slightly shaded, damp localities on fertile soils (preferring sandy loams with much organic matter), e.g. along stream banks, on or near paths, alongside walls and in damp, open grassland, from sea-level up to 2500 m altitude. It is an early colonizer of fallowed land in shifting cultivation sytems, but may occur also on recently disturbed habitats and even on undisturbed sites. It may carpet the ground completely, but in regions with a monsoon climate usually only during the rainy season.

Propagation and planting Asiatic pennywort can be easily propagated vegetatively by runners which root on the nodes, although reproduction by seed is possible. It often regenerates from fragments of stems buried in the soil during hoeing.

Stem pieces with one node are planted directly in the field or first in a nursery. Shading is not necessary, but sufficient soil moisture is essential. In Sri Lanka, planting distance is 30 cm × 25 cm for the bush type cultivar and 15 cm × 15 cm for the creeping type cultivar. A planting distance of 50 cm × 60 cm has been reported from Indonesia and Malaysia. At planting, organic fertilizer is added at a rate of 1.5 kg/m^2. Runners can be planted directly in the field ploughed to 20 cm deep.

In vitro production of active compounds Cell suspension cultures of Asiatic pennywort can be grown on a modified Murashige and Skoog medium supplemented with growth regulators, 30 g/l sucrose and 500 g/l casein hydrolysate. They can be subcultured at intervals of 14 days in flasks on a shaker at 24°C and a 16-hour photoperiod.

Cell suspension cultures are used to convert the cytotoxic compound thiocolchicine, a hemisynthetic substrate obtained from natural colchicine (from seeds of *Colchicum autumnale* L.), to thiocolchicoside (3-O-glucosylthiocolchicine), a drug used as a myorelaxant and analgesic. The thiocolchicine can be administered to 7-day-old suspension cultures, and the glucosides are localized intracellularly. Thiocolchicoside accounts for 85% of the glucosides. The cultures have also shown the ability to oxidize papaverine to papaveraldine. There is no known in vitro production of the active compounds of Asiatic pennywort.

Husbandry Cultivated Asiatic pennywort does not need much care. A planting can be maintained for 2–3 years if only leaves are harvested. Every 6 months it needs to be fertilized with 1.5 kg/m^2 of organic material. Sometimes small amounts of urea are given, to stimulate leaf growth.

Diseases and pests Asiatic pennywort is relatively little affected by diseases and pests. Bacterial wilt caused by *Pseudomonas solanacearum* has been reported from Sri Lanka, and a leaf spot disease caused by *Cochliobolus geniculatus* has been reported from India.

Harvesting If circumstances are favourable, the first harvest can be obtained 2–3 months after planting. Subsequent harvests are possible every 2 months if only leaves are to be harvested. However, creeping types are usually harvested as whole plants. For medicinal use, whole plants are generally harvested at any suitable time of the year.

Yield Bushy types may reach 8 t/ha of fresh leaves for the first harvest, and 14 t/ha for each subsequent harvest. Yields of the creeping types are lower.

Handling after harvest After harvesting, plants to be used for medicinal purposes are stripped of their roots, cleaned with water and air-dried. The dried material should be kept in tightly closed containers and stored under dry conditions. Fresh leaves harvested as a vegetable are tied together in small bundles and marketed soon, as they wilt rapidly.

Genetic resources and breeding Considerable genetic variation may occur between natural populations, due to the wide distribution of Asiatic pennywort. However, there are no known germplasm collections.
In a study of the presence of asiaticoside in various Indian ecotypes it appeared that the asiaticoside content differed significantly among them, with the highest amount (about 0.11%) in ecotypes from subtemperate Himalaya. Selection of genotypes with high asiaticoside content should be considered for commercial exploitation for medicinal purposes. No breeding work is being done.

Prospects The medicinal value of Asiatic pennywort has been acknowledged in both traditional and modern medicine. Recent studies have confirmed the efficiency of the plant and its extracts in the treatment of skin injuries and diseases. Moreover, asiaticoside is reported to have considerable medicinal value against leprosy. Therefore, it is remarkable that hardly any commercial plantings exist. As a vegetable, however, cultivation on a larger scale is successful in Sri Lanka. Research on cultivation practices and breeding for specific purposes is needed prior to large-scale production in South-East Asia for medicinal purposes. A suitable method has already been developed for fingerprint analysis and standardization of all Asiatic pennywort preparations.

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Other selected sources 97, 193, 202, 311, 315, 332, 350, 395, 560, 580, 597, 602, 705, 901, 1035, 1066, 1126, 1178, 1287, 1386, 1572, 1590.

Djoko Hargono, Pudji Lastari,
Yun Astuti & M.H. van den Bergh

Chenopodium ambrosioides L.

Sp. pl. 1: 219 (1753).
CHENOPODIACEAE
$2n$ = 16, 32, 48, 64

Vernacular names Wormseed, Mexican tea (En). Philippines: alpasotis (general), adlabon (Igorot), bubula (Bontok). Vietnam: c[aa]y d[aaf]u h[oo]i, c[aa]y d[aaf]u giun, th[oor] kinh gi[ows]i.

Origin and geographic distribution *C. ambrosioides* is native to Central and South America, and has been introduced in Europe, Africa, Asia and Australia. In the Malesian region, it is naturalized in mountainous regions in Java, Sulawesi and the Philippines, and has occasionally been found in Papua New Guinea. Its cultivation in Java for medicinal purposes was abandoned because it was unprofitable. It is still cultivated in the Philippines.

Uses Wormseed is used all over the world as a vermifuge. It is an effective anthelmintic with a long history of use, and has been used in America since about 1800. Bruised fruits are administered in small doses or the juice from the plant is given undiluted or as a decoction in milk or water. It is effective against hookworms (*Ankylostoma duodenale*, *Necator americanus*), roundworm (*Ascaris lumbricoides*) and whipworm (*Trichuris trichiura*). The essential oil, which is generally considered as nervine and anti-rheumatic, is very effective against amoebae causing dysentery. Wormseed is also commonly used externally to treat ulcers, eczema and erysipelas. Crushed leaves are widely applied as poultices on bruises, insect bites and ulcers. In the Philippines, the leaves are also used as a carminative in poultices applied to the abdomen of children suffering from dyspepsia, and are also considered an emmenagogue. In Central America, it has been used as an antispasmodic and stomachic, and a decoction used to be administered as an internal haemostatic, as a remedy for indigestion and to treat ulcers. In Brail, wormseed is used in the treatment of cutaneous leishmaniasis. Additional uses reported from southern Africa and Mexico include the application of an infusion against colds and stomachache, as an enema against intestinal ulceration, diuretic, emmenagogue and as sudorific. In India, the essential oil is employed in pectoral complaints and nervous affections. 'Di-fu-zi' is a Chinese drug widely found on markets in China. It is derived from *Kochia scoparia* (L.) Schrader (synonym: *Chenopodium scoparia* L.), but sometimes also from *C. ambrosioides* or *C. album* L.; the preparation is known for its diuretic and antifungal properties.

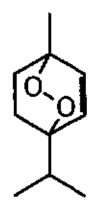
In Mexico, wormseed is used in animal health care, particularly to treat gastro-intestinal nematodes in sheep. Fish diseases caused by helminths (e.g. *Capillaria* spp., *Spirocamellanus* spp.) have been treated successfully in Mexico by using wormseed. Wormseed has been found to be unaffected by *Meloidogyne* spp., and can be used in crop rotations for sugar cane fields infested with these nematodes. In Africa Congo-Brazzaville, wormseed is traditionally used to protect groundnut from insect pests; it showed effective control of the beetle *Caryedon serratus*.

Wormseed oil or extract is used commercially as a fragrance component in lotions and perfumes. The herb is also used in Mexico as a condiment in soups, used sparingly to impart an acceptable flavour.

Production and international trade Wormseed was cultivated in the United States to control hookworms and roundworms until effective synthetic compounds became available in the 1950s. The annual world production of wormseed oil was estimated at 35 t by the end of the 1950s, but has since decreased. The price of the oil was US$ 22–31 per kg in 1983.

Properties The glandular hairs present on leaves and fruits exude an essential oil. Oil yield is highest for fruits, up to 2.5%. The oil is colourless or pale yellow, has a peculiar disagreeable odour and a bitter, burning taste. About 50 compounds have been identified in the oil, accounting for 97%. The major compounds in the essential oil are p-cymene, limonene (up to 32.5%), α-terpinene, trans-pinocarveol (up to 27%) and ascaridole (1,4-peroxido-p-menthene-2, up to 86%). The chemical composition of the oil seems to differ considerably depending on the origin of the plants and botanical variety. Limonene and trans-pinocarveol have been reported as the main constituents of the oil from Mexican plants, but high amounts of ascaridole have been reported in oil elsewhere. The flavonol glycosides kaempferol 3-rhamnoside-4'-xyloside and kaempferol 3-rhamnoside-7-xyloside, along with kaempferol, isorhamnetin and quercetin have been identified from the fruits. Per 100 g the leaves contain: 85 g water, 4 g protein, 0.7 g fat, 7.5 g total carbohydrates, 1.3 g fibre and 2.4 g ash.

The crushed plant, the expressed juice, the flower spikes, the seeds and the seed oil of *C. ambro-*



ascaridole

sioides are well known for their use as anthelmintics. The essential oil and its main component ascaridole, which is considered the main active principle, paralyze, but do not kill the intestinal worms; they must then be expelled by a laxative. Activity is reported against a variety of intestinal parasites, e.g. *Ankylostoma*, *Ascaris*, *Necator* and *Trichuris*. Leaf extracts also showed an in vitro activity against *Ascaris lumbricoides* eggs. The oil should be used with caution: mild reactions are headache, dizziness and nausea, but in overdose it can cause cardiac and respiratory disturbances, convulsions, drowsiness, vomiting and weakness. It should not be prescribed to persons with nervous, heart or kidney troubles, or to pregnant women.

The essential oil has fungitoxic activity. It has been found to show strong in vitro activity against the dermatophytes *Microsporum gypseum* and *Trichophyton rubrum*, and also against *Aspergillus fumigatus* and *Cladosporium trichoides*. Experimental ringworm infection in guinea-pigs was cured within 7–12 days by an ointment containing the oil. The essential oil inhibited growth of *Aspergillus flavus* effectively at 2000 ppm, and mycelial growth of *Rhizoctonia solani* (causing damping-off of seedlings of e.g. mungbean (*Vigna radiata* (L.) Wilczek) was totally inhibited by the oil at 1000 ppm on malt extract agar medium, without showing phytotoxic effects on germination and seedling growth. The lack of effect on germination and early growth of crops recorded in these experiments is contradictory to the allelopathic activity of wormseed oil and extract reported from other experiments. Storage for one year did not affect the fungitoxicity of the oil, neither did heating to 100°C. Dry residues of wormseed plants mixed with soil (10 g of residue with 90 g of soil) effectively controlled *Phytium aphanidermatum* and *Rhizoctonia solani* infection of common bean (*Phaseolus vulgaris* L.). At 1000 ppm wormseed oil was found to provide complete protection to stored wheat from all fungi investigated, without showing any phytotoxic effect. Ascaridole itself also has antifungal activity. In laboratory tests this compound gave over 50% inhibition of *Sclerotium rolfsii* (*Corticium rolfsii*) at a concentration of 1 mg/ml.

Experiments with mice showed that a methanol extract of the dried aerial parts of *C. ambrosioides* has a hypothermic effect at 2 g/kg, as well as inhibitive effect on acetic acid-induced writhing at 3 g/kg, suggesting that the plant has some sedative and/or analgesic effects. Separation and isolation using these bioassays revealed that these effects can be attributed to ascaridole. Oral administration of ascaridole in mice at a dose of 100 mg/kg showed a significant hypothermic and analgesic effect, prolonged the anesthesia induced by sodium pentobarbital and reduced the locomotor activity enhanced by methamphetamine. Doses of 300 mg/kg, however, had lethal toxicity.

Ascaridole is also reported to be a potent inhibitor of plasmodial growth in lower concentrations, and to kill malarial parasites in higher concentrations. It is effective at about the same dose as chloroquine and artemisinin. Like artemisinin the compound is one of the few naturally occurring terpenes bearing a peroxide group. This peroxide group must be essential for the antimalarial activity of ascaridole, because 1,8-cineol (which has an epoxide group instead of a peroxide group) at identical concentrations is inactive.

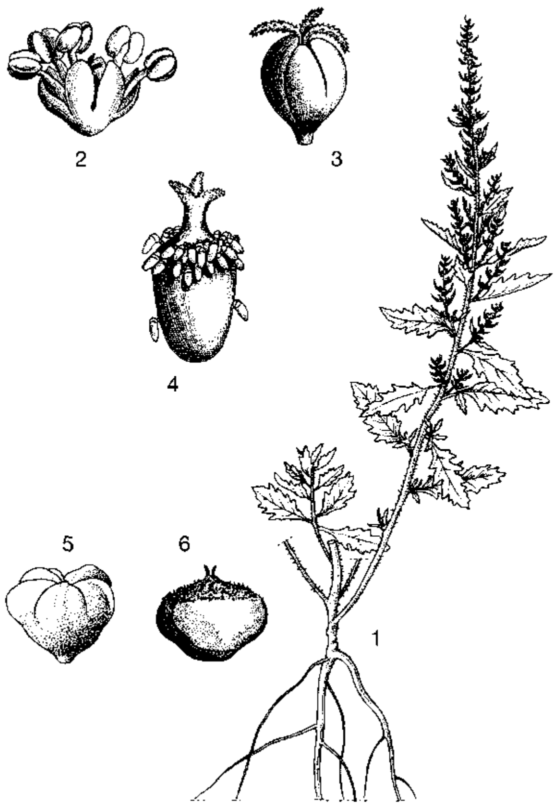
Wormseed contains saponin, which is located mostly in the roots; the aglycone fraction of the saponin is echinocystic acid. The saponin is reported to have antifungal and molluscicidal activity.

Wormseed kills and repells insects, and also acts as an antifeedant. Dried plants give stored products some protection against weevils and beetles. Foliage has been used successfully to control the gelechiid moth *Phthorimaea operculella*, a pest of stored Irish potato. Limonene is insecticidal against a variety of flies, mosquitoes, ants, beetles, weevils, fleas, wasps, crickets, ticks and mites.

The terpenes p-cymene, ascaridole and aritazone have an allelopathic effect, and may inhibit seed germination and seedling growth of other plants. Wormseed has a role in traditional agro-ecosystems in Mexico in controlling weeds and reducing nematodes. Farmers allow it to grow only when crops are ready to be harvested because of its allelopathic activity. Wormseed extracts showed a moderate antioxidant effect on feed fats. Leaf extracts are effective in inhibiting infection of crops such as common bean by tobacco mosaic virus.

Adulterations and substitutes In order to reduce the high ascaridole content to the minimum permissible requirement, synthetic chemicals corresponding to the constituents of the oil are frequently substituted for wormseed oil. Some *Artemisia* species were also popular as vermifuge in Europe, and commonly replaced wormseed there.

Description An erect or ascending annual herb up to 100(–150) cm tall, often very branched,



Chenopodium ambrosioides L. – 1, flowering plant; 2, bisexual flower; 3, female flower; 4, ovary with glands; 5, fruit enclosed by perianth; 6, fruit after removal of perianth.

strong-smelling; stem angularly ribbed, glabrous or finely pubescent. Leaves alternate, oblong-lanceolate, 1.5–15 cm × 0.5–5 cm, acute and often almost decurrent at base, acute to obtuse at apex, usually coarsely or shallowly serrate-dentate but highest leaves entire, herbaceous, bright green, lower surface variably densely studded with yellow glands, otherwise subglabrous, secondary veins thin; petiole short; stipules absent. Flowers in 3–25-flowered clusters in the axil of bractlike leaves, united in lax spikes together forming a leafy panicle, small, bisexual or some female, sometimes some male; perianth 4–5-cleft to near the base, 1–1.5 mm long, pale green with a paler base, with ovate-triangular, very concave segments; stamens (1–)4–5, filaments free, slightly exceeding the perianth; ovary superior, depressed globose, with many small, yellow glands on top, 1-celled, stigmas (2–)3–5; fruit a nut entirely concealed by the connivent tepals, 1-seeded. Seed usually horizontally in fruit, broadly obovoid or ellipsoid, 0.6–0.8 mm in diameter, shiny brownish-black.

Growth and development Wormseed flowers and fruits throughout the year. It produces massive amounts of seed.

Other botanical information *Chenopodium* comprises perhaps up to 250 species. *C. ambrosioides* is very variable and shows an extremely large area of distribution. Several infraspecific taxa have been distinguished giving rise to at least 12 different varieties. Most important are var. *ambrosioides* and var. *anthelminticum* (L.) A. Gray (synonym: *C. anthelminticum* L.) which are commonly cultivated in many warmer parts of the world.

Several other *Chenopodium* species are used in folk medicine in Central and South America for similar purposes as wormseed, e.g. *C. chilense* Schrader, *C. graveolens* Willd. and *C. multifidum* L.

Ecology *C. ambrosioides* occurs locally abundantly along roadsides and in waste places, sometimes also in upland rice fields; in Java it occurs at 1600–2000 m altitude.

Propagation and planting Wormseed is propagated by seed. It is reported that 6–10 kg/ha of seed is sufficient. Seeds germinate 7–21 days after sowing. Germination is promoted by light and optimum temperatures are 15–35°C. Imbibed seed should be pretreated with low temperatures. The optimal planting distance in Java is 1 m between rows and 0.5 m within the row.

Husbandry Wormseed needs plenty of water during early growth, but later it is quite drought tolerant. Large doses of N fertilizer reduce the ascaridole content of the plants; it is common practice to apply N fertilizer at 40 kg/ha. A leguminous cover crop, e.g. *Vigna hosei* (Craib) Backer ex K. Heyne, is sometimes used in Indonesia, making N fertilization redundant.

Diseases and pests In South America, downy mildew caused by *Peronospora* spp. is an important disease in cultivated *Chenopodium* spp., including wormseed. Weedy wormseed can be a host of powdery mildew; the disease can spread to tomato.

Harvesting Wormseed is harvested when the fruits are ripe. Usually they are stripped off by hand in the early morning and in dry weather.

Yield An experimental plantation in Java yielded about 8 t/ha of dried fruits during a period of 1.5 years with 3 successive harvests; after each of the first two harvests the plants were cut and fertilizer was applied. Fruits may yield 1–2% of oil on distillation, thus giving a yield of 80–150 kg of oil per ha. Experimental plantations in Germany yielded 70 t of fresh and 14 t of dried whole plant material per ha.

Handling after harvest Harvested fruits are sun-dried and cleaned from broken leaflets and flower remains by sieving. The oil is obtained by steam distillation at 130–140°C and at a pressure of 3.5–4 atmosphere. Pure oil can be obtained when cooled to 50°C or more.

Genetic resources and breeding Wormseed is spread worldwide and needs no protection measures. It exhibits considerable variation in morphology and chemical composition and offers potential for breeding for specific purposes (e.g. var. *anthelminticum* has a high proportion of ascaridole).

Prospects Although the importance of wormseed as anthelmintic has waned, it may have promising prospects for various uses. The leaves seem safe to be used as a medicinal tea, as long as it is not overused. Stored products such as beans could possibly be treated with wormseed oil for pest protection, provided there are no toxic effects for mammals. The effects of a wormseed crop in the control of weeds and nematodes in a rotation with field crops should be further investigated.

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Other selected sources 97, 332, 373, 374, 380, 733, 742, 979, 1035, 1126, 1149, 1178.

Undang A. Dasuki

Cinchona L.

Sp. pl. 1: 172 (1753); Gen. pl. ed. 5: 79 (1754).
RUBIACEAE
$x = 17$; *C. officinalis*, *C. pubescens*: $2n = 34$

Major species *Cinchona officinalis* L., *C. pubescens* Vahl.

Vernacular names Cinchona, quinine (En). Quinquina (Fr). Indonesia: kina. Malaysia: kuinin. Cambodia: kini:n. Thailand: quinin. Vietnam: canh ki na.

Origin and geographic distribution *Cinchona* comprises about 50 species. The centre of diversity lies along the Andes mountains of Bolivia, Peru, Ecuador, Colombia and Venezuela. There the species and natural hybrids flourish on the misty and humid eastern slopes at 800–3000(–3700) m altitude.

The collection of *Cinchona* germplasm for dispersal outside its centre of origin started in 1848. Hasskarl's expeditions to South America (1852–1854) provided the Dutch in Java (Indonesia) with plant material. A British expedition under Markham did likewise for India and Sri Lanka (1859). In both cases, the plant material adapted to the local conditions with no problems. However, the bark of the vigorously growing trees appeared to contain such small amounts of quinine that it was not profitable to start cultivation. Seeds Ledger (1864) collected in Bolivia produced weakly growing seedlings in Java, some of which had an unusually high percentage of quinine in the bark. Meanwhile, seed samples from South America and from importations from surrounding countries had arrived in nearly every country of South-East Asia.

Cinchona started to be distributed worldwide in the second part of the 19th Century. Around 1880, Sri Lanka had become a major producer of cinchona bark, albeit of low quality. By 1895 it had been superseded by the Dutch East Indies (Indonesia) as the main producer, mainly because of the better quality of the bark (*C. officinalis*). The crop was introduced into West and East Africa (Guinea, Cameroon, Kenya, Tanzania) and Central Africa (Congo Kinshasa, Rwanda) in the 1930s. In all of these countries, except for Congo Kinshasa, production has dwindled. After the rapid decline of bark production in South America around 1880, interest revived in Latin America around 1940, especially in Guatemala, but declined sharply after 1945.

In Asia, *Cinchona* cultivation is still important in Indonesia and India. The plantations in Burma (Myanmar), the Philippines, Sri Lanka and Vietnam have been abandoned, as have those in Australia (Queensland) and Papua New Guinea.

Uses The Spanish conquerors of Central and South America reported the use of cinchona bark by Indian miners in the Andes to suppress shivering from the cold in the mines. Later, Jesuits found that shivering was caused by fever. This led to the discovery of cinchona bark as a remedy against malaria. Anti-malarial drinks containing small quantities of quinine, one of the major alkaloids found in cinchona bark, were developed for use in the tropics especially in India; they are still very popular (e.g. tonic water).

Malaria is a disease mostly found in tropical areas, where it constitutes a major medical problem. It is characterized by attacks of severe fever, which recur at regular intervals. There is also a form with irregular attacks of severe fever. The disease is caused by a parasitic protozoan of the genus *Plasmodium*, which uses mosquitos of the genus *Anopheles* as an intermediary host. When an infected mosquito bites a person, sporozoites enter the blood, but they disappear rapidly from the circulation to localize in the parenchymal cells of the liver in which they grow and segment. On reaching maturity these merozoites are released from the liver cells and penetrate erythrocytes where further division and development takes place. When this process is complete, the erythrocytes burst open and the merozoites enter the blood stream. It is this periodic breaking of erythrocytes that induces the chill so characteristic of malaria. The fever following the chill is the body's response to the liberated foreign protein and cell products.

Some of the merozoites infect new blood corpuscles, while others develop into the sexual form, called gametes. The gametes can pass to a healthy mosquito when it bites a person suffering from malaria. The gametes conjugate in the mosquito, forming sporozoites, and the circle is complete. Quinine acts by killing the merozoites in the blood, except for those in the reproductive stages.

Quinine has largely been replaced by synthetic anti-malarials (e.g. chloroquine), which have fewer side-effects. In recent years, however, renewed interest has arisen in quinine and related alkaloids because of the growing resistance of malaria-causing agents (*Plasmodium* spp.) to industrial anti-malarial drugs currently in use. Additionally, large amounts of quinine are used as a bitter flavouring in soft drinks and in innumerable other products, such as hair oils and shampoos, sun-tan oil, insecticides, as a vulcanizing agent in the rubber industry, and in the preparation of certain metals.

Another cinchona alkaloid, quinidine (a stereoisomer of quinine) is also active against malaria, but is nowadays mainly employed as an anti-arrhythmic. Minor uses of cinchona alkaloids include the treatment of ophthalmia, internal haemorrhoids and hiccups. A tincture has been used as a bitter to stimulate appetite and digestion. The alkaloids are also used in insecticides and moth repellants. Other applications of cinchona alkaloids are in the asymmetrical catalysis of chemical reactions. After extraction of alkaloids, the bark is still useful for tanning leather.

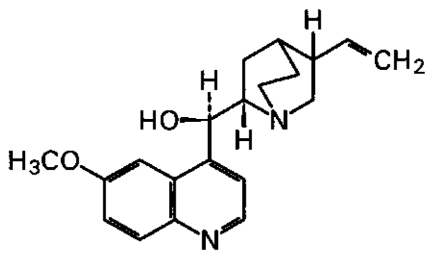
Production and international trade Indonesia maintained an almost total monopoly on the production of cinchona bark for nearly 50 years, up to the Second World War. In terms of ready product, this amounted to roughly 800 t/year of quinine sulphate. Since the Second World War, Indonesia has been gradually caught up and surpassed by Congo Kinshasa, although substantial quantities of quinine sulphate are still being produced in Indonesia, Guatemala, Tanzania and other countries.

International trade figures are often difficult to interpret because of the varying ways the quinine content of cinchona bark is indicated. In the past SQ2 and SQ7 were used most frequently, indicating 2 and 7 water molecules respectively. Nowadays, percentages are generally indicated as QAA, the anhydrous form of quinine salts: 1% QAA = 1.206% SQ2 = 1.345% SQ7.

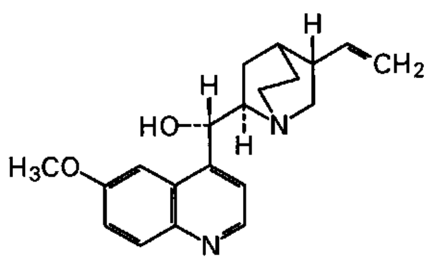
At present, world production of cinchona alkaloids is estimated at about 600 t/year of QAA, for which about 10 000 t of bark are extracted, with Congo Kinshasa producing about 55%, Indonesia 30%, India 8% and the other countries 7%. Stripe canker (*Phytophthora cinnamomi*) is a threat to production in East and Central Africa.

Although there are factories in bark-producing countries (Indonesia, India, Guinea, Congo Kinshasa and Rwanda) that extract alkaloids, most of the end-products are still manufactured in Europe (West Germany, the Netherlands, France). About 60% of the production is used for pharmaceuticals, most of the remaining 40% in the food and beverage industry.

Properties More than 36 different alkaloids have been reported as constituents of various *Cinchona* barks, the most important being quinine, quinidine, cinchonine and cinchonidine. Biosynthetically, these alkaloids are derived from the amino acid tryptophan and a monoterpenoid skeleton of the *Corynanthe* type. Quinine and quinidine are stereoisomers, their difference being the configurations at C-8 and C-9. Cinchonine and cinchonidine form another set of stereoisomers which lack the methoxy group at the C-6' position. Quinine and quinidine are of medicinal value; they are used to treat malaria and cardiac arrhythmias, respectively. Approximately 30–50% of the quinine produced is chemically converted to quinidine. The other alkaloids are not used medicinally, although they show effects similar to quinine and quinidine. Cinchonine showed inhibition of human platelet aggregation.



quinine



quinidine

The composition and content of alkaloids vary with species, genotype, environment and age of the bark. Generally, the alkaloid concentration is higher in bark from the bole than in branch bark. Selected clones of *C. officinalis* have been reported to yield as much as 14–16% quinine from dry bark. Normally, *Cinchona* bark has a total alkaloid content of 3–15%, and pharmaceutical bark must contain at least 6%. The quinidine content is generally low: about 1% of the total amount of alkaloids. Quinine can be converted into quinidine by means of a rather complicated chemical process. Alkaloids known as the cinchophyllines have been isolated from leaves of *C. officinalis*; they may be regarded as indole analogues of emetine and have shown in vitro amoebicidal activity. Research on the anti-microbial activity of a series of quasi-dimeric alkaloids found activity against gram-positive bacteria, but no activity against gram-negative bacteria, yeast and several fungi. A weak local anesthetic activity was found for cinchophyllamine, as well as some analgesic activity.

Adulterations and substitutes Numerous plant resources have been used and are still used in traditional medicine to treat malaria. One of the most important alternatives to cinchona is the herb *Artemisia annua* L. (or its isolated active compound artemisinin), which is widely used in Vietnam and China ('Quinghaosu'). Other species used in traditional medicine to treat malaria that have recently shown in vitro antiplasmodial activity are *Azadirachta indica* A.H.L. Juss., *Brucea javanica* (L.) Merr., *Cyclea barbata* Miers and *Dichroa febrifuga* Lour.

Description Evergreen woody shrubs or small to medium-sized trees, 8–16 m, occasionally up to 30 m tall; bark thick, greyish-brown to brown. Leaves opposite, oblong-elliptical, simple and entire; stipules interpetiolar, deciduous and leaving a characteristic scar. Inflorescence a terminal panicle, many-flowered. Flowers 1–2 cm long, fragrant, 5-merous, heterodistylous, pink or yellowish; calyx small, with pointed lobes; corolla tubular with spreading lobes with a fringe of hairs along the margins; stamens alternating with the corolla lobes and inserted in the corolla tube; ovary inferior, bilocular, style at the base with a circular disk, ending in a bifid stigma. Fruit a 1–3 cm long capsule containing 40–50 seeds. Seeds flat, winged, 4–5 mm × 1 mm.

Growth and development Freshly harvested *Cinchona* seeds include varying numbers of im-

mature and deteriorated ones. After these have been removed the germination percentage is usually more than 90% after 2–3 weeks of incubation. The seeds remain viable over a year if stored dry, cool and dark. Light promotes the germination.
The tiny seedlings develop slowly at first but then speed up: after about 2 months 2–3 pairs of leaves have formed. Flowering starts after 4–7 years or even earlier under stress conditions. There is a periodicity in flowering which has not been fully investigated. Cross-pollination is by insects, mainly bees, butterflies and flies. Fruits mature about 7–8 months after flowering.

Other botanical information Most *Cinchona* cultivated in South-East Asia is known under the name *C. ledgeriana*, and most probably are high-yielding selections of *C. officinalis*. *Cinchona* known under the name *C. succirubra* belongs to *C. pubescens*.
The majority of the species and hybrids from the centre of diversity do not produce valuable chemical compounds, but might nevertheless be of interest for breeding.

Ecology In the natural habitat of *Cinchona*, high, evenly distributed annual rainfall (up to 4000 mm) and high relative humidity prevail. *Cinchona* grows optimally with a rainfall of 2500–3800 mm well distributed throughout the year. Nevertheless, *Cinchona* is known to grow under drier conditions as well (1500 mm, with distinct dry season) and it can stand an annual precipitation of 5000 mm, provided this is well distributed throughout the year. Low irradiation (misty slopes, forest canopy) is frequently encountered in regions where *Cinchona* occurs naturally. In Asia, *Cinchona* grows well in areas with an average minimum temperature of 14°C and an average maximum temperature of 21°C. Growth is hampered severely below 7°C and above 27°C. Altitudinal range is largely determined by the prevailing climatic conditions, but generally lies between 800–2000 m. It has been reported that the yield of quinine is low in plants cultivated under 800 m altitude, and that the plants are susceptible to diseases. Growth is slow at elevations above 2000 m. *Cinchona* cannot stand waterlogging.
Favourable soil types are slightly acid, well drained, with a good water-retaining capacity. *Cinchona* grows well on soils of volcanic origin. The most important species, *C. officinalis*, is very vulnerable to weed competition; *C. pubescens* is more competitive.

Propagation and planting *Cinchona* is propagated by seed as well as by vegetative means. Seedbeds are carefully prepared to give a fine tilth. The small seeds are broadcast on the soil surface (3000–12 000/m^2 corresponding with 1–4 g/m^2) and protected against wind, rain and direct sunlight. Germination starts within 2–3 weeks; after 4–6 months plantlets are 5–10 cm tall and are moved to nursery beds where they stay 6–7 months. The seedlings require temperature, light and ventilation to be carefully controlled, to avoid damping-off and other hazards. Young plants can be transplanted to the field when 1–1.5 years old. The rather delicate *C. officinalis* is often grafted on the more robust and vigorous *C. pubescens*. Seedlings of the latter reach the proper size for grafting after about 1 year. The scion is usually inserted by side-tongue grafting, but green-budding is also applied. Cuttings are difficult to root; cuttings taken from shoots formed after topping give better results.
The isolation and multiplication of high-yielding or disease-tolerant trees by in vitro culture techniques is a promising new method that may result in high-yielding and disease-resistant clones being available for planting in the near future. In vitro micro-grafting of *C. officinalis* on *C. pubescens* has proved to be successful and is comparatively simple.
Cinchona is almost exclusively grown as an estate crop, except in Congo Kinshasa where smallholders occasionally grow it. It is mostly grown as a sole crop, although in Congo Kinshasa it is occasionally intercropped with beans. *Cinchona* is planted in the field in holes of 50 cm × 50 cm × 50 cm, 80–150 cm apart, in rows or in a triangular arrangement depending mainly on the topography of the field. Before planting, the plants are pruned back about one-third, or defoliated by 50%. The planting out takes place at the beginning of the rainy season. Leguminous cover crops may be planted between the rows (e.g. *Desmodium* in Congo Kinshasa, *Crotalaria trichotoma* Bojer or *Shuteria vestita* Wight & Arnott in Indonesia) or on the contour to prevent erosion (e.g. *Leucaena leucocephala* (Lamk) de Wit).

In vitro production of active compounds In recent decades, much attention has been paid to the biosynthesis of cinchona alkaloids in in vitro cell, tissue and organ cultures. Fine cell suspensions do not produce alkaloids, and only cultures showing some form of differentiation produce alkaloids in reasonable amounts. Studies of possible biotechnological production of alkaloids with plant cell cultures are in progress, but have not yet led to large-scale processes.

Hypocotyl explants from seedlings can be induced to form callus on solid Gamborg B5 medium (0.7% agar), containing 2,4-dichlorophenoxyacetic acid (1 ppm) and kinetin (0.2 ppm). Alkaloid production is low and growth slow in cell and tissue cultures. It has been found that growth and indole alkaloid production (e.g. cinchonamine) was improved by increasing the auxin concentration in callus cultures, but anthraquinone production and quinoline alkaloid levels (e.g. quinidine) were highest when auxin concentrations were reduced. Low and medium cytokinin concentrations benefit the production of quinoline alkaloid. Adding the precursor tryptophan increases the amount of alkaloids produced, but reduces growth. The best growth was obtained in the light, although many media resulted in no growth at all in the light. From the results of the experiments with tissue culture it was concluded that the pathways leading to the various secondary products (anthraquinones, indole alkaloids and quinoline alkaloids) are, at least partly, regulated independently.

Husbandry Two systems of cultivation are applied:

- A short-term, intensive, high-production system with a relatively short production cycle of about 10 years from planting to harvesting. It is practised mainly in Congo Kinshasa. Planting is at densities of 10 000–12 000 plants/ha. Weeding is mostly by hand, although the use of herbicides is increasing. Around the third year after planting, weeds are shaded out because of the development of the canopy. At the same time pruning and thinning starts, producing the first harvest of low-quality bark. Thinning continues until, around 10 years after planting, a stand of 3000 well-shaped trees is left. These are then harvested completely, producing a minimum of 3.5 kg of high-quality bark per tree.
- A long-term, extensive, intermediate-production system with a longer occupation period. It is practised in Indonesia and Guatemala. Planting is at a density of 5000 plants/ha. Weeding is necessary over a longer period, while pruning is only carried out to shape the trees. After 7–8 years, when competition for light becomes a limiting factor, all trees are coppiced to a height of 15–20 cm. In maintaining a maximum of 2–3 shoots per stool, a new cycle is started which is treated in the same way as the first one. If proper care is taken and mortality after coppicing is not too high, this system of production can be maintained for several decades. It is also suitable for *Cinchona* cultivation under the shade of rainforest trees, which are left to prevent serious erosion.

A combination of both systems is practised in West Bengal (India), where *C. officinalis* seedlings are first coppiced and then after completion of the second cycle, harvested completely. Modifications of these 2 systems have been developed to meet local conditions. One involves grafting clonal *C. officinalis* or hybrids on a rootstock of *C. pubescens*, giving uniform planting material, better growth and tolerance or resistance to *Phytophthora cinnamomi*. This method is practised in Indonesia and Guatemala.

Composite fertilizers such as NPK (20-10-10 or 15-15-15) are widely applied, although other compounds such as phosphates and oligo-elements are used as well, depending on the local conditions. In general, a final dressing of nitrogenous fertilizer (100–600 kg/ha of the above-mentioned NPK) about 6 months prior to harvest increases the alkaloid content of the bark. Where soils are low in organic matter, *Cinchona* responds well to the mulching.

Mechanization is not widespread in *Cinchona* cultivation, partly because of the fields are often undulating. For the time being, it is mainly limited to the application of herbicides and insecticides and, to a lesser extent, to the harvest and stripping of the trees. However, mechanization is becoming more important where labour is scarce.

Diseases and pests Seedlings are susceptible to *Pythium* spp., *Rhizoctonia solani* (causing damping-off), *Fusarium solani* (causing wilt), *Phytophthora cinnamomi*, *Sporotrichium* and *Verticillium* species (causing stem blight) and *Sclerotium rolfsii* (causing seedling blight). Attacks can easily be overcome by chemically sterilizing the seedbed, and by regularly shifting the nursery site. In later stages, *Cinchona* is vulnerable to *Phytophthora cinnamomi*, *P. parasitica* (causing top blight and girdle canker), *Corticium salmonicolor* (dieback of branches), and *Armillaria* sp. (root rot). Other fungi (*Alternaria*, *Cercospora* and *Sclerotium* spp.) are of little economic importance. In areas with *Phytophthora cinnamomi* and *P. parasitica*, a combination of cropping techniques (e.g. cover crops) should be practised to avoid infestation, because once these diseases have taken hold the application of fungicides is almost impossible and too expensive. *Phytophthora cinnamomi* can also be avoided by grafting on a *C. pubescens* rootstock. The outbreak of *Corticium salmonicolor* can be avoided by timely pruning of trees, and of *Armil-*

laria sp. and *Fomes noxius* by consistent removal of old stumps. There are indications that insufficient drainage and planting too deep may favour the incidence of a physiological canker.
The main pest in *Cinchona* is *Helopeltis* spp., which can cause considerable damage by sucking young shoots and leaves. *Helopeltis* outbreaks can be avoided by timely application of insecticides. Occasional outbreaks of other pests such as various caterpillars (e.g. *Delephila nerii*) and borers occur, but are only of local importance.

Harvesting In general, two phases of harvest can be distinguished: pruning and thinning in the early years and the final harvest.
The bark is removed in various ways. In Indonesia and Congo Kinshasa, bark is removed by clubbing, but in Tanzania and Guatemala knives are used. Bark peeling machines are used occasionally.

Yield Pruning and thinning result in relatively low yields of bark and alkaloids. At the final harvest, yields of at least 10 t/ha of dry bark are obtained with the short-term production system. The bark from selected planting material may contain at least 7% QAA on average, resulting in more than 700 kg/ha of QAA. Both bark yield and alkaloid content vary considerably, as they are affected by various factors.
Yields from the long-term production system are generally lower in terms of production per ha per year. However, this system can be more advantageous in terms of return on investment.
As a guideline, industrial *Cinchona* plantations should produce an average of 50–100 kg/ha per year of QAA to give a safe return on investment. A plantation should be at least 300 ha in size to sustain the initial and overhead costs involved.

Handling after harvest The stripped bark is left to dry, preferably in the shade, or dried artificially. Drying in the open air has to be well supervised, because heating of wet bark may result in substantial losses of alkaloids. The bark should be spread thinly and turned over regularly. It is ready for further treatment when its moisture content is about 10%. Properly dried bark can be kept for several months without deterioration. It can be milled before packing, to facilitate shipment over long distances. Extraction and processing of the alkaloids to either totaquina, quinine bisulphate, quinine sulphate, quinine HCl or quinidine is mainly carried out in western Europe.

Genetic resources and breeding The dispersal of *Cinchona* seeds in the mid-19th Century is well documented. However, the limited survival rate of seeds and the destruction of earlier, low-yielding introductions have resulted in a very limited genetic variation in the germplasm available outside the centre of diversity. Care should be taken to preserve the germplasm present in the centre of diversity for future use. Most work on breeding has been carried out in Indonesia. At an early stage it was concluded that besides a high quinine content, other parameters such as bark production, tree shape and vegetative growth were also important in determining yield. The 'ring method' was developed; this involves calculating the amount of quinine (in g) in a ring of bark 1 dm in width, at a height of 1 m, by multiplying the girth (in dm) at that height by the amount (in g) of water-free bark/dm^2 and the average quinine content of the bark. However, since the girth of a tree is a function of the plant density, this method proved insufficiently reliable for judging the amount of bark.
In 1931, some *C. officinalis* seeds of Indonesian origin had reached Congo Kinshasa to start a selection programme at the Mulungu experimental station near Bukavu. Elite trees were selected from the original population, vegetatively propagated, and planted in isolation. Seeds from these plots were harvested and distributed to local farmers and plantation enterprises. This policy resulted in rapid progress in bark production in Congo Kinshasa and neighbouring countries. Quinine percentages of up to 15% QAA were found in trees of about 10 years. However, there has been little further progress since the mid 1960s.
In India, breeding work has focused on selection of elite types, vegetative propagation of these types for industrial plantings, and controlled crosses between selected parents. Various methods of vegetative propagation have been tried: cuttings, air layering, budding, grafting, inarching. Budding and the production of cuttings by top-working have been most successful. This breeding programme has not been very successful, as the quality of the bark has not improved over the years. In the 1940s and 1950s a breeding programme was undertaken in Guatemala: hybrids of *C. pubescens* and *C. officinalis* were grafted on a *C. pubescens* rootstock or planted as cuttings. However, this programme was short-lived. Most breeding programmes have been abandoned (Congo Kinshasa, Guatemala) or give disappointing results (India, Indonesia). However, progress could be achieved for instance, by producing and distributing selected plant material, selecting suitable *C. pubescens* rootstocks to be used for grafting, and breeding for appropriate rooting architecture and disease re-

sistance in *C. officinalis.* Although not much progress is to be expected in obtaining higher quinine content in selected individuals, there is potential to increase QAA production per ha per year by at least 50%. In Indonesia, over 300 clones of *C. officinalis* and *C. pubescens* are maintained in germplasm collections.

Prospects Interest in *Cinchona* has recently been increasing. Vegetative propagation by means of tissue culture has provided a tool for more effective breeding programmes. It will play an increasingly important role in future plantings. The introduction of high-yielding, multi-line cultivars may improve productivity significantly. Improved cropping techniques (e.g. mechanization) will play an important role in the economics of the crop. Research has also been focused on the production of alkaloids by means of cell culture. Although stable cultures have been successfully established and small quantities of QAA have been produced, this method is still far removed from industrial application. *Cinchona* alkaloids have played a useful role in human life for more than 350 years. There are encouraging prospects of obtaining higher production levels at lower costs. This may be an important contribution in future malaria treatment, since the need for a cheap, effective therapy is becoming more important because of the increasing occurrence of this disease.

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Selection of species

Cinchona officinalis L.

Sp. pl. 1: 172 (1753).

Synonyms *Cinchona calisaya* Wedd. (1848), *Cinchona ledgeriana* Moens ex Trimen (1881).

Vernacular names Crown cinchona, Ledger cinchona, yellow cinchona (En).

Distribution Naturally distributed in South America from Colombia to Bolivia; planted in many tropical countries, e.g. in India and Indonesia (Java).

Uses The bark is the traditional source of quinine, the classical industrial anti-malaria drug.

Observations A small tree, up to 16 m tall; leaves 7–28 cm × 2.5–13 cm, glabrous and with domatia beneath; flowers with glabrous calyx and yellowish-white to fleshy-coloured or red corolla, 8–17 mm long; fruit up to 25 mm long, glabrous or sparsely pubescent. *C. officinalis* occurs naturally in mountainous regions at 1200–3000 m altitude. In Java, it is planted at 800–2000 m.

Selected sources 97, 99, 202, 501, 580, 900, 1167, 1178, 1277.

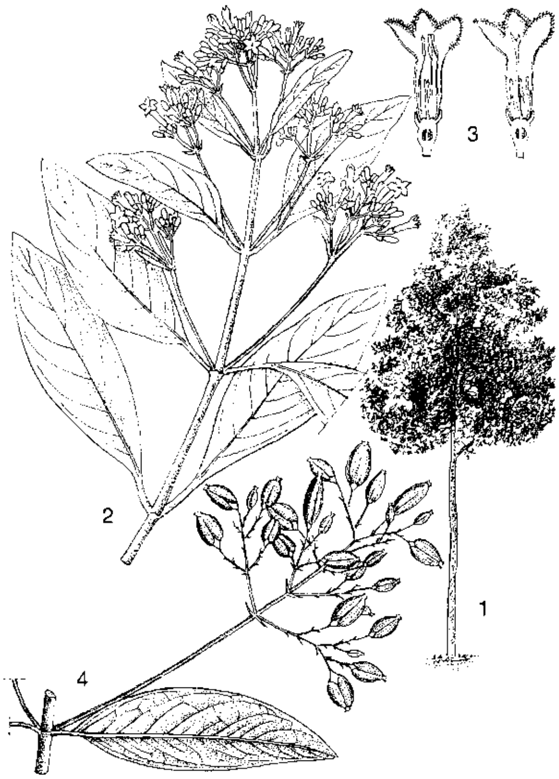
Cinchona pubescens Vahl

Skrivt. Naturh. Selsk. 1: 19 (1790).

Synonyms *Cinchona cordifolia* Mutis (1793), *Cinchona succirubra* Pav. ex Klotzsch (1858).

Vernacular names Red cinchona (En).

Distribution Naturally distributed in Central



Cinchona officinalis L. – 1, tree habit; 2, flowering twig; 3, flowers in longitudinal section showing heterodistyly; 4, fruiting twig.

and South America from Costa Rica to Bolivia; planted in many tropical countries, e.g. in India and Indonesia (Java).

Uses The bitter constituents of the bark are a traditional anti-malarial of South-America, and have been used in the Malesian region since the 19th Century. The quinine is rather difficult to extract from the bark; also used as rootstock for *C. officinalis*.

Observations A small to medium-sized tree, up to 30 m tall; leaves 24–50 cm × 17–40 cm, pubescent and without domatia beneath; flowers with calyx pubescent outside and greenish-white corolla reddish towards lobes, 15–21 mm long; fruit (20–)30–40 mm long, initially pubescent but glabrescent. *C. pubescens* occurs naturally in mountainous regions at 1000–3700 m altitude. In Java, it is planted at (1000–)1250–1600(–2000) m.

Selected sources 97, 99, 202, 350, 501, 580, 900, 1167, 1178, 1277, 1640.

G. Staritsky, E. Huffnagel, A. Dharmadi & S.L. Dalimoenthe

Cissampelos pareira L.

Sp. pl. 2: 1031 (1753).
MENISPERMACEAE
$n = 12$

Vernacular names Indonesia: mangaloke (Moluccas). Philippines: sansau (Tagalog), sampare (Bisaya), kalaad (Iloko). Thailand: khong khamao (northern), khruea ma noi (eastern), krung khamao (peninsular). Vietnam: d[aa]y m[oos]i, m[oos]i tr[of]n, ti[ees]t d[ee].

Origin and geographic distribution *Cissampelos* consists of 20–25 species and has a pantropical distribution.
Only the pantropical *C. pareira* var. *hirsuta* (Buch.-Ham. ex DC.) Forman occurs in Malesia. In Asia it is found from Nepal and India, through Burma (Myanmar), Indo-China, southern China, Thailand and Malesia (but is not known from Peninsular Malaysia, Sumatra and Java), to Australia (Queensland).

Uses Preparations of *C. pareira* have a large array of uses in tropical countries and are applied against a variety of complaints. For instance, the root decoction is used to treat complaints in the following organs:
- Urinary tract: diuretic (the Philippines, Thailand, India, Africa, Central and South America), acute and chronic cystitis (India), solvent of urinary calcifications (the Philippines, India, Africa, Madagascar, Central and South America).
- Gastro-intestinal tract: colic (antispasmodic action: Indo-China, South America), purgative (Africa, Madagascar), diarrhoea (Thailand, Africa), dysentery (India), emetic (Madagascar).
- Genital tract: emmenagogue (Thailand, Africa, Central and South America), painful menstruation and pre- and postnatal pains (antispasmodic action: South America), prevention of a threatened miscarriage (South America), to stop uterine haemorrhages (South America).
- In general: febrifuge (the Philippines, Thailand, India, Africa, Central and South America), pectoral (the Philippines), cough (Africa), blennorrhoea (Indo-China), heart trouble (India), rheumatism (Africa, Central and South America), jaundice (Thailand, Central and South America), treatment for snake bites (Africa, Central and South America), sores (externally, Thailand, India).

The (pounded) leaves are applied to snake bites (the Philippines), they are used to cure scabies (the Philippines), in the treatment of abscesses, wounds and ulcers (Thailand, India, Africa, Central and South America) and as a stomachic (India). The plant is locally used by tribals in India in prevention of pregnancy.

The leaves, crushed in water, give a jelly which is used as a refreshment. In the Philippines, the fibres of the bark are made into ropes, which are used as a fish poison.

Production and international trade *C. pareira* is only used in local medicine and is not traded on the international market.

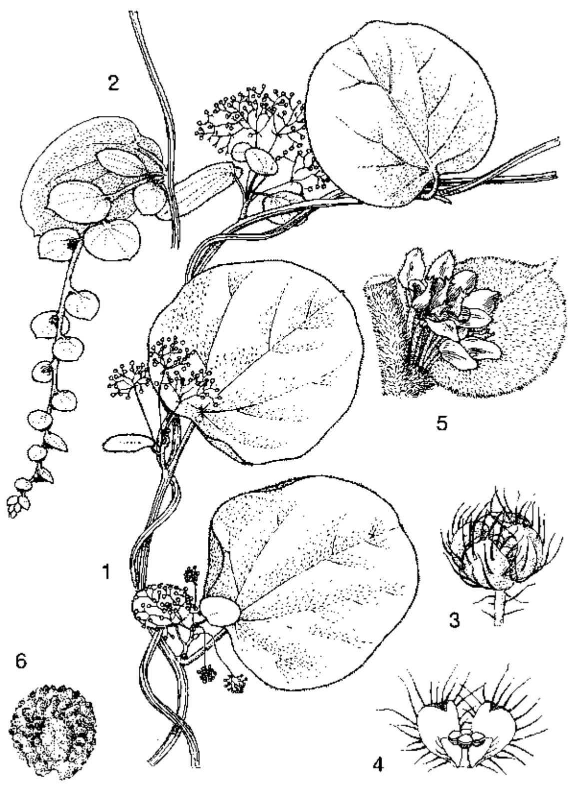
Properties *C. pareira* contains a number of alkaloids, especially bisbenzylisoquinoline alkaloids: hayatine (= d,l-bebeerine = d,l-curine), hayatidine (= d,l-4'-O-methylbebeerine = d,l-4'-O-methylcurine), hayatinine (= l-4'-O-methylbebeerine = l-4'-O-methylcurine), d-4'-O-methylbebeerine (= d-4'-O-methylcurine), l-bebeerine (= l-curine), d-isochondodendrine, d-dicentrine, d,l-dehydrodicentrine, d-insularine (all from roots), l-cycleanine (from roots and leaves) and cissampareine (from plants). Hayatinine (in the form of its methochloride) has been evaluated for its muscle-relaxant properties. The molecule is structurally very similar to that of d-tubocurarine from *Chondrodendron tomentosum* Ruiz & Pavón (*Menispermaceae*, South America) and also shows comparable neuromuscular blocking activities. Both have a non-depolarizing mode of action, and the blocking site is at the cholinergic (nicotinic) receptor in the postsynaptic membrane. Additionally, l-cycleanine has shown significant inhibition of nitric oxide production in vitro, and reduced the level of tumour necrosis factor in vivo, using a mouse model for fulminant hepatitis.

The roots have also been found to be a rich source of tropoloisoquinoline alkaloids. Using bioassay-directed purifications, guided by cytotoxicity against P388 cells, pareirubrine A, pareirubrine B, grandirubrine, isomerubrine and pareitropone have been isolated, all of which showed potent antileukemic activity. Furthermore, two cytotoxic azafluoranthene alkaloids, structurally strongly related to tropoloisoquinoline alkaloids, have been isolated from the same root extract. One of the tetrahydroprotoberberine group of alkaloids, cissamine chloride (= cyclanoline chloride) has been isolated from the roots. *C. pareira* exhibits curare-like activity, depressing the central nervous systems, relaxing smooth muscles and with hypotensive and hypoglycaemic action.

In tests in Africa, extracts of *Cissampelos* roots and leaves controlled storage pest species, such as the small beetles *Acanthoscelides obtectus* on cowpeas, *Prostephanus truncatus* on maize grains and *Sitophilus oryzae* on wheat grains.

Adulterations and substitutes Other *Menispermaceae* have similar or related alkaloids such as benzylisoquinolines, and similar applications. *Cyclea barbata* Miers is known to be used as a substitute.

Description A dioecious scandent shrub with woody older stems and slender leafy stems, glabrous to densely pubescent. Leaves arranged spirally, simple and entire, broadly ovate, 4.5–11 cm × 4.5–12 cm, with rounded, truncate or cordate base and acuminate to obtuse apex, mucronate at the tip, hairy below, sparsely pubescent above, palmately 5–7-veined; petiole 2–9 cm long, pubescent; stipules absent. Male inflorescence an axillary subcorymbose peduncled cyme, 2–4 cm long, solitary or a few together; female inflorescence axillary, thyrsoid, narrow, up to 18 cm long, composed of a pseudoraceme of fascicles with accrescent suborbicular bracts. Flowers unisexual, pedi-



Cissampelos pareira L. – 1, flowering stems of male plant; 2, flowering stem of female plant; 3, male flower; 4, sectioned male flower; 5, part of female inflorescence; 6, endocarp.

cel up to 2 mm long; male flower greenish or yellowish, with 4 sepals pilose outside, a cupuliform corolla and stamens completely fused, having 4 anther-cells; female flower with one sepal, one petal and one pilose carpel having a thick style with divaricately 3-lobed stigma. Fruit a pubescent, orange to red drupe, about 5 mm long, curved with style-scar near base; endocarp with 2 dorsal rows of very prominent transverse ridges. Seed horseshoe-shaped; embryo elongate, narrow, embedded in endosperm, cotyledons flattened.

Growth and development The flowers are probably pollinated by small insects such as flies and bees, and possibly small beetles and moths.

Other botanical information C. pareira has been subdivided into 2 varieties: var. *pareira* occurs in the West Indies, var. *hirsuta* (Buch.-Ham. ex DC.) Forman (synonyms: *C. pareira* L. var. *orbiculata* (DC.) Miq., *C. pareira* L. var. *peltata* Scheff., *C. pareira* L. var. *typica* Diels) is pantropical. *C. pareira* has been erroneously recorded from Peninsular Malaysia and Java. These records are based on misidentified specimens of *Pericampylus glaucus* (Lamk) Merr.
C. owariensis P. Beauv. ex DC. is cultivated in Africa as a medicinal plant.

Ecology *C. pareira* occurs in primary and secondary forest, in Thailand also in bamboo forest, and in thickets, up to 1300 m altitude. It climbs over trees and river banks.

Genetic resources and breeding *C. pareira* is very widespread and locally common (e.g. in the Philippines, Vietnam, Cambodia, Laos and Thailand). There is no reason to suppose any danger of genetic erosion. The quantity and composition of the alkaloids found in the roots seem to differ between accessions from different regions of the extremely large area of distribution. Although it cannot be excluded that this is partly due to misidentifications, it is possibly a result of great genetic diversity.

Prospects The alkaloids present in *C. pareira* have interesting properties, e.g. antileukaemic and neuromuscular blocking activity. The roots are used in traditional medicine in different parts of the world for similar purposes, which seems to confirm their effectiveness.

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Other selected sources 979, 1554.

S.F.A.J. Horsten & R.H.M.J. Lemmens

Curculigo orchioides Gaertner

Fruct. sem. pl. 1: 63 (1788).
HYPOXIDACEAE
$2n = 18, 36$

Vernacular names Papua New Guinea: tupaaui (Kenemote, Eastern Highlands). Philippines: taloangi (Bagobo), tataluangi (Bukidnon), sulsulitik (Bontok). Thailand: waan phraao (northern). Vietnam: ng[ar]i cau, s[aa]m cau, ti[ee]n mao.

Origin and geographic distribution *C. orchioides* occurs from the subtropical Himalayas of Pakistan and India, to Cambodia, Vietnam and Laos, southern China, Taiwan, southern Japan, to Thailand and Malesia (at least known with certainty from Java and the Philippines), and possibly also to northern and eastern Australia. The distribution in Malesia is very incompletely known.

Uses A decoction of the powdered rhizomes ('Curculiginis Rhizoma') is used in Chinese traditional medicine as a general tonic and analeptic in the treatment of decline (especially of physical strength). In the Philippines, Nepal and India, the rhizome is used as diuretic and aphrodisiac, and to cure skin diseases (externally), peptic ulcers, piles, gonorrhoea, leucorrhoea, asthma, jaundice, diarrhoea and headache. In Thailand, the rhizome is used as a diuretic and to treat diarrhoea. In Papua New Guinea, the rhizome and leaves are softened by being heated over a fire, before being rubbed on the body to serve as a contraceptive. In China, additional reported indications include the treatment of lumbago, arthritis, chronic nephritis, hypertension and the use as an emmenagogue, and in India, *C. orchioides* is used to induce abortion. Powdered rhizomes are normally used in decoction, but are also sometimes given with an equal quantity of sugar in a glass of milk. It is reported that the rhizomes are also used to produce flour in India.

Production and international trade Sliced and dried rhizomes of *C. orchioides* are traded in small quantities in local markets in China and Indo-China.

Properties The rhizome tastes slightly bitter and is mucilagenous. The alcoholic extract from the rhizome is reported to have adaptogenic, anti-inflammatory, anticonvulsive, sedative, androgenic and immuno-stimulating activity. The water extract of the rhizomes exhibits andrenergic receptor blocking (alpha 2), cholecystokin receptor binding, hypoxanthine-guanine phosporibosyltransferase inhibition and uterine activating activity. Swelling of the tongue has been reported as a side-effect after drinking a decoction from the rhizome; in China the recommended antidote is a decoction of *Rheum tanguticum* Maxim. ex Balf. with sodium sulphate.

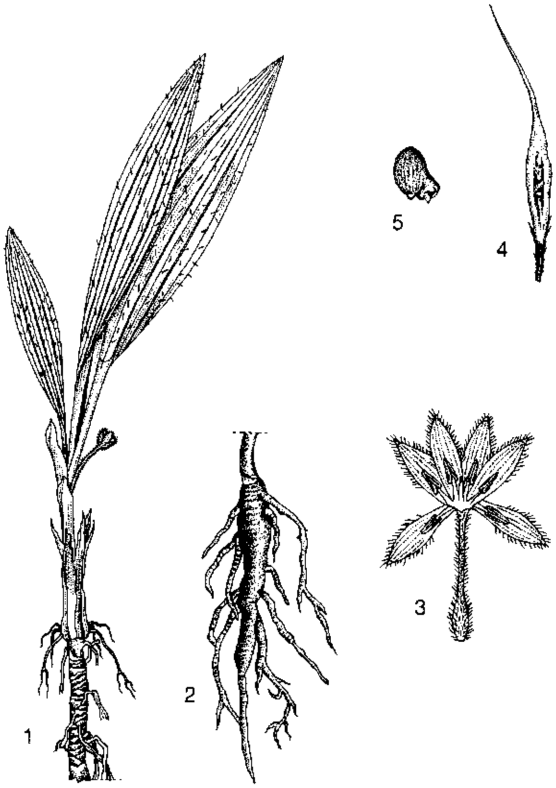
A series of 10 triterpenoidal saponins (curculigosaponins A–J) have been isolated from the rhizomes. All these compounds have curculigenine A (3β,11α,16β-trihydroxycycloartane-24-one) as the aglycone. Pharmacological studies have shown that curculigosaponins C and F can promote the proliferation of spleen lymphocytes in mice very significantly, and that curculigosaponins F and G increase the weight of the thymus in vivo in mice. The triterpene alcohol, curculigol (24-methylcycloart-7-en-3β,20-diol), whose structure is very similar to curculigenine A, has also been isolated.

Four phenolic glycosides have been isolated and identified: curculigoside, orcinal glycoside, curculigine A and corchioside A. Curculigoside from the rhizomes exerts immunological and protective effects. It has been found a characteristic constituent of 'Curculiginis Rhizoma', and a quantitative determination method using HPLC has been developed. The determination was performed indirectly by measuring the content of 2,6-dimethoxybenzoic acid, the hydrolysis product of curculigoside. Using this method, an average content of 0.2% curculigoside has been found in rhizomes from China.

Several aliphatic hydroxy-ketones (e.g. 27-hydroxytriacontan-6-one) have been reported from *C. orchioides*. The powdered rhizomes furthermore contain approximately 8% water, 4% alcohol-extractable matter, 1.5% ether-extractable matter, 15% crude fibre, 20% mucilage and 8.5% ash.

From the fruits of *Curculigo latifolia* Dryander, which grows wild in western Malaysia, 114 amino acids containing the peptide curculin were isolated. Curculin itself elicits a sweet taste (550 times sweeter than sucrose on a weight basis), which disappears rather rapidly after holding it in the mouth. Tasting a lemon (or ascorbic, citric or hydrochloric acid) afterwards then elicits a sweet, orange-like taste. This taste-modifying sensation lasts for about 10 minutes.

Description A perennial herb up to 50 cm tall, with vertical, more or less tuberous, blackish rhizome and rather stout roots. Leaves alternate, clustered and sessile on rhizome, narrowly lanceolate, 20–30 cm × 1–2 cm, long-tapering at base into a pseudo-petiole which is sheath-like at its base, and also long-tapering at apex, plicate, sparsely pilose with long hairs or glabrous, with few to several parallel veins. Inflorescence axillary, inconspicuous among the leaf-bases, spike-like, few-flowered or with a solitary flower, and with a very short scape or peduncle; bracts lanceolate, spathaceous, 2–4 cm long, membranous, surpassing the peduncle and ovary. Flowers long-pilose, lower ones in the inflorescence bisexual, upper ones male; perianth with long slender tube 2–3 cm long (resembling a pedicel) and 6 equal, spreading lobes which are lanceolate to elliptical, 5–8 mm long, few-veined, pale outside and bright yellow inside; stamens 6, inserted on bases of perianth lobes, about half as long as perianth lobes, with short filaments attached to the bases of the linear anthers; ovary inferior, 3-locular, locules imperfect, style short and thick, with 3 stigmas. Fruit berry-like, rather fleshy, ellipsoid, about 1.5 cm in



Curculigo orchioides Gaertner – 1, flowering plant; 2, rhizome; 3, flower; 4, fruit; 5, seed.

diameter, surpassed by the bract, beaked by the persistent perianth tube, 1–4-seeded. Seeds subglobose to oblong, about 4 mm long, with beak (elaiosome) lateral to hilum; testa crustaceous, striate, black and shiny.

Growth and development Rhizomes of *Curculigo orchioides* may reach 30 cm × 11.5 cm. Only 3–5 leaves are found on the plant at a given time. The flowers and fruits are inconspicuous because they are close to the ground and partially covered by the bracts and leaves.

Other botanical information *C. orchioides* belongs to a genus of approximately 10 species with pantropical distribution. *Curculigo* has been variously included in *Amaryllidaceae* and *Liliaceae*, but is nowadays usually considered as belonging to the comparatively small family *Hypoxidaceae* with about 10 genera.

C. ensifolia R. Br., a species recorded for Australia, is possibly conspecific with *C. orchioides*.

Ecology *C. orchioides* occurs in open fields and grasslands. In Java it grows on periodically very dry, sunny or slightly shaded localities in grasslands and teak forest up to 400 m altitude. In the Philippines it is also found in grasslands, often dominated by *Imperata*.

Propagation and planting There is no information about tests on propagation of *C. orchioides*, but the method described for *C. latifolia* may be applicable. In trials with tissue culture of *C. latifolia* for propagation for ornamental purposes, cultures of rhizomes showed the best results. A half-strength Murashige and Skoog medium was used, supplemented with sucrose (30 g/l), thiamine (0.4 g/l), coconut water (150 ml/l), kinetin (5 mg/l) and indole-acetic acid (2.5 mg/l). About 90% of the plants potted out survived.

Diseases and pests In India, rust (*Puccinia hypoxidis*) is reported from *C. orchioides*.

Harvesting *C. orchioides* is not planted and rhizomes are collected from the wild.

Handling after harvest The rhizomes are washed, freed from roots, and sliced; the slices are dried in the shade. Usually the dried slices are powdered, and small amounts of powder are mixed in a glass of milk with sugar or used to prepare a decoction for drinking.

Genetic resources and breeding *C. orchioides* has been recorded amongst the rare and endangered ethno-medical plants in India. However, it has a large area of distribution, is locally rather common, is by no means restricted to endangered vegetation types, and therefore does not seem endangered or liable to genetic erosion.

Prospects *C. orchioides* may prove a valuable medicinal plant because its active compounds are known and comparatively well documented and a suitable method has been developed for quantifying one of them (curculigoside), which is important for quality control of the drug. However, more research is needed and appropriate cropping techniques should be developed so that *C. orchioides* can be cultivated.

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Other selected sources 190, 552, 597, 622, 895, 954, 1004, 1539, 1549.

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Curcuma L.

Sp. pl. 1: 2 (1753); Gen. pl. ed. 5: 3 (1754).

ZINGIBERACEAE

$x = 16, 21$; *C. aurantiaca*: $2n = 42$, *C. longa*: $2n = 32$, 62–64, *C. petiolata*: $2n = 64$, *C. xanthorrhiza*: $2n = 63$, *C. zedoaria*: $2n = 63, 64, 66$

Major species *Curcuma longa* L., *C. xanthorrhiza* Roxb., *C. zedoaria* (Christm.) Roscoe.

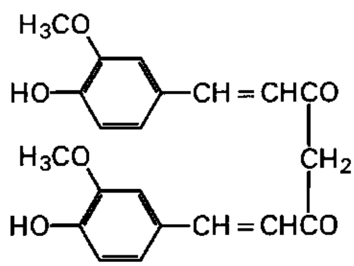
Vernacular names Curcuma (En, Fr), turmeric (En). Indonesia: temu. Malaysia: temu. Laos: kachièw, khminz. Thailand: khamin. Vietnam: ngh[eej].

Origin and geographic distribution *Curcuma* comprises some 40–50 species and is native to the Indo-Malesian region, from India to Indo-China, Taiwan and Thailand, throughout Malesia, towards the Pacific and northern Australia. Some 20 species are present within Malesia. Several species have been introduced elsewhere in tropical and subtropical areas. The centre of diversity is located in India.

Uses Rhizomes of many *Curcuma* species are used medicinally, often to treat liver diseases (jaundice, gallstones), but also for various abdominal complaints. They are considered stomachic, carminative, haematic and styptic. Furthermore, they are sometimes applied to asthma, cough and bronchial catarrh, or to treat itch, scurf, skin infections in general, or are applied to wounds and ulcers. The rhizomes of several *Curcuma* species are a well-known source of spice (turmeric), of starch and of a yellow-orange dye. The latter may be used in colouring clothing and food as such, or in the preparation of other dyes.

Production and international trade Annually about 20 000 t of cured dried whole rhizomes of turmeric (*C. longa*) enter into international trade. India is the largest producer with 400 000 t from 130 000 ha and dominates the international trade. Within Malesia, Indonesia is a major producer. All Asian producers are heavy consumers as well and some are even net importers. No information is available, except on *C. longa*.

Properties All *Curcuma* species are rich in essential oils. On distillation, rhizomes of *C. longa* yield 1.3–5.5% essential oil whose main constituents are sesquiterpenes called turmerones (about 60%, e.g. ar-turmerone, α-, β-turmerone) and the sesquiterpene zingiberene (about 25%). Dried rhizomes of *C. xanthorrhiza* contain on average 3.8% essential oil with ar-curcumene, xanthorrhizol, α-, β-curcumene and germacrene as major constituents. The compounds cyclo-isoprenemyrcene and p-tolylmethylcarbinol which are often mentioned as essential oil constituents in older literature are artifacts which originate from the distillation process and fractionation of oils at higher temperatures. The phenolic sesquiterpene xanthorrizol is species specific: its presence can thus be used to distinguish *C. xanthorriza* from e.g. *C. longa*. In young rhizomes the essential oil content may be higher; 29.5% essential oil has been found in rhizomes that are just beginning to develop. Dried rhizomes of *C. zedoaria* contain about 1.5% essential oil with cineol, borneol, d-camphor, camphene and d-α-pinen as main constituents. A further group of constituents in the rhizomes of *Curcuma* species are the curcuminoids. Curcuminoids are referred to as curcumin (diferuloyl methane or curcumin I) and its deriva-



curcumin I

tives desmethoxy-curcumin (feruloyl-p-hydroxycinnamoyl methane or curcumin II) and bisdesmethoxy-curcumin (bis-(p-hydroxycinnamoyl)-methane or curcumin III). The name curcumin is also often used for the complex yellow-orange mixture of curcuminoids as a whole, isolated from the plant. Curcumin has some broad-spectrum antimicrobial activity, but therapeutic utility of *C. longa* for this indication has not been recognized. Curcumin I derived from *C. longa* inhibited the 5-lipoxygenase activity in rat peritoneal neutrophils as well as the 12-lipoxygenase and the cyclooxygenase activities in human platelets. In a cell-free peroxidation system, curcumin exerted strong antioxidative activity. Thus, its effects on the dioxygenases are probably due to its reducing capacity. Oral administration of the antioxidant curcumin, from *C. longa*, at a concentration of 200 μmol/kg body weight significantly reduced the lung collagen hydroxyproline in whole-body γ-irradiated rats. Serum lipid and liver lipid peroxidation, which were increased by irradiation, were reduced significantly by the antioxidant treatment. The increased frequency of micronucleated polychromatic erythrocytes after whole-body irradiation of mice was significantly reduced by antioxidant treatment. The actual quantity of the three known curcuminoids, which in fact are all potent antioxidants, does not fully explain the antioxidant activity of the extracts of several *Curcuma* species.

Three non-phenolic diarylheptanoids isolated from *C. xanthorrhiza* have been identified as trans,trans-1,7-diphenyl-1,3-heptadien-4-one (alnustone), trans-1,7-diphenyl-1,3-hepten-5-ol, and trans,trans-1,7-diphenyl-1,3-heptadien-5-ol. They all exerted significant anti-inflammatory activity in the carrageenin-induced hind paw oedema assay in rats. 1E,3E,1,7-Diphenylheptadien-5-one exerted potent anti-inflammatory activity (ID_{50} value of 67 μg/ear, topically applied) in an ethylphenylpropiolate-induced ear oedema model in rats. The ED_{50} value of the water extract of *C. longa* after intraperitoneal administration was 4.7 mg/kg in carrageenin-induced rat paw oedema, that of the alcoholic extract 307 mg/kg, of the petroleum ether extract 40.7 mg/kg, of the sodium curcuminate 2.1 mg/kg and that of curcumin 8.7 mg/kg, but an ED_{50} of only 0.36 mg/kg has also been reported; the oral ED_{50} of curcumin was 100.2 mg/kg in mice and 48.0 mg/kg in rats. The mechanism by which curcumin inhibits inflammation is still poorly understood. Curcumin has been found to inhibit several types of phospholipases, notably phospholipase D, and it also inhibited phospholipase D activation induced by 12-0-tetradecanoylphorbol-13-acetate. This suggests that the anti-inflammatory and anti-carcinogenic action of curcumin is partly due to the inhibition of phospholipase D and prostaglandin synthesis.

The aqueous extracts of the crude drug of *C. aeruginosa* showed significant protective effects against CCl4-induced liver injury in rats and D-galactosamine/lipopolysaccharide-induced liver injury in mice. The aqueous extract of the rhizomes of *C. xanthorrhiza* significantly reduced the acute elevation of serum glutamate oxaloacetate transaminase (alanine aminotransferase) and serum glutamate pyruvate transaminase (aspartate aminotransferase) induced by paracetamol or CCl4 in mice; it alleviated the degree of liver damage 24 hours after intraperitoneal administration of the hepatotoxic compounds. When the aqueous extract of rhizomes of *C. xanthorrhiza* (100 mg/kg by oral administration) was investigated in rats treated with β-D-galactosamine (288 mg/kg, intraperitoneally administered), the extract reduced the elevated concentrations of alanine aminotransferase and aspartate aminostransferase, and reduced histopathological changes induced 24 hours after administration. Antihepatotoxic activity of the rhizome of *C. longa* has also been reported.

Active principles other than curcuminoids from *C. xanthorrhiza* can modify the metabolism of lipids and lipoproteins. α-Curcumene which can make up to about 65% of the essential oil of *C. xanthorrhiza* was shown to lower triglyceride levels in rats.

Streptozotocin-induced diabetic rats maintained for 8 weeks on a diet containing 0.5% curcumin showed a significant decrease in blood triglyceride and phospholipid levels, as do diabetic animals maintained on a high cholesterol diet, where hypercholesterolaemia and phospholipidemia is even more severe. In streptozotocin-induced diabetic rats which were fed on purified diets containing 5% *C. xanthorrhiza* the diabetic symptoms improved. This diet specifically modified the amount and composition of faecal bile acids. The essential oil of *C. longa* and *C. xanthorrhiza* and its component d-camphor caused a persistent increase of bile secretion in anaesthetized rats. p-Tolylmethylcarbinol activates the secretion of bile from the gall bladder and curcumin causes rhythmic contractions of the gall bladder. Furthermore, the liquid balm of *C. xanthorrhiza* was found to lower the total cholesterol content and the total lipid content in rabbits.

Furanogermenone and (4S,5S)-(+)-germacrone-4,5-epoxide had a potent preventive effect against stress ulceration. Moreover, oral administration of fractions of the methanol extract significantly inhibited the formation of both HCl-induced and indomethacin-induced gastric ulcers.

Water extracts of *C. zedoaria* inhibited the growth of mouse L5178Y leukaemia cells in a dose-dependent manner; inhibitory effects of alcohol extracts were not significant. The bisabolane sesquiterpenoids α-curcumene, ar-turmerone, β-atlantone and xanthorrhizol were isolated as major antitumour constituents from the rhizomes of *C. xanthorrhiza*. Curcumin from *C. longa* inhibited the growth of hormone-dependent and -independent, and multi-drug resistant human breast tumour cell lines in a time- and dose-dependent way. The effect was correlated with the compound's inhibition of ornithine decarboxylase activity. A 5% turmeric diet significantly inhibited the tumour burden and tumour incidence in fore-stomach tumours induced by benzo-[a]-pyrene in Swiss mice and oral mucosal tumours induced by methyl-(acetoxymethyl)-nitrosamine in Syrian golden hamsters. Curcumin isolated from *C. longa* inhibited human colon cancer cell proliferation in vitro, mainly by causing cells to accumulating in the G2/M phase; this effect is independent of its ability to inhibit prostaglandin synthesis. In an assay studying the promotion of tumours induced by croton oil, 90% of the control animals had papillomas in the 10th week of tumour initiation, compared with only 10% of animals treated with curcumin III, 20% of the animals treated with curcumin II, and 40% of animals treated with curcumin I. Of the synthetic curcuminoids studied, salicylcurcuminoid, which had caused no papillomas by the 10th week, was the most potent anti-carcinogen. In vitro and in vivo tests with aqueous and ethanolic extracts of *C. longa* and *C. xanthorrhiza* showed marked antitumour activity. Topical application of curcumin together with 5 nmol of the tumour-promoting agent 12-0-tetradecanoylphorbol 13-acetate (TPA) twice weekly inhibited the number of TPA-induced tumours by 39% at a dose of 1 μmol, 77% at a dose of 3 μmol, and 98% at a dose of 10 μmol.

When the antispasmodic activity of *C. longa* was tested using the isolated guinea-pig ileum, the ED_{50} values of sodium curcuminate were 30.2 μg/ml (nicotine), 77.2 μg/ml (acetylcholine), 82.8 μg/ml (5-hydroxytryptamine), 81.8 μg/ml (histamine) and 171.4 μg/ml (barium chloride), respectively. Concentrations of this magnitude will not appear in the blood, because if curcumin is absorbed in the blood at all, it is rapidly metabolized in the liver and excreted through the bile.

ar-Turmerone isolated from *C. longa* is a potent antidote to snake bite. Furthermore, curcumin has a median inhibitory concentration (IC_{50}) for strand transfer of 40 μM on purified human immunodeficiency virus type 1 (HIV-1) integrase.

In a clinical study on turmeric, significant improvement was observed in patients with rheumatoid arthritis or with respiratory diseases. Limited clinical trials on the effects of orally administered turmeric on peptic ulcers showed promising results. Another clinical trial carried out in Thailand showed good results on dyspepsia.

The inhibitory activity of turmeric oil and curcumin isolated from *C. longa* was tested in *Trichophyton rubrum*-induced dermatophytosis in guinea-pigs. Turmeric oil at dilutions of 1:40–1:320 inhibited the dermatophytes. At dilutions of 1:40–1:80 it inhibited 4 isolates of pathogenic fungi. Curcumin had no inhibitory effect on either dermatophytes or pathogenic fungi. The essential oil from turmeric showed a moderate antibacterial activity against *Escherichia coli*.

Curcumin from *C. longa* has demonstrated phototoxicity to several species of bacteria and to mammalian cells, using a rat basophilic leukaemia cell model, under aerobic conditions. The rhizome powders of *C. longa* and *C. zedoaria* applied on *Cajanus cajan* (L.) Millsp. and *Vigna radiata* (L.) Wilczek seed before being stored were moderately effective to effective against the pulse beetle *Callosobruchus chinensis*; the LD_{50} of the extract of *C. longa* was 0.05–0.1 ppm. Insecticidal as well as antifungal activity of *Curcuma* species has also been reported. The extract of the rhizome of *C. zedoaria* showed significant antifungal activity against *Cladosporium cladosporioides*.

In a contact residue bioassay the most active sesquiterpenoids xanthorrhizol and furanodienone showed pronounced toxicity against neonate larvae of *Spodoptera littoralis*. The LD_{50} of xanthorrhizol following topical application was found to vary between 6.92 and 8.13 μM/kg fresh weight irrespective of the larval stages studied. Xanthorrhizol, however, did not cause significant mortality of neonate larvae when incorporated into artificial diet, suggesting that the compounds are inactived in the larval gut. The chloroform extract of *C. longa* proved economically useful in the treatment of *Trichophyton verrucosum* ringworm in cattle.

Description Perennial, rhizomatous, erect herbs with spurious stems; subterranean parts fleshy, aromatic, roots fleshy, often bearing ellipsoidal tubers. Leafy shoots bearing bladeless sheaths forming a spurious stem on which less than 10, distichous, pinnately veined leaves develop; petiole well developed; ligule narrow. Inflorescence either terminal on a leafy shoot or on a separate shoot, spike-like, cylindrical; peduncle well developed; spike with large bracts which are joined for about half their length, forming pouches from which a cincinnus of 2–7(–10) flowers arises, uppermost bracts often larger and forming the 'coma'. Flowers bisexual, zygomorphic; bracteoles thin, not connate, enclosing the flower bud; calyx tubular, split unilaterally, about half as long as the corolla, unequally toothed; corolla tube united with the staminal tube, cylindrical below, cup-shaped above, lobes 3, translucent white or pink to purplish, the dorsal lobe hooded and ending in a hollow hairy point; staminodes 3, petaloid, the anterior one, called labellum, obovate, with a thickened median band, the 2 lateral ones elliptical-oblong, their inner edges folded under the hood of the dorsal corolla lobe; fertile stamen 1, filament short, broad, anther versatile, thecae parallel, often spurred at base, connective sometimes enlarged at the apex into a small crest; ovary inferior, 3-locular with axillary placentation and many ovules, style 1, filiform with a cup-shaped, 2-lobed stigma, held between the thecae. Fruit an ellipsoid capsule, crowned by the calyx remnants; pericarp thin, irregularly dehiscing. Seeds embedded in mucilage, ellipsoidal, with a lacerate aril of few segments free to the base.

Growth and development The primary rhizome of *Curcuma* is at first surrounded by small scales, that remain visible by their annular scars. Secondary and tertiary rhizomes develop from axillary buds of the primary and secondary rhizome, respectively. In Java, most *Curcuma* species flower in September-February(-March) and June-August; *C. aeruginosa*, *C. purpurascens* and *C. xanthorrhiza* flower almost throughout the year. Flowers generally open late in the afternoon and wither before the next morning. Although flowering is abundant and flowers have been observed to be frequently visited by insects searching for pollen, in Java only *C. aurantiaca* forms fruits. This is probably because it is diploid whereas virtually all other *Curcuma* are triploid. In Java, no dormancy period was observed after flowering, but this phenomenon has been reported from northern India, where it usually occurs during winter. Vesicular-arbuscular mycorrhizae have been observed in *C. longa* and *C. zedoaria*; many of the sporulating mycorrhizae belong to the genus *Glomus*.

Other botanical information *Curcuma* belongs to the tribe *Hedychieae* and is characterized by the partly fused bracts. Its taxonomy is still unsatisfactory, the various species being very closely related and sometimes doubtfully distinct. Intensive cultivation, and possibly hybridization, makes it difficult to distinguish species and a thorough revision is badly needed. The fact that many 'species' appear to be triploids may be an indication of an origin from cultivation. Although the taxonomic treatment of the Flora of Java is not followed here, the rigorous lumping of species may eventually be justified. As *C. aurantiaca* is the only Javanese species producing fruit, it may indeed be the only indigenous species of Java. Two subgenera are distinguished: *Curcuma* with elongated rhizomes, a non-auriculate ligule, conspicuous coma bracts and longitudinally grooved and folded staminodes, and *Paracurcuma* with short rhizomes, an auriculate ligule, inconspicuous coma bracts and straight staminodes.

Ecology In the wild, most *Curcuma* are found in the undergrowth of tropical or subtropical forests or slightly shaded places such as forest margins and plantations, up to 1150 m altitude, but in the Himalayan foothills up to 2000 m. They grow best on well-drained, loamy or alluvial, fertile, friable soils and cannot stand waterlogging. They often occur in deciduous monsoon forest, in Java especially in teak forest, in areas with an annual rainfall of about 1000–2000 mm, exceptionally up to 4000 mm.

Propagation and planting Propagation of *Curcuma* is by mother (primary) rhizomes, cut mother rhizomes or by finger rhizomes (also referred to as daughter or lateral rhizomes). Seed rhizomes need to be stored for 2–3 months prior to planting. Finger rhizomes of *C. longa* store better, are more tolerant to wet soil conditions and can be planted at a lower rate. *C. longa* is planted in ridges at 30–40 cm distance or in flat beds usually at a spacing of 25 cm, although good results have been obtained using a spacing of 15 cm. *C. xanthorrhiza* is planted at a distance of 60 cm and *C. zedoaria* at 25–45 cm. *Curcuma* is best planted under partial shade and in soils that have been ploughed or turned over to a depth of 30 cm.

Husbandry Mulching increases resprouting of the *Curcuma* rhizomes and rhizome yield and should be done at planting and 2 months thereafter. *Curcuma* requires heavy manuring to obtain a high yield; about 25 t/ha of manure is usually recommended. Recommendations for fertilization vary widely between locations.

Diseases and pests Leaf spot or leaf blotch caused by *Taphrina malucans* and rhizome rot caused by *Pythium aphanidermatum* are considered the most important diseases of turmeric. Bacterial wilt caused by *Pseudomonas solanacearum* has been found killing *C. mangga* in Java.

Harvesting *Curcuma* propagated by whole mother rhizomes can be harvested after 8–12 months; if propagated from cut mother rhizomes or finger rhizomes, plants can be lifted after 2 years. Rhizomes of *C. longa* begin to develop about 5 months after planting and can be lifted after 7–10 months when the lower leaves turn yellow. At harvesting, care should be taken not to damage the rhizomes; the finger rhizomes are separated from the mother rhizomes.

Yield Yields of *Curcuma* are 17–23 t/ha when irrigated. Under rainfed conditions 6.5–9 t/ha are obtained for *C. longa*, 20 t/ha for *C. xanthorrhiza* and 7.5–12 t/ha for *C. zedoaria*.

Handling after harvest Whole rhizomes of *Curcuma* are dried, or first cut in slices and then dried.

Genetic resources and breeding A germplasm collection of about 500–600 *C. longa* accessions is maintained in India, but crop improvement of turmeric is limited. Neither germplasm collections nor breeding activities are known to exist for the other *Curcuma* species.

Prospects Many *Curcuma* species are planted in home gardens by small farmers. Hardly any efforts have been undertaken in agronomy, plant breeding and pest management, not even in the well-known spice *C. longa*, to improve performance. *C. longa* and *C. xanthorrhiza* show promising prospects for medicinal applications but research is needed to establish their therapeutic value.

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Selection of species

Curcuma aeruginosa Roxb.

Asiat. Res. 11: 335 (1810).

Vernacular names Indonesia: temu hitam (general), temu ireng (Javanese, Balinese), koneng hideung (Sundanese). Malaysia: temu erang, temu hitam (Peninsular). Thailand: waan mahaamek (central). Vietnam: ngh[eej] ten d[oof]ng.

Distribution Burma (Myanmar), Vietnam, Cambodia, Thailand, Peninsular Malaysia, Sumatra and Java; cultivated at least in Vietnam, Cambodia, Java and the Moluccas.

Uses In Indo-China rhizomes are used as a medicine for colic. In Peninsular Malaysia they have been prescribed to treat asthma and cough, applied externally to scurvy, and suggested as an application for mental derangement. In Indonesia and Thailand, rhizomes are the chief ingredient of a decoction given to women after childbirth to accelerate the lochia. They are considered to be depurative and used both internally and externally for treating exanthema, and as a poultice to treat itch. Other medicinal applications are against obesity, rheumatism, and as an anthelmintic. During periods of famine the starch extracted from the rhizomes is used as a substitute for cassava or maize. A dye can be obtained from the rhizome.

Observations A herb with rhizome up to 16 cm long and 3 cm thick, outside grey and shiny, tips pink, inside bluish or blue-green with white cortex; leaf sheaths to 50 cm long, blades elliptical to oblong-lanceolate, 30–80 cm × 9–20 cm, green with wide purplish-brown suffusion on each side of midrib on distal half; inflorescence on a separate shoot, bracts pale green, coma bracts purple; corolla about 4.5 cm long, deep crimson-pink; labellum about 17 mm × 17 mm, pale yellow with deep yellow median band, other staminodes longitudinally folded, pale yellow, anther spurred. *C. aeruginosa* is found in grassy places and teak forest, at 400–750 m altitude.

Selected sources 202, 314, 455, 558, 580 615, 681, 1126, 1128, 1380, 1496, 1507, 1552.

Curcuma aurantiaca v. Zijp

Recueil Trav. Bot. Néerl. 12: 345 (1915).

Vernacular names Indonesia: koneng kalamasu (Sundanese), temu blobo, temu purot (Javanese).

Distribution Peninsular Malaysia and Java; possibly also in India.

Uses Rhizomes are used medicinally for their astringent properties and have a camphor scent. Locally, young inflorescences are eaten as a vegetable in 'sayur' (soup).

Observations A herb with rhizome not elongated, inside cream-coloured; leaf sheaths to 12 cm long, blades elliptical, 19–50 cm × 8–21 cm, dark green; inflorescence terminal on a leafy shoot, bracts yellow-green, coma bracts red to pink or purple; corolla about 4.5 cm long, orange to orange-yellow; labellum about 2 cm × 1.5 cm, orange with a darker centre, other staminodes straight, orange, anther not spurred. *C. aurantiaca* is fairly common in Java, where it is found in teak forest.

Selected sources 97, 202, 314, 380, 615, 1157, 1290, 1496.

Curcuma euchroma Valeton

Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 42 (1918).

Vernacular names Indonesia: kunir kebo, temu batok, temu ketek (Javanese).

Distribution Java.

Uses Rhizomes are sometimes used medicinally as a substitute for those of *C. longa*.

Observations A herb with branched rhizome, outside and inside bright orange or orange-yellow, tips whitish; leaf sheaths up to 50 cm long, blades obovate-elliptical, 26–72 cm × 12–25 cm, green with a dark red-brown midrib; inflorescence terminal on a leafy shoot, bracts pale green to pale yellow-green, coma bracts slightly violet-dotted; corolla almost 2 cm long, pinkish; labellum about 17 mm × 16 mm, ochraceous with a darker median band, other staminodes longitudinally folded, ochraceous, anther with long spurs. *C. euchroma* is found in teak forest.

Selected sources 97, 202, 1496.

Curcuma heyneana Valeton & v. Zijp

Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 54 (1918).

Vernacular names Indonesia: temu giring (Javanese).

Distribution Java, mostly in Central and East Java, both wild and cultivated.

Uses Rhizomes are the principal ingredient of a body lotion or powder used in traditional Javanese skin treatment, often administered to the bride-to-be. The bitter rhizomes are given, together with other medicinal herbs, to treat fatty degeneration, also as a folk medicine for brides to combat fatigue. They are also often applied in modern beauty parlours. Rhizomes are also considered to be cooling and detergent, useful to treat skin diseases, abrasions and injuries, and are used as an anthelmintic, especially against pinworms, and against lipomatosis in combination with other plants. They yield starch that can be made into a porridge.

Observations A herb with much branched and elongated rhiome, outside pale yellow, inside whitish with yellowish centre to bright yellow throughout; leaf sheaths 22–35 cm long, blades elliptical, 17.5–42 cm × 7.5–13 cm, uniformly green; inflorescence on a separate shoot, bracts pale green, coma bracts pale pink with a dark tip; corolla about 4 cm long, whitish; labellum about 16 mm × 16 mm, white with a dark yellow median band to yellow, other staminodes longitudinally folded, whitish to yellow, anther with short spurs. *C. heyneana* grows wild in secondary forest, teak forest and abandoned places, up to 750 m altitude.

Selected sources 97, 202, 314, 380, 1496, 1507.

Curcuma longa L.

Sp. pl. 1: 2 (1753).

Synonyms *Curcuma domestica* Valeton (1918).

Vernacular names Turmeric (En). Curcuma, safran des Indes, turmeric (Fr). Brunei: kunyit, temu kuning, temu kunyit (Dusun, Malay). Indonesia: kunyit (general), kunir (Javanese), koneng (Sundanese). Malaysia: kunyit, temu kunyit, tius. Papua New Guinea: lavar, tamaravirua (Gunantuna, New Britain). Philippines: dilaw (Tagalog), kalabaga (Bisaya), kunik (Ibanag). Cambodia: ro miet. Laos: khi min, 'khmin² 'khun². Thailand: khamin (general), khamin kaeng (northern), khamin chan (central). Vietnam: ngh[eej], ngh[eej] v[af]ng, u[aas]t kim.

Distribution Turmeric probably originated from South or South-East Asia, most probably from India. It is not known in a true wild state although in some places it appears to have become naturalized (e.g. in teak forests of East Java). Turmeric has been grown in India since time immemorial. It reached China before the 7th Century, East Africa in the 8th Century and West Africa in the 13th Century. It was introduced into Jamaica in the 18th Century. Presently turmeric is widely cultivated throughout the tropics but cultivation on a considerable scale is largely confined to India and South-East Asia.

Uses The main rhizomes are stomachic, stimulant, carminative, haematic or styptic in all kinds of haemorrhages, and a remedy for certain types of jaundice and other liver trouble. Externally they are applied to relieve itch, small wounds, insect bites and certain skin eruptions and smallpox, also as a maturative. A decoction affords relief for a burning sensation in eye disease. The rhizomes are considered to be very good for irregular menstruation; they promote circulation, dissolve blood clots and are prescribed as a remedy for urinary infections and for abdominal, chest, and back pains. Turmeric is a remedy for diarrhoea, rheumatism, and to relieve cough and tuberculosis. It is further considered anti-spasmodic, and as a cure for inflammation of the gums. Turmeric also has insecticidal, fungicidal and nematicidal properties which make it a potential biocide. The leaves are used in preparing a special medicinal bread in Nepal and India, whereas in Papua New Guinea they are applied to skin pains, bruises, eye irritations, catarrh and colds. The major use of turmeric rhizomes is, however, as a spice. They are also applied as a yellow dye for clothing and food, and as a cosmetic and pH indicator. The rhizomes are an auspicious article in all religious observances in Hindu households, and have many other uses in daily life in connection with birth, marriage, and death, and in agriculture.

Observations A herb with branched rhizome, bright orange inside and outside, young tips white; leaf sheaths up to 65 cm long, blades oblong-lanceolate to ovate-lanceolate, 7–70 cm × 3–20 cm, densely studded with pellucid dots; inflorescence terminal on a leafy shoot, bracts pale green with white streaks or white margins, coma bracts white, sometimes pink-tipped; corolla 4.5–5.5 cm long, white; labellum suborbicular to obovate, 12–22 mm in diameter, white with a yellow median band, other staminodes longitudinally folded, creamy white, anther with large spurs. *C. longa* is found naturalized mainly in teak forest, but also in sunny places, on clayey to sandy soils, up to 2000 m altitude.

Curcuma longa L. – 1, rhizome; 2, flowering clump.

Selected sources 31, 59, 73, 90, 97, 202, 287, 304, 314, 326, 350, 363, 413, 455, 479, 531, 580, 583, 597, 615, 681, 776, 897, 1035, 1066, 1097, 1126, 1128, 1158, 1163, 1178, 1337, 1380, 1421, 1450, 1452, 1458, 1467, 1481, 1496, 1507, 1525.

Curcuma mangga Valeton & v. Zijp

Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 50 (1918).

Vernacular names Indonesia: temu mangga (general), koneng lalab (Sundanese), temo pao (Madurese). Malaysia: temu pauh (Peninsular). Thailand: khamin khao.

Distribution Only known from cultivation in Thailand, Peninsular Malaysia and Java.

Uses Rhizomes are part of a mixture given to treat continued fever. They are chewed to cause the womb to contract after childbirth. The starch is recommended by traditional healers to treat abdominal illness. The main use of *C. mangga* is as a vegetable.

Observations A herb with branched rhizome, yellowish outside, the top white, inside lemon-coloured to sulphur-yellow with a white outer layer; leaf sheaths 30–65 cm long, blades elliptical-oblong to oblong-oblanceolate, 15–95 cm × 5–23 cm, green; inflorescence on a separate shoot, bracts green, coma bracts white at base, purple towards the top; corolla 3–4 cm long, white; labellum 15–25 mm × 14–18 mm, white with a yellow median band, other staminodes longitudinally folded, white, anther with long, narrow spurs. *C. mangga* is cultivated in very fertile soils, up to 1000 m altitude.

Selected sources 97, 108, 202, 314, 380, 615, 681, 1066, 1126, 1356, 1420, 1496.

Curcuma petiolata Roxb.

Fl. ind. (Carey ed.) 1: 36 (1820).

Vernacular names Indonesia: temu badur (Javanese), temu putri (Malay, Jakarta), temu tihing (Balinese).

Distribution Burma (Myanmar), Java and Bali; possibly also in the Moluccas.

Uses Rhizomes are used in the treatment of anorexia, puerperal fever and colic.

Observations A herb with rhizome not elongated, forming a compact mass, outside sallow-yellow, inside pale yellow; leaf sheaths 20–30 cm long, blades broadly elliptical-ovate to elliptical-lanceolate, 15–65 cm × 6–30 cm, green; inflorescence terminal on a leafy shoot, bracts greenish with violet streaks to entirely violet, coma bracts dark red to purplish; corolla 3–3.5 cm long, white with yellow or pink tips; labellum 13–17 mm × 15–17 mm, pale orange, other staminodes straight, pale orange, anther with short spurs. *C. petiolata* is naturalized in teak forest, upland fields, near bamboo stools and in other shaded places, up to 1600 m altitude. The status of this species needs further attention.

Selected sources 108, 314, 380, 1496, 1511.

Curcuma purpurascens Blume

Enum. pl. Javae 1: 46 (1827).

Vernacular names Indonesia: koneng ping-gang, koneng tinggang (Sundanese), temu tis (Javanese).

Distribution West and Central Java.

Uses Rhizomes are used against tussis and, when mixed with *Alyxia stellata* (Forst.) Roem. & Schultes, applied as a poultice after childbirth. The main tubers contain extractable starch. The tender central parts of the shoots and young rhizomes are eaten fresh or cooked as 'lalab'.

Observations A herb with branched rhizome, outside and inside orange-yellow with whitish tips; leaf blades elliptical, 55–70 cm × 19–23 cm, green but purple along the midrib above; inflorescence terminal on a leafy shoot, bracts pale green, coma bracts white at base and pale green towards the top or almost entirely white, outside pale brown spotted at the top; corolla about 5 cm long, white; labellum about 17 mm × 17 mm, pale creamy yellow with a dark yellow median band, other staminodes pale creamy yellow, anther with long spurs. *C. purpurascens* grows spontaneously in teak forest. It is cultivated up to 1000 m altitude.

Selected sources 97, 314, 580, 1066, 1496.

Curcuma soloensis Valeton

Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 46 (1918).

Vernacular names Indonesia: temu blenyeh, temu glenyeh, temu bayi (Javanese).

Distribution Java; fairly widely cultivated in Central Java.

Uses Rhizomes are used in the preparation of many traditional medicines against boils, scabies, cough and fever, and are especially used for children.

Observations A herb with branched rhizome, outside orange or orange-brown, inside orange-yellow; leaf blades elliptical, 29–55 cm × 12.5–19 cm, green; inflorescence terminal on a leafy shoot, bracts very pale green, coma bracts nearly white at base, dark violet towards the top; corolla about 5 cm long, pale pink; labellum 15–16 mm × 16–17 mm, orange, other staminodes longitudinally folded, orange, anther with long spurs. *C. soloensis* is found in teak forest and similar habitats, up to 900 m altitude.

Selected sources 97, 580, 1496.

Curcuma xanthorrhiza Roxb.

Fl. ind. (Carey ed.) 1: 25 (1820).

Vernacular names Indonesia: koneng gede (Sundanese), temu lawak (Javanese), temo labak

(Madurese). Malaysia: temu lawas, temu raya (Peninsular). Thailand: wan chakmotluk (central). Vietnam: ngh[eej] v[af]ng, ngh[eej] r[eex] v[af]ng.

Distribution *C. xanthorrhiza* is native to Java, Bali and the Moluccas. It is commonly cultivated in Java, Peninsular Malaysia, the Philippines and Thailand, occasionally also in India.

Uses Rhizomes are used to treat various abdominal complaints and liver disorders (jaundice, gallstones, promoting the flow of bile). A decoction of the rhizome is also used as a remedy for fever and constipation, and taken by women as a galactagogue and to lessen uterine inflammation after giving birth. Other applications are against bloody diarrhoea, dysentery, inflammation of the rectum, haemorrhoids, stomach disorders caused by cold, infected wounds, skin eruptions, acne vulgaris, eczema, smallpox and anorexia. In Indonesia, rhizomes enter as an important ingredient into many 'jamus'. They yield a starch, and a yellow dye. Young stems and rhizome parts are eaten as a vegetable either raw or cooked. The inflorescences are eaten cooked. In Java, a soft drink called 'bir temu lawak' is prepared by cooking dried pieces of rhizomes.

Observations A herb with branched rhizome, outside dark yellow to reddish-brown, inside orange or orange-red; leaf sheaths up to 75 cm long, blades elliptical-oblong to oblong-lanceolate, 25–100 cm × 8–20 cm, green with a reddish-brown band along the midrib; inflorescence on a separate shoot, bracts pale green, coma bracts purple; corolla 4–6 cm long, pale red; labellum 2–2.5 cm × 1.5–2 cm, yellowish with a darker yellow median band, other staminodes longitudinally folded, yellowish-white, anther with long spurs. *C. xanthorrhiza* is found in thickets and teak forest, mainly on moist, fertile, humus-rich soils, up to 750 m altitude.

Selected sources 97, 202, 269, 270, 310, 314, 329, 350, 414, 580, 615, 660, 681, 776, 866, 867, 912, 1066, 1097, 1098, 1112, 1211, 1212, 1380, 1496, 1507, 1622, 1623, 1624.

Curcuma zedoaria (Christm.) Roscoe

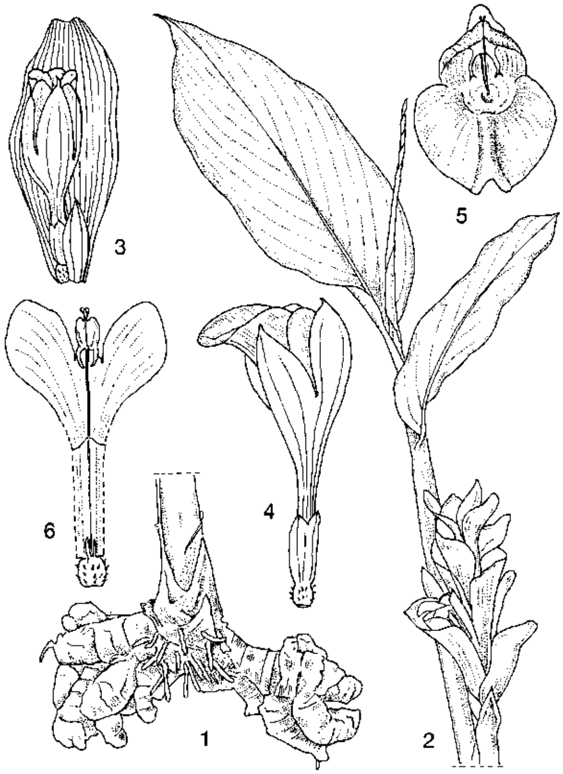
Trans. Linn. Soc. London 8: 354 (1807).

Synonyms *Curcuma pallida* Lour. (1790), *Curcuma zerumbet* Roxb. (1810).

Vernacular names Long zedoary, round zedoary, zedoary (En). Zédoaire (Fr). Indonesia: koneng tegal (Sundanese), temu putih (Malay, Jakarta). Malaysia: kunchur, temu kuning, temu lawak (Peninsular). Philippines: alimpuyas (Cebu Bisaya), barak (Tagalog), tamahilan (Bikol). Burma (Myanmar): thanuwen. Cambodia: prâtiël prèah 'ângkaôl. Laos: 'khmin[2] khai. Thailand: khamin khun (northern), khamin oi (central). Vietnam: ngh[eej] den, nga tru[aaj]t, ng[ar]i t[is]m.

Distribution Probably native to north-eastern India. Distributed through cultivation to South and South-East Asia and probably throughout Malesia, China and Taiwan from where it easily escapes. Occasionally it is cultivated elsewhere (e.g. in Madagascar).

Uses Rhizomes are widely used as stimulant, stomachic, carminative, diuretic, anti-diarrhoeal, anti-emetic, anti-pyretic and depurative, the latter especially after childbirth, but also to clean and cure ulcers, wounds and other kinds of skin disorders. Rhizomes are also chewed against bad breath, and a decoction is drunk against stomachache, indigestion and colds. The major use of rhizomes is for starch. In Indonesia, the heart of young shoots is used as a vegetable, young rhi-



Curcuma zedoaria (Christm.) Roscoe – 1, rhizome; 2, leafy shoot and inflorescence; 3, flower with bract and bracteole; 4, flower in lateral view; 5, flower in front view; 6, stamen, lateral staminodes and pistil.

zome parts are eaten raw and inflorescences cooked. The leaves are used for flavouring foods. In India, rhizomes are also used in perfumery.

Observations A herb with branched rhizome, outside grey, inside pale yellowish to bright yellow; leaf sheaths 35–60 cm long, blades oblong to oblong-lanceolate, 25–75 cm × 7–20 cm, green with a purple band along the midrib; inflorescence on a separate shoot, bracts green or green with a purple margin, coma bracts purple or dark pink; corolla 3.5–4.5 cm long, yellowish-white; labellum 2–2.5 cm × 1.5–2 cm, yellowish-white with a darker yellow median band, other staminodes longitudinally folded, yellowish-white, anther with long spurs. *C. zedoaria* is found in various shady, damp localities on various soils, but prefers well-drained sandy soils, up to 1000 m altitude.

Selected sources 97, 117, 202, 203, 287, 314, 332, 363, 414, 455, 479, 531, 580, 615, 639, 897, 1035, 1066, 1112, 1126, 1128, 1178, 1211, 1212, 1287, 1380, 1496, 1507, 1525.

Trimurti H. Wardini & Budi Prakoso

Cyclea Arn. ex Wight

Ill. Ind. Bot. 1: 22 (1840).

MENISPERMACEAE

x = unknown

Major species *Cyclea barbata* Miers and *C. laxiflora* Miers.

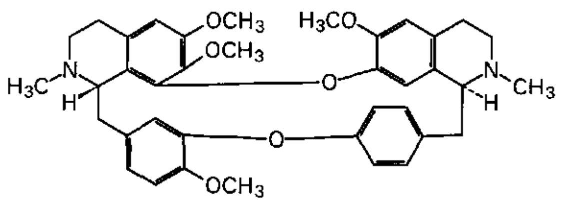
Origin and geographic distribution *Cyclea* includes about 30 species and occurs in India, Burma (Myanmar), Indo-China, southern China, Thailand and western and central Malesia (Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines). In Malesia, 10 species have been found. *Cyclea* is occasionally planted, e.g. in Java.

Uses A decoction of the roots is used in local medicine in Indonesia and Malaysia against fever and haemorrhoids, after childbirth and as a vermifuge for children. In Thailand, *C. barbata* ('krung khamao') is a rather well-known medicinal plant; the bitter decoction of its roots is used against (malarial) fever, in the treatment of lower abdominal pains, eye diseases, jaundice and as a tonic. *Cissampelos pareira* L., which has similar attributed uses and qualities, is also called 'krung khamao'. In Java, fresh crushed leaves of *C. barbata* are mixed with water, filtered and kept overnight to prepare a jelly called 'cincau' or 'cincau hijau' (green cincau), which is used as a refreshment and as a remedy against stomach complaints and fever as it has a cooling effect. In Thailand, a comparable preparation is used as appetizer and in the treatment of lower abdominal pains associated with malaria. The stem and roots of *Cyclea* are used in local medicine in southern China and Indo-China as diuretic, depurative, febrifuge and antidysenteric, and to treat jaundice, eye diseases and framboesia. In Chinese medicine extracts from the roots are used as anaesthesia during surgery.

Production and international trade The roots are traded and used on a local scale, and have no importance on the international market. The jelly is traded in a small-scale syrup industry.

Properties Many *Menispermaceae* species are known to contain mixtures of alkaloids; in the case of *C. barbata* contents of 4–7% in the roots are reported. This mixture is of complex nature. The principal components are a series of related bisbenzylisoquinoline alkaloids, including (+)-S,S-tetrandrine (main alkaloid, up to 3% in the roots), (±)-tetrandrine, (+)-R,S-isotetrandrine, (–)-R,R-limacine, (±)-fangchinoline, (+)-R,S-isofangchinoline (= thalrugosine), (+)-R,S-berbamine, (+)-R,S-homoaromoline, (+)-S,S-N-methyltetrandrine, (+)-S,S-tetrandrine-2'-β-N-oxide, (–)-cycleapeltine, (–)-2'-norlimacine, (+)-cycleabarbatine, (–)-repandine, (+)-cycleanorine, (+)-daphnandrine, (+)-coclaurine, (–)-N-methylcoclaurine, (–)-curine (= (–)-berbeerine = R,R-chondodendrine), R,R-isochondodendrine and R,S-chondocurine. Besides the bisbenzylisoquinoline alkaloids, α-cyclanolin and its epimer β-cyclanolin (two tetrahydroprotoberberine type alkaloids) and magnoflorine (an aporphine type alkaloid) have also been isolated from *C. barbata* roots. Dicentrine, an alkaloid structurally related to magnoflorine has been isolated from the roots of *C. laxiflora*. The only non-alkaloid isolated from *C. barbata* roots is the sugar protoquercitol, which is often found in *Menispermaceae*.

An extract derived from the roots of *C. barbata* has demonstrated in vitro cytotoxic and antimalarial activity. Using bioactivity guided isolation procedures, 5 bisbenzylisoquinoline alkaloids (i.e. (+)-tetrandrine, (–)-limacine, (+)-thalrugosine, (+)-homoaromoline and (–)-cycleapeltine) have been isolated as active principles. These compounds are capable of inhibiting the growth of both cultured *Plasmodium falciparum* strains and tumour cell lines. However, their 'selectivity index' (activity against mammalian cells/activity against cultured *P. falciparum* strains) typically ranges from 2 to 100, which is low compared to a selectivity index over 1000 for quinine or artemisinin.



(+)-S,S-tetrandrine

Methylation of (−)-curine has yielded dimethyl-(−)-curine dimethochloride, whose chemical structure is closely related to (+)-tubocurarine from South American *Chondrodendron tomentosum* Ruiz & Pavón (*Menispermaceae*). The muscle-relaxant activity of dimethyl-(−)-curine dimethochloride was found to be within the range of that of (+)-tubocurarine. Both have a non-depolarizing mode of action, and the blocking site is at the cholinergic (nicotinic) receptor in the postsynaptic membrane. The muscle-relaxant action and the inhibition of breathing could be antagonized by neostigmine. Side-effects are limited to mild hypotension and temporary facial cooling, whereas cardiovascular disturbances are insignificant. Dimethyl-(−)-curine dimethochloride is therefore considered a safe muscle relaxant for surgery.

S,S-tetrandrine, one of the pure isolated bisbenzylisoquinolines, has undergone extensive pharmacological investigations. It has been shown that this compound is a new kind of blocker of the voltage-activated L-type Ca^{2+} channel in a variety of excitable cells, such as cardiac, GH_3 anterior pituitary, neuroblastoma cells and rat neurohypophysial nerve terminals. As well as blocking L-type Ca^{2+}, it also blocks the voltage-dependent T-type Ca^{2+} channel. S,S-Tetrandrine's action in the treatment of cardiovascular diseases, including hypertension and supraventricular arrhythmia, is primarily due to its blocking of these voltage-activated Ca^{2+} channels. Furthermore, the alkaloid is a potent blocker of the Ca^{2+} activated K^+ channels of neurohypophysial nerve terminals. There is no obvious clinical application of this action, but S,S-tetrandrine makes a promising ligand for the study of the K^+ channel function.

Other pharmacological effects include anti-inflammation and immunosuppression. These actions often require higher doses than those needed to produce the cardiovascular effects. The mechanism(s) by which S,S-tetrandrine exerts these actions are unknown, although in vitro experiments have demonstrated inhibition of the production and release of inflammatory mediators and cytokines such as histamine, prostaglandins, leukotrienes, platelet activating factor, interleukin-1, tumour necrosis factor and nitric oxide. The inhibition of tumour necrosis factor has also been shown in vivo, using a mouse model for fulminant hepatitis. A selective inhibition of T-cell dependent immune responses by S,S-tetrandrine has been observed in mice, and suppression of the chronic inflammation in an arthritis model in the rat.

In media containing calcium, the stereoisomer of S,S-tetrandrine, R,S-isotetrandrine, exerts similar, although less specific, calcium channel activities. In contrast to S,S-tetrandrine, the mechanism of action of R,S-isotetrandrine also involves intracellular mechanisms, since it has been shown that this component is also active in calcium-free media, whereas S,S-tetrandrine is not. Other activities of R,S-isotetrandrine are inhibition of histamine release (in vitro), inhibition of nitric oxide production (in vitro) and selective inhibition of T-cell dependent immune responses (in vivo, mouse). Isotetrandrine also markedly suppressed the tumour-promoting effect of 12-O-tetradecanonylphorbol-13-acetate in a mouse-skin carcinogenesis test.

Biological activities of R,S-chondocurine include suppression of nitric oxide production (in vitro), selective inhibition of T-cell dependent immune responses (in vivo, mouse), suppression of delayed type hypersensitivity (in vivo, mouse) and reduction of the level of tumour necrosis factor in a fulminant hepatitis model (in vivo, mouse).

Finally, (+)-homoaromoline and fangchinoline show inhibition of the histamine production by RBL-2H3 cells in vitro.

Adulterations and substitutes Other *Menispermaceae* have similar or related alkaloids such as bisbenzylisoquinolines and protoberberines, and have similar applications. There is a report of *C. barbata* being substituted by *Cissampelos pareira*. In Java, *C. barbata* leaves are sometimes substituted by the leaves of *Stephania capitata* (Blume) Sprengel or *Canthium horridum* Blume, for the production of 'cincau' jelly.

Description Slender dioecious lianas up to 15 m long; stem herbaceous or woody, hispid to glabrous; roots sometimes tuberous. Leaves arranged spirally, simple and entire, often peltate, palmately veined; stipules absent. Inflorescence axillary, terminal or cauliflorous, pseudoracemose or thyrsoid. Flowers unisexual, calyx with free or connate sepals, corolla with free or connate petals (rarely absent); male flower 4(–5)-merous, with stamens fused into a peltate synandrium with 4–5 anthers; female flower 2–3-merous, with 1 carpel having a 3–5-fid stigma, without staminodes. Fruit a curved, obovate to rotund drupe with style-scar near base; endocarp bony, dorsally ornamented with 3–6 rows of tubercles. Seed horseshoe-shaped; embryo narrow, embedded in endosperm.

Growth and development The flowers are pollinated by insects such as small flies and bees and possibly also small beetles and moths, which are attracted by the scent of the flowers and possibly also by the smell of the leaves.

Other botanical information *Cyclea* is closely related to *Stephania*, which differs in its 2 whorls of sepals in the male flowers and its umbelliform or disciform inflorescences.

Ecology *Cyclea* occurs in forest, often in secondary forest, coastal forest, teak forest and bamboo forest, and in scrub vegetation, hedges, cultivated land and alang-alang (*Imperata cylindrica* (L.) Raeuschel) fields, up to 1200 m altitude. Some *Cyclea* species have been found at altitudes as high as 2800 m.

Propagation and planting Cultivated *C. barbata* fruits erratically, so propagation is by stem or root cuttings. Cuttings from young woody stems, 25–30 cm long, are planted near hedges, trees or trellises, for support at a later stage. Cuttings may also be planted in the field at a spacing of 2 m x 1.5 m, supported by stakes, under shade trees. Before planting 5 kg manure and 10 g triple superphosphate is added per planting hole. Two weeks later an additional 10 g ammonium sulphate and 10 g potassium chlorite is given.

Harvesting A first harvest of *C. barbata* leaves from stem cuttings can be expected after 6–8 months. Consecutive harvests are at intervals of 2–3 months.

Handling after harvest To make good quality jelly, 'cincau hijau', young well-developed leaves should be used. The shelf-life of the jelly at ambient temperature is 1–2 days.

Genetic resources and breeding *C. barbata* and *C. laxiflora* are locally rather common, the former in Java and the latter in Peninsular Malaysia, and occur particularly in disturbed forest. They do not seem at risk of genetic erosion. However, some other *Cyclea* species are endemic to comparatively small areas (e.g. *C. kinabaluensis* Forman on Mount Kinabalu) and are more likely to become endangered.

Prospects *Cyclea* root extracts show some interesting properties that deserve more research. In particular the powerful neuromuscular blocking property comparable to d-tubocurarine chloride, and the antimalarial activity warrant more attention.

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Selection of species

Cyclea barbata Miers

Contr. bot. 3: 237 (1871).

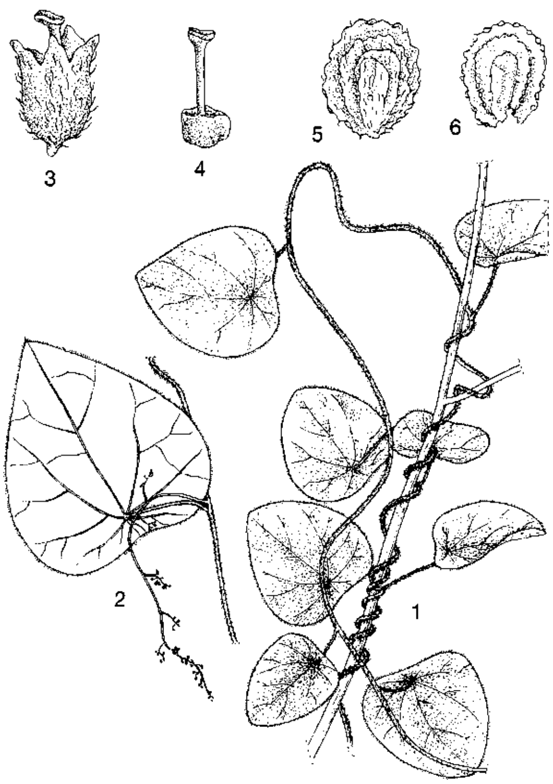
Synonyms *Cyclea peltata* auct. non (Lamk) Hook.f. & Thomson.

Vernacular names Indonesia: cincau (general), camcauh (Sundanese), camcao (Javanese). Thailand: krung khamao (peninsular), krung badan (south-eastern). Vietnam: d[aa]y s[aa]m, s[aa]m l[oo]ng.

Distribution India (Assam), Burma (Myanmar), Indo-China, Thailand, Simeuluë, islands in the Sunda Strait and Java.

Uses A decoction made of the roots is used in local medicine against fever. The leaves are used in Java to prepare a jelly called 'cincau' or 'cincau hijau' (green cincau), which is used as a refreshment and as a medicine against stomach complaints.

Observations A slender herbaceous or woody climber up to 8 m long, root fleshy, thick and long, pale brown outside, whitish or yellowish inside, stem hispid when young, later glabrescent; leaves ovate, deltoid-ovate or broadly ovate, up to 17.5 cm long, hairy below, petiole up to 6.5 cm long, hispid; male flowers with puberulous calyx and connate petals, female flowers tightly crowded in subglobose heads, with tomentose carpels; fruit puberulous. *C. barbata* occurs in forest including teak forest and bamboo forest, and in grassland with scrub vegetation, sometimes on limestone, occasionally cultivated, up to 1100 m altitude.



Cyclea barbata Miers – 1, leafy stem; 2, stem with leaf and male inflorescence; 3, male flower; 4, male flower with calyx removed; 5, fruit; 6, endocarp.

Selected sources 305, 421, 422, 423, 493, 580, 751, 907, 1035, 1374, 1597, 1615, 1638.

Cyclea laxiflora Miers

Contr. bot. 3: 241 (1871).

Vernacular names Malaysia: akar gasing bukit, akar rempenang, metimun tikus (Peninsular).

Distribution Thailand (peninsular), Peninsular Malaysia, Sumatra, Bangka and the Anambas Islands.

Uses A decoction made of the roots is used in local medicine in Peninsular Malaysia against fever and piles, after childbirth, as a vermifuge for children and applied externally to the nostrils in caries of the nasal bones.

Observations A slender herbaceous or slightly woody climber up to 15 m long, stem hispid to glabrous; leaves triangular-ovate, deltoid-ovate or broadly ovate, up to 16 cm long, hairy below, petiole up to 6 cm long, usually hispid; male flowers with glabrous or subglabrous calyx and free petals, female flowers in lax clusters, with glabrous or subglabrous carpels; fruit glabrous. *C. laxiflora* occurs in secondary and coastal forest, scrub vegetation, hedges and cultivated land, up to 1200 m altitude.

Selected sources 202, 421, 422, 423.

R.H.M.J. Lemmens & S.F.A.J. Horsten

Cyperus L.

Sp. pl. 1: 44 (1753); Gen. pl. ed. 5: 26 (1754).

CYPERACEAE

$x = 8, 9$; *C. brevifolius*: $n = 9$, $2n = 32, 120$, *C. iria*: $n = 36, 56, 64$, $2n = 18$, *C. kyllingia*: $n = 43, 62$, *C. rotundus*: $n = 40, 42, 48, 50, 54, 56, 64, 69, 76$, $2n = 16, 26, 96, 108, 152$

Major species *Cyperus kyllingia* Endl., *C. rotundus* L.

Vernacular names Nut sedge, nut grass, cyperus (En). Indonesia: teki. Malaysia: teki. Thailand: ya kok, ya haeo. Vietnam: c[os]i, l[as]c.

Origin and geographic distribution *Cyperus* comprises about 600 species distributed worldwide, with the vast majority occurring in the tropics and subtropics. In Malesia 76 species occur, but most of them have a pantropical or paleotropical distribution.

Uses In general, *Cyperus* is economically unimportant and better known for its weeds than its useful plants; several species are pernicious weeds in agriculture.
Several of the weedy species, particularly *C. rotundus*, are used in local medicine. In South-East Asia, the most widespread medicinal applications of the tubers are against hepatic disorders, as an emmenagogue and for post-partum treatment, as a stomachic, as a febrifuge, against renal and urologic disorders, and to treat ulcers. It is interesting that *Cyperus* species are used in similar ways in other parts of the world, e.g. in South America. Other medicinal uses in South-East Asia are as a stimulant, diuretic, anthelmintic (in large doses), galactagogue, sudorific, as a mouthwash against diseases in the mouth and toothache, and as an astringent against diarrhoea and dysentery.
Usually the powdered tubers (often in decoctions) are used internally, but for ulcers, scorpion stings and snake bites a poultice is applied externally. *Cyperus* species are also well known in Chinese and Japanese traditional medicine and are reported to be used in India as stimulants, diuretics, anthelmintics and stomachics for example. In the Ayurvedic system of medicine the tubers are believed to be tonic, and to act as a nourisher and rejuvenator; they are part of several complex preparations.
Because of their aroma, the tubers are used to perfume clothing and to repel insects. The roasted tubers have also been used as a substitute for coffee and as an adulterant for cocoa.
The fatty oil extracted from the tubers was formerly used to make soap. The dried stems are used to make mats, ropes, baskets and other wickerwork. Tubers and aboveground parts can also serve as a forage. Some species are used for their edible tubers (especially in times of food scarcity), for their edible stems (as vegetable or as forage), and some are used as garden ornamentals.

Production and international trade All *Cyperus* species are considered as weeds that are difficult to eradicate. *C. rotundus* is considered to be one of the world's most pernicious weeds. The sole medicinal use of the tubers of this species is in local medicine.

Properties The underground parts of several weedy species contain essential oils, about 0.5–1% in the case of the fresh tubers of *C. rotundus*, mainly consisting of terpenoids or sesquiterpenoids (e.g. cyperone, cyperol, cyperolone, cyperene, copadiene, epoxy-guiaene, rotundone, rotundol, patchoulenone (= cyperotundon), kobusone, sugeonolacetate, sugetriol, oxido-eudesmenol, mustakone and β-selinene).
When Tanzanian medicinal plants were screened, *C. rotundus* showed activity in a test for in vitro antimalarial activity. Further phytochemical investigations revealed the presence of several active compounds: α-cyperone, an auto-oxidation product of β-selinene, patchoulenone, caryophyllene epoxide, 4,7-dimethyl-1-tetralone (all sesquiterpenes) and 10,12-peroxycalamenene (a sesquiterpene endoperoxide). There is evidence that the peroxide moiety of the latter molecule is important in the activity against malarial parasites, as are artemisinin (from *Artemisia annua* L.) and ascaridole (from *Chenopodium* oil).
The essential oils furthermore have nematicidal and insecticidal activity (e.g. against bugs, beetles and caterpillars), and the insect- repellent activity is comparable to that of citronella oil. The aggressive spread as a weed may also be partly attributed to the sesquiterpenes present in the oil, which inhibit the growth of seedlings of agricultural crops.
Several investigations have focused on the anti-inflammatory and/or anti-pyretic effects of *C. rotundus*. Preliminary observations were made on the ethanolic extracts of the roots. The mechanism of activity was subsequently found to be inhibition of prostaglandin synthesis. In addition to the effects mentioned, some antihistaminic, smooth muscle relaxant, anti-emetic, antihepatotoxic and antifungal activities were observed. A carrageen-induced oedema test in rat revealed that the triterpenoid in the light petroleum ether extract of the root is the main active compound with in vivo anti-inflammatory activity.
Small amounts of saponins have been reported from *C. rotundus*, and the main substance of the lipid fraction in tubers of *C. iria* has been shown to be hentriacontanol. In Malaysia, a compound isolated from a steam distillate of the whole plants of *C. iria* appeared to be identical to juvenile hormone produced by insects. Nymphs of the acridid *Melanoplus sanguinipes* feeding on *C. iria* showed pronounced morphogenetic effects when they moulted to adults, so the compound can be considered as the plant's defence mechanism against insects. The water extract of rhizomes exhibits bradycardia and cardia depressant, coronary vasodilator, hypotensive and diuretic activities. Clinical trials with root extracts in 64 obese patients found hypotensive activity in those patients with hypertension, but no effect in normal patients.

Adulterations and substitutes The following species combine several of the major applications of *Cyperus*: *Artemisia* spp. (e.g. emmenagogue, stomachic, febrifuge, diuretic and ulcers), *Desmodium* spp. (e.g. hepatic disorders, stomachic, febrifuge, diuretic and ulcers), *Hibiscus* spp. (e.g. emmenagogue, stomachic, febrifuge, diuretic and ulcers), *Elephantopus scaber* L. (e.g. emmenagogue, febrifuge, diuretic and ulcers), *Heliotropium indicum* L. (e.g. emmenagogue, stomachic, diuretic and ulcers), *Leonurus* spp. (e.g. emmenagogue and for post-partum treatment, febrifuge and diuretic) and *Tinospora* spp. (e.g. hepatic disorders, stomachic, febrifuge and ulcers). However, the active compounds are in general quite distinct and the similar medicinal use is not a result of chemical conformity. Chemically related substances are found in some grass genera such as *Cymbopogon*; their essential oils have very similar sesquiterpenes and some similar applications.

Description Perennial or annual herbs, tufted or with creeping rhizome or stolons, sometimes with tubers at intervals; stem usually erect, triangular in cross-section, solid, usually leafy only at the base. Leaves tristichous, narrowly linear, grass-like, the lower ones often scale-like. Inflorescence terminal, simple to decompound, umbel-like or capitate; rays subtended by a leaf-like bract forming an involucre; spikelets subcompressed, quadrangular to subterete, 1–many-flowered; glumes distichous, usually 2 basal ones empty. Flowers bisexual, the uppermost of the spikelet often male or sterile; stamens 1–3; style continuous with the ovary, with 2–3 stigmas. Fruit a sessile or short-stalked nut, trigonous or lenticular.

Growth and development Most *C. rotundus* plants originate from a tuber; seed production is possible but unimportant. The sprouting tuber produces a rhizome which terminates as a green aerial shoot. While emerging from the soil a swelling (usually called a 'basal bulb') appears on the rhizome, often near the surface, but up to a depth of 20 cm. Roots form on the basal bulb and rhizomes grow out from it horizontally for a distance of 1–30 cm before the tip turns up to produce a new aerial shoot with another basal bulb, or, alternatively, to form a subterranean tuber from which another rhizome appears at the apical end, thus forming chains of tubers. The basal bulb and aerial shoot population may increase fivefold in the first 4 weeks after a tuber has been planted. It is believed that there are no buds at the nodes of the rhizomes and that no new plants can grow from rhizome fragments. Rhizomes and tubers are white and fleshy when young and some become firmly packed with starch. On aging they darken, harden, and most of the tissue outside the endodermis of the rhizomes sloughs off to leave a wiry structure resistant to desiccation and decay. Most tubers are found in the top 15 cm of the soil, and when planted at 90 cm depth are unable to grow to the surface. In cropped areas the starch reserves are greatest in tubers that are below the disturbed layer; in uncropped land they are greatest in tubers near the soil surface.

Short photoperiods stimulate flowering; the period from emergence to flowering varies between 3–8 weeks. Short photoperiods might also stimulate tuber formation and it is believed that tubers do not form until flowering begins. Flowers are cross-pollinated, mostly by wind. Although many seeds are formed, they are rarely viable: seed germination averages 1–5%.

C. iria spreads by seed that may germinate immediately as soon as it falls on the ground. Germination percentage is about 40% but is much lower if the soil is under water.

Other botanical information *Cyperus* is classified in the subfamily *Cyperoideae* and the tribe *Cypereae*. It seems to be most closely related to *Bulbostylis* and *Fimbristylis*. *Cyperus* is subdivided into 3 subgenera and numerous sections. Subgenus *Cyperus* includes most species in the Malesian Archipelago (about 60) and is characterized by a trigonous or, when lenticular, dorsoventrally compressed nut, and often 3 stigmas. Subgenus *Pycreus* includes 9 species in Malesia and has a laterally compressed nut, persistent rachilla and 2 stigmas. Subgenus *Kyllinga*, which has often been treated as a separate genus, includes 7 species in Malesia (e.g. *C. brevifolius* and *C. kyllingia*) and is characterized by its laterally compressed nut, disarticulating rachilla and 2 stigmas.

Ecology Most *Cyperus* species are hygrophilous and grow in moist or wet localities at low and medium altitudes, only a few occurring above 2000 m altitude in the tropics. Several species occur commonly in grasslands, on roadsides, river banks and waste places. Some species are noxious weeds in cropped land, and other species are colonizers of muddy and sandy flats near river mouths and along the coast. *C. rotundus* is found in fields, on roadsides, in neglected areas, at the edges of woods, along irrigation canals and streams, all over the world up to about 50° latitude in both hemispheres, beyond which low temperatures limit its further expansion. It grows readily at any elevation, humidity, in almost any soil type, soil moisture and pH, and can survive very high temperatures. Only low temperatures, shade, and very saline soils can limit its growth, and the tubers can remain dormant for a long time to carry the plant through the most extreme conditions of heat, drought, flooding or lack of aeration.

Propagation and planting All *Cyperus* species can be propagated by seed, and tuber-forming species can be easily propagated by tubers.

Husbandry Some *Cyperus* species, especially *C. rotundus* are serious weeds of rice, sugar cane, maize and vegetables in South-East Asia. Digging up all rhizome parts and/or the planting of crops that produce continuous shade for several years can eradicate them. Biological control methods have not yet been successful.

Diseases and pests *C. rotundus* has been reported as a host plant for *Rhizoctonia* disease and for root-knot nematodes (*Meloidogyne* spp.).

Yield *C. rotundus* may produce up to 40 t subterranean plant material per ha per year.

Handling after harvest The tubers of *C. rotundus* are briefly scorched by fire to get rid of the fine roots. They are then washed and dried in the sun or by hot air.

Genetic resources and breeding No germplasm collections and breeding programmes of *Cyperus* are known to exist.

Prospects It is expected that in South-East Asia *Cyperus* will primarily remain a weed problem for which effective herbicides and biological control methods still have to be found. It is not recommended to plant weedy species for medicinal purposes. Comparatively little research has been done on the chemistry and pharmacology. More research seems worthwhile on those *Cyperus* species used for similar medicinal purposes in many areas of the world.

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Selection of species

Cyperus brevifolius (Rottb.) Hassk.

Cat. Hort. Bog.: 24 (1844).

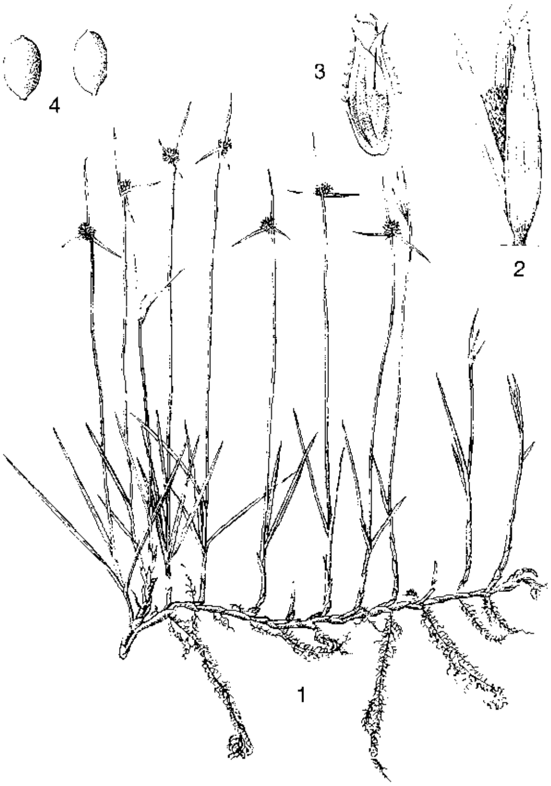
Synonyms *Kyllinga brevifolia* Rottb. (1773).

Vernacular names Indonesia: jukut pendul (Sundanese), rumput sadanan (Javanese), rumput kapas (Sumatra). Malaysia: kanching bayu jantan, rumput sekepet burit, rumput teki (Peninsular). Philippines: boto-botonisan (Tagalog), kadkadot (Igorot), pugo-pugo (Central Bisaya). Thailand: yaa kok dok khaao (Bangkok), yaa hua mong (Surat Thani). Vietnam: b[aj]c d[aaf]u l[as] ng[aws]n.

Distribution Throughout the tropical and warm temperate regions of the world; very common throughout Malesia.

Uses The pounded rhizome is used as poultice for sores; it has anti-inflammatory properties. A decoction of the whole plant is used as diuretic and against malaria. Leaves are taken internally against diarrhoea. It is sometimes used as a fodder.

Observations A perennial herb with rhizome creeping horizontally under or close to the ground surface, stem 3–40(–50) cm long; leaves 1–3 mm wide, canaliculate, scabrid on the margins in the upper part, grass-green; inflorescence usually consisting of a single terminal head, involucral bracts (2–)3–4(–6), up to 6(–20) cm long, spikelets closely



Cyperus brevifolius (Rottb.) Hassk. – 1, plant habit; 2, inflorescence enclosed by involucral bracts; 3, spikelet; 4, nuts.

packed, 1(–2)-flowered; stamens 1–2(–3), stigmas 2; fruit biconvex, laterally compressed, obovoid or ellipsoid, yellowish-brown. *C. brevifolius* is extremely variable. It occurs up to 1500(–1900) m altitude in grasslands, along roads, in forest clearings and on river banks.

Selected sources 202, 332, 580, 722, 760, 1178.

Cyperus cyperoides (L.) O. Kuntze

Rev. Gen. Pl. 3, 2: 333 (1898).

Synonyms *Mariscus sieberianus* Nees ex Clarke (1893).

Vernacular names Indonesia: jukut bebalean (Sundanese), suket lumbungan (Javanese), tetemung (southern Sumatra). Malaysia: menderong ekur tupai, rumput janggut baung, rumput mesiyang (Peninsular). Papua New Guinea: kaiga (Ialibu, Southern Highlands). Philippines: mangilang, kupiupi (Subanum), okokiang (Bontok). Thailand: yaa rang-kaa (Loei).

Distribution Throughout the tropics of Africa, Asia and Australia, also in the West Indies, but there probably introduced; throughout Malesia.

Uses *C. cyperoides* may be used as a vermifuge; some occult uses are known in Papua New Guinea. Sometimes it is used as a fodder.

Observations A perennial herb with a very short rhizome, lacking stolons, stem 20–75 cm long; leaves 3–6 mm wide, flat, scabrid in the upper part; inflorescence usually simple, involucral bracts 5–10, up to 30 cm long, rays 5–17, up to 6(–10) cm long, spikelets linear; stamens 3, stigmas 3; fruit trigonous, linear, slightly curved, rufous to chestnut-coloured. *C. cyperoides* occurs up to 1800 m altitude in grassland, roadsides, in forest clearings and in secondary forest and thickets; it is a common weed in gardens.

Selected sources 202, 580, 597, 722, 1178.

Cyperus diffusus Vahl

Enum. pl. 2: 321 (1805).

Vernacular names Indonesia: cekeng (Javanese), pukul sedapan (Riau). Malaysia: rumput bumbat, rumput chukor karbau, parah-parah (Peninsular). Philippines: tuhog-dalag (Tagalog), singao (Mindanao), barsanga-bakir (Iloko). Thailand: yaa teen kaa (Nakhon Ratchasima). Vietnam: c[or] g[aas]u n[uw][ows]c.

Distribution From India, southern China and Indo-China to the Solomon Islands; throughout Malesia except the Lesser Sunda Islands.

Uses It has been reported that in the Philippines (Mindanao) the roots are used to treat diseased lips. In Thailand, the roots are used as an antipyretic, analgesic, cardiotonic, diuretic and against coughing.

Observations A perennial herb with a very short rhizome, stem 15–80 cm long; leaves 5–10(–20) mm wide, channelled at the base, scabrid on the margins, grass-green above, pale green below; inflorescence decompound, diffuse and lax, involucral bracts 4–10, up to 50 cm long, primary rays up to 20, unequal, up to 20 cm long, spikelets digitately arranged, (4–)6–12(–20)-flowered; stamens 3, stigmas 3; fruit triquetrous, ellipsoid or subpyramidal, dark brown to dusky black. *C. diffusus* occurs up to 700 m altitude in thickets and moist forests on river banks, and on shady roadsides.

Selected sources 722.

Cyperus halpan L.

Sp. pl. 1: 45 (1753; 'haspan').

Vernacular names Indonesia: rembang (Sumatra), para-para (Riau), rumput kudung (Kalimantan). Malaysia: rumput sumbu, rumput bilis jantan (Peninsular). Philippines: balabalangutan (Tagalog), barsanga (Iloko), bungotbungot (Panay Bisaya). Thailand: kok naa (Trang), yaa kok chaai (Prachin Buri). Vietnam: c[us] c[ow]m.

Distribution Tropical and subtropical regions of the world; common throughout Indo-China, Thailand and Malesia.

Uses In Malaysia, smoke from the pith is used as febrifuge and a decoction of the plant is used internally against shingles. The pith has also been used for lamp wicks. *C. halpan* is sometimes used as fodder.

Observations A perennial herb, often flowering in the first year, with a short rhizome and reddish roots, stem usually slender, 10–40(–100) cm long; leaves 2–5 mm wide, flat, smooth or scaberulous at the top; inflorescence compound or decompound, involucral bracts 2–3, up to 10(–15) cm long, primary rays up to 20, up to 15(–20) cm long, spikelets digitately arranged, 10–30(–40)-flowered; stamens 1–3, stigmas 3; fruit trigonous, broadly obovoid, whitish, later yellowish. Two subspecies are distinguished: subsp. *halpan* with slender and short stems, 1 stamen and small nut, and subsp. *juncoides* (Lamk) Kük. with more robust stems, (2–)3 stamens and slightly larger nut; the former is a common weed, the latter prefers more natural habits. *C. halpan* occurs up to 1900(–3150) m altitude in open wet locations such as muddy places in swamps; it is a characteristic weed in lowland rice fields.

Selected sources 202, 722.

Cyperus iria L.

Sp. pl. 1: 45 (1753).

Vernacular names Indonesia: babawangan (Sundanese), rumput jekeng kungit (Javanese), rumput silupak (Sumatra). Philippines: sud-sud, alinang (Bikol), okokiang (Bontok). Thailand: kok huadaeng (Singburi), yaa kok saai (Nakhon Sawan), yaa kok lek (Ang Tong). Vietnam: c[os]i g[aj]o.

Distribution From Iran, Afghanistan, China and Japan to Australia, also in eastern Africa; common throughout Indo-China, Thailand and Malesia. Introduced and naturalized in the southeastern United States and the West Indies.

Uses In India the plant is used as tonic, stimulant, stomachic, febrifuge, astringent, and for amenorrhoea. In Vietnam, the whole plant is used to treat rheumatism, to regulate menstruation; the rhizomes are used as a diuretic. It is sometimes used as fodder.

Observations An annual or sometimes perennial herb with fibrous, yellowish-red roots, stem (5–)15–50(–80) cm long; leaves 3–6(–8) mm wide, flat or channelled, scabrid on the margins in the upper part; inflorescence simple or compound, involucral bracts 3–5(–7), up to 40 cm long, primary rays 3–5(–8), very unequal, up to 10(–18) cm long, spikelets spicately arranged, 6–20(–24)-flowered; stamens 2–3, stigmas 3, minute; fruit triquetrous, obovoid or ellipsoid, shining dark brown to black. *C. iria* occurs up to 700(–1200) m altitude in open wet locations and is a characteristic weed in lowland rice fields, but it may also occur as a weed in vegetables, maize, sugar cane, groundnut and soya bean. It also occurs on roadsides and river banks.

Selected sources 202, 614, 722, 1178, 1465.

Cyperus kyllingia Endl.

Cat. horti Vindob. 1: 94 (1842).

Synonyms *Kyllinga monocephala* Rottb. (1773).

Vernacular names Indonesia: jukut pendul bodas (Sundanese), melaran (Javanese), kembilikembili (Batak). Malaysia: rumput teki, rumput butang (Peninsular). Philippines: anuang (Tagalog), borobotones (Bisaya), borsa-ñga-dadakkel (Iloko). Cambodia: smao kak kdam. Thailand: yaa tumhu (Bangkok), yaa nuai faai (Nakhon Si Thammarat). Vietnam: c[or] b[aj]c d[aa]u, c[or] n[us]t [as]o.

Distribution Common in tropical and warm-temperate Asia, less common in tropical Africa and Australia and rare in South America; common throughout Malesia.

Uses In India, the roots are considered an antidote to poisons. In Indonesia, they are used against diarrhoea and measles, and sometimes as a poultice for skin problems. In the Philippines, a decoction of the rhizomes is employed as a diuretic and, mixed with oil, it is applied externally to combat certain forms of dermatosis. In Vietnam, a poultice of the whole plant is used in the treatment of ulcers, sore throat, bacillary dysentery and fever. In Guam, the roots are used as abortifacient. *C. kyllingia* is sometimes used as a fodder.

Observations A perennial herb with horizontally creeping rhizome, stem 5–45 cm long; leaves 2–4(–5) mm wide, canaliculate, scabrid on the margins in the upper part, grass-green; inflorescence consisting of a terminal head with usually 1–3 much smaller, sessile heads at the base, involucral bracts 3–4, up to 30 cm long, spikelets very closely packed; stamens 3, stigmas 2; fruit biconvex, laterally compressed, oblong or oblong-obovoid, yellowish-brown to chestnut-coloured. *C. kyllingia* occurs up to 1750 m altitude in open grassland, waste places, roadsides and regrowth.

Selected sources 190, 202, 580, 722, 760, 1035, 1178.

Cyperus malaccensis Lamk

Tabl. encycl. 1(1): 146 (1791).

Vernacular names Indonesia: darengdeng (Sundanese), kumbu (Sumatra), rumput kuluwing (Sulawesi). Malaysia: menderong darat (Peninsular). Philippines: balangot (general), baga-as (Panay Bisaya), tikog (Manobo). Thailand: yaa saam liam (Bangkok). Vietnam: l[as]c, c[os]i.

Distribution From Irak through India to southern China, northern Australia and Polynesia; throughout Malesia.

Uses The rhizomes are used for post-partum treatment and against oedemas in Vietnam; they are considered to be diuretic. The stems are commonly used for making ropes, baskets, mats, hats and slippers.

Observations A perennial herb with stout stolons clothed with dark brown scales hardening into a woody rhizome, stem 60–175 cm long; leaves 5–10(–18) mm wide, scabrid at the top; inflorescence compound or subdecompound, involucral bracts 3–4, up to 30 cm long, primary rays 3–6(–10), very unequal, spikelets spicately arranged, 16–20(–40)-flowered; stamens 3, stigmas 3; fruit trigonous, slightly compressed dorsally, narrowly oblong, dark brown to black. *C. malaccensis* grows in moist localities, usually within the influence of salt or brackish water; it is an abundant colonizer on mud flats in estuaries and on sandy shores.

Selected sources 190, 202, 580, 722, 1035.

Cyperus rotundus L.

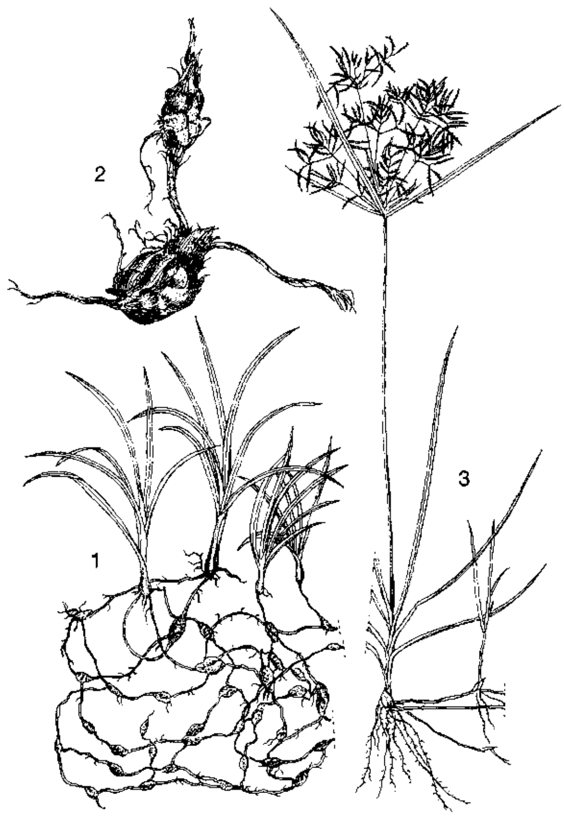
Sp. pl. 1: 45 (1753).

Vernacular names Purple nut grass, purple nut sedge (En). Souchet rond (Fr). Indonesia: teki (general), mota (Madura), karelawai (Sumba). Malaysia: teki, rumput haliya hitan. Philippines: mutha (Tagalog), ahos-ahos (Bisaya), boto-botones (Bikol). Burma (Myanmar): monhnyin-bin. Cambodia: krâva:nh chru:k. Laos: hèwz hmu:. Thailand: yaa haeo muu, yaa khon muu (general). Vietnam: c[ur] g[aas]u, h[uw][ow]ng ph[uj].

Distribution *C. rotundus* is thought to originate from Africa. Now it is widely distributed throughout the warmer parts of the world and it is very common all over South-East Asia.

Uses *C. rotundus* is widely used medicinally for various diseases and complaints (see the genus entry). It is also used as a fodder. The tubers are sometimes eaten. The oil extracted from the tubers was formerly used to make soap.

Observations A perennial herb with long, slender, stout, wiry, dark brown rhizomes giving rise at intervals of 5–25 cm to tubers, forming tuber chains, tubers subglobose or ellipsoid, 0.5–2.5 cm long, white and succulent when young, turning fibrous brown-blackish, stem slender, 15–30(–75) cm long; leaves 2–6 mm wide, flat, scabrid on the margins in the upper part; inflorescence simple or compound, involucral bracts 2–4(–6), up to 30 cm long, primary rays 3–9, very unequal, up to 10 cm long, spikelets spicately arranged, 10–40(–100)-flowered; stamens 3, stigmas 3; fruit trigonous, oblong-obovoid, brown to black, rarely maturing. Two subspecies are distinguished: subsp. *rotundus* and subsp. *retzii* (Nees) Kük. Subsp. *retzii* (synonym: *C. retzii* Nees) differs from subsp. *rotundus* by its stouter habit (stem 50–75 cm tall), the somewhat broader spikelets (about 2.5 mm



Cyperus rotundus L. – 1, young plant with rhizomes and tubers; 2, tubers; 3, flowering plant.

wide when ripe) and the paler elliptical-oblong glumes, 3.5–4 mm long; it appears in moist localities, sometimes as a weed, but never as a pest. Subsp. *rotundus* occurs up to 1000 m altitude in open grasslands, roadsides and waste places, and is often a serious pest in cultivated land, e.g in lowland rice, maize, sugar cane and vegetables.

Selected sources 72, 202, 350, 414, 580, 597, 614, 664, 722, 757, 761, 930, 1035, 1178, 1315, 1454, 1514, 1533, 1558, 1559, 1563.

Cyperus stoloniferus Retz.

Observ. bot. 4: 10 (1786).

Vernacular names Philippines: apulid-gapang (Tagalog). Vietnam: c[ur] g[aas]u bi[eer]n, h[uw] [ow]ng ph[uj] bi[eer]n.

Distribution Madagascar, Mauritius, whole South-East Asia, but only locally in the Philippines, to Melanesia and northern Australia.

Uses The tuber is used in India as a stomachic and heart stimulant. In Vietnam, *C. stoloniferus* is used as a substitute for *C. rotundus*, but has in general a stronger effect. It is considered useful as a sand binder.

Observations A perennial herb with long, creeping stolons hardening into a woody rhizome, forming stout tubers, stem 15–50 cm long; leaves 1.5–4 mm wide, scabrid in the upper part, glaucous; inflorescence simple or subcompound, involucral bracts 2–3, up to 30 cm long, primary rays 2–5, very unequal, 1–6 cm long, spikelets spicately arranged, 8–20-flowered; stamens 3, stigmas 3; fruit dorsoventrally compressed, broadly ovoid to ovoid, shining dark brown to blackish. *C. stoloniferus* is fairly common on coastal sands of dunes and beaches and occasionally occurs in saline, muddy locations.

Selected sources 202, 722, 1178, 1533.

Nguyen Khac Khoi

Datura L.

Sp. pl. 1: 179 (1753); Gen. pl. ed. 5: 83 (1754).

SOLANACEAE

$x = 12$; *D. metel*: $2n = 24, 48$, *D. stramonium*: $2n = 24$

Major species *Datura metel* L.

Vernacular names Thorn apple (En). Pomme épineuse, stramoine (Fr). Indonesia: kecubung. Malaysia: kechubong. Philippines: talong-punay (Tagalog). Thailand: ma khuea ba (northern), lamphong (central). Vietnam: c[af]d[ooj]c d[uw] [ow]c.

Origin and geographic distribution *Datura* consists of approximately 10 species. It is believed to have originated in the southern part of North America (Mexico) but has since been introduced throughout the world. Some species have a long history in the Old World; the first references to them are from the middle of the 16th Century, and it is probable that they were introduced soon after the discovery of America. Only *D. metel* and *D. stramonium* are found in South-East Asia.

Uses One of the main uses of *D. metel* in South-East Asia is for relieving asthma by smoking the dried leaves (and stems) or flowers. These 'asthma cigarettes' have been shown to be very efficient in some cases, but in other cases they had little or no effect. However, indiscriminate use can have serious, or even fatal consequences. Other traditional uses include the treatment of haemorrhoids, boils and sores, skin diseases, rheumatism, headache, toothache, cholera, parasites such as ringworm, and as an anaesthetic. In India, *D. metel* has similar medicinal applications, and it is used additionally to treat hydrophobia, syphilis, inflammations of the breasts, epilepsy, convulsion, smallpox, mumps and leprosy. The Chinese use the flowers as anaesthetic and to treat asthma, cough, eruptions and swellings, and as a pain reliever. In Africa, *D. metel* is used as an abortifacient and to treat asthma.

In South-East Asia, *D. stramonium*, which is only found in Java, where it occurs locally, is sometimes used in traditional medicine to treat fatigue, pain and for curing sprains. Elsewhere, e.g. in India, Europe and Africa, it is used similarly to *D. metel*.

Datura species contain (–)-hyoscyamine and (–)-scopolamine as the major alkaloids. The natural occurring, pharmacologically active (–)-hyoscyamine is easily racemized, yielding (±)-hyoscyamine, commonly known as atropine. Its pharmacological effect is the same as that of (–)-hyoscyamine, but it must be used in double doses, because the (+)-isomer is practically inactive. (–)-Hyoscyamine and atropine have an anti-cholinergic (parasympatholytic) action. Modern therapeutic uses of these alkaloids therefore include: as a remedy against spasms in skeletal muscles, the urinary tract (e.g. in the treatment of renal colic), and the respiratory tract (asthma, bronchitis), for the suppression of secretions (e.g. overproduction of hydrochloric acid in the stomach, and as pre-anaesthetic to reduce salivation and respiratory secretions), as an antidote (treatment of cholinesterase-inhibitor poisoning, e.g. by nerve gases or certain insecticides), and in some special cases of Parkinsonism, acute myocardial infarction and bradycardia. (–)-Hyoscyamine and atropine are also available in eye drops for the treatment of uveitis and as a diagnostic aid (mydriatic) in certain eye examinations.

Like (–)-hyoscyamine, (–)-scopolamine has an anti-cholinergic effect, but unlike (–)-hyoscyamine, it is also a central nervous system depressant. Its uses include treatment of certain painful spasms, as a component of pre-anaesthetic medication and in ophthalmology, but the current main use is for the prevention of motion sickness (often applied as a skin patch behind the ear). The derivative scopolamine-butylbromide is frequently used in the treatment of gastro-intestinal spasms and renal or biliary colic.

The usefulness of *Datura* preparations in the treatment of asthma, and the route of application (cigarettes) is questionable and obsolete. A derivative, ipratropium bromide (isopropyl-atropine), is now commonly used instead. As an inhalation, it appears to be very effective in the treatment of chronic bronchitis, but somewhat less effective in asthma.

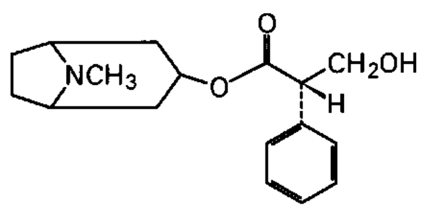
Hallucinogenic uses of *Datura* spp. are common among native tribes in Central and South America, but are apparently uncommon in South-East Asia. Although comparatively few cases of death have been recorded, its experimental use by, for example, adolescents, is very dangerous because the user often tries to harm himself or others. Criminals have used *Datura* to stupefy their victims. In Thailand, the seeds with a high concentration of scopolamine are used for this purpose.

Datura is also used in veterinary medicine, e.g. to control ectoparasites. *D. metel* has been shown to be efficient as a pesticide. Extracts have been used successfully against the larvae of the lepidopterous *Plecoptera reflexa*, which is a serious pest in *Dalbergia sissoo* Roxb. ex DC. plantations in India, and against cotton pathogens. They also reduce insect damage in stored wheat and maize, and are useful to control the root-knot nematode *Meloidogyne javanica*. *D. metel* is commonly cultivated as an ornamental, particularly the forms with double and purplish flowers.

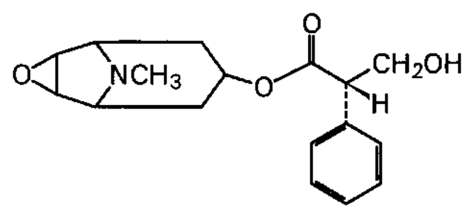
Production and international trade No trade statistics are available for *Datura*, although it is occasionally used for industrial extraction of tropane alkaloids. At the beginning of the 1980s the market prices of scopolamine hydrobromide and hyoscyamine sulphate were approximately US$ 850/kg and US$ 470/kg, respectively. In South-East Asia, *Datura* is only traded on a small scale on local markets.

Properties The drugs used consist of the dried leaves, sometimes mixed with flowering tops and sometimes with fruits of *Datura* spp. The leaves are often rolled, wrinkled, agglomerated or broken in commercial samples. They have a characteristic, disagreeable odour and a slightly nauseous, bitter taste. The drug is rich in minerals (15–18%), and it must be emphasized that it is very toxic. The drug is generally used for the preparation of galenicals and not for the industrial extraction of alkaloids. The *D. stramonium* powder listed in the Dutch Pharmacopoeia (8th edition) is titrated to contain 0.23–0.27% total alkaloids. It is an ingredient of antitussive syrups, but is mostly used in the form of cigarettes to relieve respiratory difficulties, together with other drugs.

The concentration of total alkaloids in the leaves of *D. stramonium* is normally 0.2–0.5%, with (–)-hyoscyamine and (–)-scopolamine (= (–)-hyoscine) as the major compounds and apoatropine, tropine, belladonnine and (–)-hyoscyamine-N-oxide as minor compounds. Biosynthetically these so-called tropane alkaloids are derived from the amino acid ornithine. An alkaloid content of about 0.6% has been reported for the flowers and fruits. The leaves of *D. metel* contain about 0.2–0.6% total alkaloids, the flowers 0.1–0.8% and the seeds 0.2–0.5%. (–)-Scopolamine is by far the chief constituent (up to 75% of the total alkaloid amount in mature leaves), together with (–)-hyoscyamine,



(–)-hyoscyamine



(–)-scopolamine

(–)-norhyoscyamine, (–)-norscopolamine, hydroxy-6-(–)-hyoscyamine and meteloidine. Although also atropine ((±)-hyoscyamine) often has been reported to be present in *Datura*, it is very unclear whether it is really a natural product or an artefact obtained during isolation. Simply choosing different conditions throughout alkaloid extraction procedures (e.g. using sodium hydroxide instead of ammonia) can easily cause (–)-hyoscyamine to racemize into atropine.

Atropine, (–)-hyoscyamine and (–)-scopolamine are anti-cholinergics (parasympatholytics); they have been the starting point from which synthetic organic chemistry has created several other anti-cholinergics. Although (–)-hyoscyamine has a stronger activity than racemic atropine (the (+)-isomer is not active), the latter is more commonly prepared and used. These compounds act by competitively and reversibly inhibiting of the transmitter acetylcholine from binding to its (muscarinic) receptors, and this antagonism leads to sympathomimetic-like effects in the organs. They increase the heart rate by suppressing vagal inhibition, induce relaxation and motor inhibition in the smooth muscle fibres, decrease secretions, and induce passive mydriasis in the eyes which is very characteristic. Although at low doses their action tends to be depressant and sedative, at high doses they cause substantial excitation: agitation, disorientation, exaggerated reflexes, hallucinations, delirium, mental confusion and insomnia. (–)-Scopolamine has a similar activity, but less marked, especially on the myocardium. It potentiates neuroleptics, improves Parkinsonism, and at high doses causes speech and locomotor difficulties, affects intellectual faculties, and may lead to coma. *Datura* is also toxic to animals such as cattle, sheep and goats. The main clinical signs are disturbances in locomotion, fasciculation, hyperaesthesia, rapid respiration and reduced water intake.

D. stramonium has been tested for its ability to control pests, for which purpose *D. metel* is sometimes already used successfully.

Adulterations and substitutes Tropane alkaloids similar to those found in *Datura* are known from numerous *Solanaceae* (e.g. hyoscyamine and scopolamine in *Atropa belladonna* L. and *Hyoscyamus niger* L.). Scopolamine is found in high quantity in *Duboisia* spp., which are used for industrial production in Australia.

Description Annual herbs or short-lived perennials up to 2 m tall; stem dichotomously branched. Leaves alternate, simple, often with oblique base, entire to repand, variously toothed or lobed, petiolate, exstipulate. Flowers solitary in the branch forks, erect, large, bisexual, regular, usually 5-merous, shortly pedicelled; calyx tubular, circumscissile near the base after anthesis, lobed, base accrescent; corolla funnel-shaped or trumpet-shaped, lobes short, plicate and twisted in bud, with distinct acumens, sometimes appearing 10-lobed because of the presence of interacuminal lobules, white, yellow, purplish or violet; stamens adnate to the lower third of the corolla, anthers narrowly ellipsoid, basifixed, dehiscing longitudinally; ovary superior, 2-locular, often 4-locular at base because of a false septum, style filiform, stigma saddle-shaped and 2-lobed. Fruit an ovoid to globose capsule, 2–4-celled, with slender to stout spines, frilled at the base by the calyx base, dehiscent by 4 valves from the apex or breaking irregularly, green but becoming brown, many-seeded. Seeds almost D-shaped, compressed, testa finely pitted to coarsely sculptured, usually with well-developed funicular caruncle; endosperm present; embryo curved. Seedling with epigeal germination; hypocotyl long and slender; epicotyl growing straight upward between the narrowly ovate, petiolate cotyledons; first 2–5 leaves smaller than subsequent ones.

Growth and development The vegetative axis is restricted to the basal portion of the plant, and branching is restricted to the flowering part which forms the major part of the plant and which does not revert to vegetative growth. The flowers are closed during the day and open in the evening, and are reported to be pollinated by hawkmoths and to be largely self-fertile.

In studies in India it was found that mature leaves of about the middle of the stems of *D. metel* had the maximum alkaloid content, and that very young fruits possessed a higher content of alkaloids than later developmental stages of the fruit. In *D. metel* grown experimentally in Iran, the highest scopolamine concentrations were found in the roots (0.2%) of 16-week-old plants, and in the stems (0.3%) and young leaves (0.25%) of 6-week-old plants.

It is known that the hyoscyamine/scopolamine ratio in *D. stramonium* is influenced by the developmental stage reached by the plants. In younger plants scopolamine is the main alkaloid, whereas hyoscyamine mostly becomes the dominant alkaloid when flower development has started. It is known that alkaloids are produced in the roots and transferrred to the leaves, flowers and finally the fruits.

Other botanical information *Brugmansia* is considered here as a separate genus, although it is often treated as merely a section of *Datura* (sect. *Brugmansia* (Persoon) Bernh.). It mainly differs in its habit (a woody, comparatively long-lived arborescent shrub or small tree), its mode of growth (reproducing vegetatively by root suckers), its pendulous or inclined flowers open throughout anthesis for 4–6 days with spathe-like, not circumscissile calyx and long pedicel, and its fruit being a usually indehiscent berry with unarmed pericarp. Chemically, *Datura* and *Brugmansia* are similar, and consequently they have similar medicinal applications. However, the primary use of the *Brugmansia* species is as an ornamental.
D. metel is easily confused with other *Datura* species, especially *D. inoxia* Miller and sometimes also *D. stramonium*, but is characterized by the very short spines on the fruit and the glabrous stem and leaves. There is some evidence that *D. inoxia* can be successfully cultivated in the Philippines; it is a source of scopolamine and can be useful as antispasmodic, and is an important medicinal plant, for instance in India.

Ecology *Datura* species are usually found in more open locations: in grassland, roadsides, waste places, scrub vegetation and open forest. They tolerate various soil types but prefer clayey or loamy soils. *D. stramonium* can be a serious weed, e.g. in soya bean. The total alkaloid content of *D. metel* has been shown to peak in the hot and dry season in Nigeria, and it was lowest in the rainy season.

Propagation and planting *D. metel* is generally cultivated from seed sown either directly in the field or in a nursery bed. Soaking seed for one night in water may improve germination. Per hectare, 7–8 kg of seed is needed. Seed starts germinating after about 2 weeks, and germination is complete after one month. If the seed is sown in the nursery, seedlings are transplanted when 8–12 cm tall. Effective means of vegetative reproduction, such as root suckers in *Brugmansia*, are absent in *Datura*. Normal spacing is 70–100 cm.

In vitro production of active compounds Tropane alkaloids are biosynthesized in cell suspension cultures of *D. stramonium* in shake flasks and bioreactors. Calluses have been induced from leaves, stems and roots and cultured on Gamborg's B5 or Murashige and Skoog medium supplemented with growth regulators. The highest alkaloid content was produced in leaf calluses grown on a medium with low concentrations of growth regulators (0.1 mg/ml of benzyladenine and 2,4-D), and in cultures grown in the dark. In tests, the cell structures responded very well to elicitors in the late exponential phase, whereas addition of cell-wall fragments of *Phytophthora megasperma* enhanced the final tropane alkaloid yield by 5-fold compared with the control culture. Supplying carbon and nitrogen to cell cultures in the early stationary phase suppressed tropane alkaloid production at comparatively low C:N ratio, but at a C:N ratio of over 100 the final product yield was increased. Total alkaloid production in the cell culture supplemented with phenylalanine and ornithine was 5 times higher than in the control culture, and higher ratios of tropine to tropic acid also stimulated alkaloid production (at a ratio of 20, the productivity was 7 times higher than that in the control culture). A hyoscyamine production of up to 7.5 mg/l daily was recorded in root cultures on full-strength Gamborg's B5 medium containing 5% sucrose at 20–25°C.

Husbandry The application of a nitrogenous fertilizer increases both growth and the hyoscyamine content of *Datura* spp. As the scopolamine content is inversely related to the increase in biomass, fertilization results in accelerated decrease in scopolamine, which is the major alkaloid in young plants. Methods leading to a retarded growth by e.g. indirect sowing or thinning will lead to a retarded shift of the hyoscyamine/scopolamine ratio to hyoscyamine. However, experiments in Burundi with *D. stramonium* showed that the application of chemical fertilizer but also of manure, resulted in increased production of total alkaloids. As a result of experiments in Burkina Faso, deflowering was recommended to increase the total alkaloid content in the leaves.

Diseases and pests *Datura* spp. can be infected by wilt and root rot caused by *Sclerotium rolfsii*, root and foot rot caused by *Corticium solani*, leaf spot caused by *Alternaria* spp., and by several mosaic and other virus diseases with symptoms like leaf curl, retarded growth and yellowing of leaves. Some of these diseases can be transmitted to solanaceous crops like tomato.

Harvesting The aerial parts are usually harvested at the beginning of flowering. Plants regrow after the first harvest and can be harvested once or twice again within the same season. In experiments in Burundi it was demonstrated that the best time for harvesting leaves of *D. stramonium* was 8 weeks after sowing, because alkaloid content was then maximal. From experiments in Burkina Faso, it was recommended to harvest the leaves in the early morning or late afternoon.

Yield In India, yields per ha of 10.5–14.5 t of fresh plant material and 750–1200 kg of seed of *D. metel* have been reported. In Pakistan, 400 kg/ha of seed of *D. stramonium* were harvested. Studies in Turkey showed leaf yields as high as 50 t/ha. The highest yields of scopolamine and hyoscyamine from *D. stramonium* reported for Algeria were 7.5 kg/ha and 21 kg/ha, repectively.

Handling after harvest The foliage of *Datura* spp. is dried in the shade immediately after harvesting. The fruits are first left in the sun to dry until they are open, then threshed to remove the seeds, which are subsequently sun-dried. Dried leaves and leaf powder should be stored in well-closed containers protected from light and moisture.

Genetic resources and breeding Both *D. metel* and *D. stramonium* have an extremely wide geographical distribution and prefer anthropogenic habitats. Therefore, they are not easily liable to genetic erosion. The genetic base of *D. stramonium* in South-East Asia is probably rather small because it only occurs very locally in Java. In order to develop industrial plantations for alkaloid extraction, breeding should particularly focus on high alkaloid content, combined with the development of proper means of vegetative propagation.

Prospects Although the tropane alkaloids scopolamine, hyoscyamine and atropine can be prepared synthetically, it is more economical to extract them from plants such as *Datura* spp. However, *Atropa* and *Duboisia* species are the major sources of raw materials. Moreover, local demand in South-East Asia for the pure chemicals is too small to justify commercial production of *Datura* spp. It is likely that local demand for *Datura* will be for tincture production only. On the world market for the pure tropane alkaloids, it will be difficult to compete with producers in China and India.

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Selection of species

Datura metel L.

Sp. pl. 1: 179 (1753).

Synonyms *Datura fastuosa* L. (1759).

Vernacular names Downy thorn apple, metel thorn apple (En). Stramoine metel, concombre diable (Fr). Brunei: kecupong. Indonesia: kecubung (general), kucubung (Sundanese), kacubung (Javanese). Malaysia: kechubong, kechubong puteh, kechubong hitam. Philippines: talong-punay (Tagalog), kamkamaulau (Iloko), katchibong (Bisaya). Cambodia: slak. Laos: mak kheua ba. Thailand: ma khuea ba (northern), lamphong (central), liak (Khmer, Surin). Vietnam: c[af] d[ooj]c d[uw][owj]c, d[uw][ow]ng kim hoa, m[aj]n d[af] la.

Distribution Probably of American origin; widely cultivated and naturalized in all tropical and subtropical regions. In South-East Asia, *D. metel* is reported for Indo-China, Thailand, Peninsular Malaysia (cultivated and locally naturalized in the northern part), Brunei, Java (cultivated and naturalized), the Philippines (naturalized, sometimes cultivated) and Papua New Guinea (very locally cultivated and naturalized).

Uses Dried leaves of *D. metel* are traditionally used as 'asthma cigarettes' to relieve asthma in

Datura metel L. – 1, flowering stem and young fruit; 2, fruit; 3, seeds.

South-East Asia. In Brunei, an infusion of the flowers is drunk to relieve mental disorders.

Observations An annual or short-lived perennial herb up to 200 cm tall, stem short-haired to glabrous; leaves ovate to angular broad-ovate, 4–25 cm × 2–20 cm, entire to repand-dentate-lobed, petiole up to 16 cm long; flowers with corolla of (12–)14–18(–20) cm long, simple or double, white or purplish; fruit deflexed when mature, with numerous conical tubercles of approximately equal length. *D. fastuosa* is sometimes considered as a species distinct from *D. metel*, but more often as a variety or cultivar. *D. metel* is often cultivated in gardens and yards (often with double and purplish corolla), but also grows wild or naturalized (usually with simple and whitish corolla) and is locally abundant in waste places, roadsides, brushwood, open grassland, teak forest and on river banks, up to 1000 m altitude.

Selected sources 23, 78, 87, 97, 202, 332, 350, 528, 549, 561, 562, 580, 652, 847, 964, 1035, 1126, 1178, 1277, 1433.

Datura stramonium L.

Sp. pl. 1: 179 (1753).

Synonyms *Datura tatula* L. (1762).

Vernacular names Thorn apple, jimsonweed, devil's apple (En). Pomme épineuse, stramoine (Fr). Indonesia: kucubung leutik (Sundanese), jarak pendek, kacubung wulung (Javanese). Thailand: lanphong khao.

Distribution Probably of American origin; now found all over the world, but particularly common in warm temperate regions. In South-East Asia, *D. stramonium* only occurs in some locations in Java, where it is naturalized, and also in mountainous regions in Thailand.

Uses In Java, *D. stramonium* is an ingredient of certain traditional medicines to treat fatigue, pain and for curing sprains.

Observations An annual herb up to 120 cm tall, stem glabrous or nearly so; leaves rhombic to angular-ovate or ovate-oblong, 6–20 cm × 3–15 cm, exsculpted-dentate-pinnatilobed, petiole up to 10 cm long; flowers with corolla 5–9 cm long, simple, white or pale purplish; fruit always erect, densely covered with strong and long prickles. *D. stramonium* is locally naturalized in Java at higher altitudes (1000–2100 m) and grows in sunny and fertile locations such as on waste land and in tea plantations.

Selected sources 87, 97, 112, 193, 343, 346, 549, 561, 562, 580, 588, 652, 847, 1277.

Sri Hartati, Imastini Dinuriah & M.M. Blomqvist

Derris Lour.

Fl. cochinch.: 432 (1790).

LEGUMINOSAE

x = 10, 11, 12, 13; *D. acuminata*: $2n$ = 22, *D. elegans*: $2n$ = 22, *D. elliptica*: $2n$ = 20, 22, 24, 36, *D. malaccensis*: $2n$ = 22, 24, *D. robusta*: n = 11, *D. scandens*: $2n$ = 26, *D. trifoliata*: n = 10, 11, $2n$ = 22, 24

Major species *Derris elliptica* (Wallich) Benth., *D. malaccensis* (Benth.) Prain, *D. trifoliata* Lour.

Vernacular names Derris, tuba root (En). Touba (Fr). Indonesia: tuba. Malaysia: tuba. Philippines: tubli. Vietnam: c[os]c k[ef]n.

Origin and geographic distribution *Derris* consists of about 55 species found throughout the Old World tropics. Most species (approximately 50) are found in South-East Asia, 3 in Australia and one species extends from Asia to eastern Africa. *D. elliptica* and *D. malaccensis* are cultivated, e.g. in India, southern China, Malaysia, Indonesia, the Philippines, New Guinea, tropical Africa and America.

Uses The rotenoids from *Derris* constitute an effective alternative to regular synthetic insecticide applications in horticulture and agriculture. They can be applied to control a large array of pests on a range of crops. The insecticide is applied as dust, spray, dip or bait. In cabbage it is used to control the lepidopterous *Plutella xylostella* (diamondback moth) and *Pieris rapae*. It is also used to control the aphid *Myzus persicae*, which is a major pest of vegetables and peaches in China. Furthermore, it is applied against borers, thrips and seedling maggots on maize, golden apple snails (*Pomacea* spp.) on rice, against the tenthredinid *Caliroa cerasi* on apple and oriental pear (*Pyrus pyrifolia* (N.L. Burman) Nakai), against cotton stainer, black bean aphids, common cutworm, earcutting caterpillar, and against *Helluta undalis* on broccoli. The extract is also effective against pests of stored garlic and rice. In poultry farming it can be used to kill ticks, fleas, lice, mites, flies and to control sticktight fleas. It is reported to be ineffective against bedbugs, cockroaches, scale insects and red spiders.

D. elliptica and *D. malaccensis* are used as a fish poison throughout southern Asia and the Pacific. The pounded root is considered the strongest fish poison in South-East Asia. Rotenone is used in fisheries in the Philippines, Bangladesh and India to remove predatory and other undesired fish from rearing ponds.

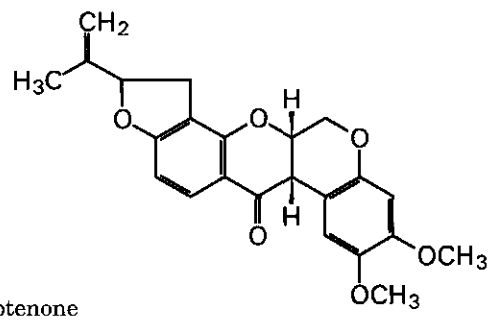
D. elliptica is traditionally used for antisepsis and applied to abscesses and against leprosy and itch, and sometimes as an abortifacient. The root of *D. scandens* is used in India to increase milk secretion after childbirth; it is crushed with or without water and the juice is given orally. The whole plant of *D. trifoliata* is used in India as a stimulant, anti-spasmodic and counter-irritant, and the bark against rheumatism, chronic paralysis and dysmenorrhoea, and in Papua New Guinea a decoction of the roots is applied externally against fever and internally against sores. A solution of crushed leaves of *D. elegans* is used to wash snake bites in Papua New Guinea. An extract from the roots of *D. elliptica* is reported to be employed as an ingredient of arrow poison in Borneo.

The stems are sometimes used for rough cordage. The wood of *D. robusta* trees is sometimes used for tea chests and implements. *Derris* can serve as soil improver. Lianas, including *D. elliptica*, may occur as weeds in forest plantations of *Acacia*, *Eucalyptus* and *Swietenia*.

Production and international trade Until 1930 in Indonesia, *Derris* was grown as single plants near houses only. Cultivation of *Derris* was forbidden by law, to prevent fish being eradicated by too intensive use of the roots. Around 1930, several plantation companies planned to cultivate *Derris* on a large scale, to produce a pesticide for use on crops where the residues of synthetic insecticides could be harmful to the consumer. Within a few years *Derris* became an estate crop from what was practically a wild plant. In Java and Sumatra the area planted with *Derris* increased from 240 ha in 1935 to 10 000 ha in 1941. By 1947, however, no regular plantations remained, since everything had been harvested during the war and no new plantations had been established.

The main producing countries in South-East Asia are Malaysia, Indonesia and the Philippines. Imports in the United States of rotenoid-containing roots, mainly from *Derris*, exceeded 3000 t annually in the early 1950s, and in 1963 about 1500 t of crude *Derris* roots and 500 t of extract were imported. The introduction of synthetic insecticides, including pyrethrin analogues, has markedly reduced the demand for plant-based insecticides over the last 40–50 years.

Properties The roots are flexible and hard, with a slightly aromatic odour and somewhat bitter taste. Chemically, *Derris* species are characterized by the presence of toxic rotenoid compounds; rotenone as isoflavone derivative (0.3–12% in the root) is the most toxic compound, followed by deguelin (0.2–2.9%), elliptone (0.4–4.6%) and toxicarol (0–4.4%). These compounds are effective respiratory poisons; rotenone is a powerful mitochondrial inhibitor of electron transport. It exhibits a considerable degree of selective toxicity; it is very toxic to insects but only slightly toxic to mammals. *Derris* preparations are comparatively safe to natural enemies (parasites and predators) being used to control insect pests on crops, since



rotenone

they deteriorate when exposed to sunlight and air. To be effective they should contain not less than 3% rotenone on a dry-weight basis.
Compounds related to rotenone, but lacking the core B-C ring system have been synthesized. They are less active than rotenone, but often still have significant levels of inhibition.
The addition of soap solution (0.1%) lowers the toxic concentration of an aqueous extract of roots for snails from 2000 ppm to 100 ppm. Ethanolic and chloroform extracts cause 100% mortality at 100 ppm and 20 ppm, respectively. An ethanolic extract is more toxic than an aqueous extract because this solvent can extract more toxic constituents from the roots. However, this is not practical for use by farmers. Besides, the ethanolic extract is very toxic to fish. Rotenone at 20 ppm causes 83% and 100% mortality in snails after 24 hours and 48 hours, respectively. Rotenone-free extracts of *D. elliptica*, obtained by chloroform extraction and thermal heating were found to be still toxic to snails, but not to fish.
Studies have been performed with cultured cells in order to more fully characterize the bioactive potential of rotenone. Intense cytotoxic activity was observed in lymphocytic leukaemia, carcinoma of the nasopharynx, and a number of human cancer cells, e.g. fibrosarcoma, lung cancer, colon cancer, melanoma and breast cancer cell lines. Thus, rotenone has been evaluated as a potential antitumour agent. The growth-inhibiting effect has been demonstrated both with cultured cells and experimental tumours. Rotenone is broadly cytotoxic, but no cell-type specificity has been discerned.
Numerous other compounds have also been isolated and identified, e.g. flavonoids, deguelin and maackiain. For instance, roots of *D. elliptica* contain the rotenoid elliptinol and tubaic acid (0.01% of air-dried root). The latter compound showed anti-microbial activity, inhibiting the growth of *Bacillus subtilis*, *Staphylococcus aureus* and *Escherichia coli* at high concentrations. Other tests, however, showed no antibacterial activity of *D. elliptica* decoctions or macerations. Several amino acids (e.g. related to pipecolic acid) have been isolated from its leaves, and also the amino-alcohol 2,5-dihydroxymethyl-3,4-dihydroxypyrrolidine (0.1% of fresh leaves). Compounds with a pyrrolidine ring structure might be of pharmacological interest, since some of them are known to have adrenolytic and vasodilating properties. Other related compounds have been found to possess antibacterial activity.
Nine pure compounds have been isolated from the roots of *D. robusta*: 4 isoflavones and 5 3-phenyl-4-hydroxycoumarins. The isoflavones include derrubone, robustone and robustone methyl-ether; the 3-phenyl-4-hydroxycoumarins include robustic acid and robustin. Seven pure compounds have been isolated from the stems of *D. scandens*, e.g. the prenylated isoflavones warangalone, 8-γ,γ-dimethylallylwighteone and 3'-γ,γ-dimethylallylwighteone, and the 3-phenyl-4-hydroxycoumarin robustic acid. All the prenylated isoflavones and robustic acid were found to be potent inhibitors of the catalytic subunit of cyclic AMP-dependent protein kinase (cAK, from rat liver, in vitro). None of the compounds, however, was able to inhibit Ca^{2+} dependent and phospholipid-dependent protein kinase C (PKC, from rat brain, in vitro). The flavonoid compound dehydrorotenone, lupeol and a straight-chain ketone have been isolated from the roots of *D. trifoliata*, but these compounds seem to have no appreciable insecticidal activity. Pentacyclic triterpenoids have also been isolated, whereas the leaves of *D. trifoliata* have yielded the flavonoid rhamnetin 3-0-neohesperidoside. Fresh leaves of *D. trifoliata* contain 25 mg/g of lipid, 3 mg/g sterol and 3 mg/g triterpene. The sterol fraction consists of 1.5% cholesterol, 7.5% campesterol, 9% stigmasterol, 21.5% sitosterol and 60.5% stigmast-7-en-3β-ol, the triterpene fraction of 10% β-amyrin, 12% α-amyrin and 78% lupeol. The bark contains up to 9.5% tannin. Seeds of *D. robusta* contain the pyranoisoflavone derrone, the isoflavones derrugenin, robustigenin and 5-hydroxy-7-methoxyisoflavone, and rubone, a chalcone.
Aqueous extract of fruits of *D. trifoliata* with an LC_{50} value of 0.002–0.003 ppt showed toxicity to fish. The LC_{50} value for roots of *D. elliptica* for catfish in Bangladesh was 64–115 ppm. The toxicant in the root powder had completely detoxified in 6–7 days. Root powder is effective for eradicating predatory fishes in fish ponds at 5 ppm in fresh water and at 10–30 ppm in brackish water. *Derris* extract also has some fungicidal activity. The leaves of *D. elliptica* are said to be poisonous enough to kill cattle.
The wood of *D. robusta* is pale brown, with heartwood not distinctly demarcated from the sapwood. It is hard and heavy; the density is about 850 kg/m^3 at 15% moisture content.

Adulterations and substitutes Rotenoids are also obtained from the roots of other legumes such as *Lonchocarpus*, *Millettia*, *Piscidia* and *Tephrosia* spp. Other insecticides of plant origin used in

South-East Asia are present in seeds of *Croton tiglium* L., stem and roots of *Tinospora* spp., leaves of *Vitex negundo* L., *Nicotiana tabacum* L. and *Azadirachta indica* A.H.L. Juss. They are also found in leaves, fruits and bark of *Melia azedarach* L., whole plants of *Tanacetum cinerariifolium* (Trev.) Schultz-Bip., *Tagetes* spp. and *Lantana* spp., and in leaves, roots and seeds of *Annona squamosa* L. As a fungicide, star anise (*Illicium verum* Hook.f.) is more effective. Other piscicidal plants include *Croton tiglium*, *Myrica esculenta* Buch.-Ham. and *Sapindus saponaria* L.

Description Woody climbers or scandent shrubs, or sometimes trees (*D. robusta*) or erect shrubs; roots up to more than 2 m long and up to 2 cm in diameter, dark reddish-brown or greyish-brown; stem of lianas up to 20 m long and up to 10 cm in diameter, often ridged and densely lenticellate. Leaves alternate, imparipinnate with opposite leaflets, stipules small, stipels sometimes present. Inflorescence terminal or axillary, pseudoracemose or pseudopaniculate, sometimes contracted, with flowers crowded on the short ultimate branchlets or clustered at the nodes. Flowers bisexual, 5-merous; calyx tube usually cupular, almost toothless or with short teeth, the upper pair variably joined; corolla papilionaceous, much longer than the calyx, white, pink or purplish, standard often green at base, glabrous or hairy, wings adhering to the keel petals; stamens 10, united into a tube with openings at the base on either side of the upper filament; ovary superior, 1-loculate, with few ovules, style curved and tapering to a very small stigma. Fruit an oval or elliptical to linear-oblong, flattened, indehiscent pod with wings along upper edge or both edges, 1-few-seeded. Seeds usually reniform, smooth or wrinkled.

Growth and development *Derris* lianas may climb over trees and other vegetation forming a thick cover and thus act as a serious weed in forest plantations. *D. elliptica* may start flowering at 18 months of age. Wild plants flower and fruit normally. Pods ripen about 4 months after fertilization. The roots form nitrogen-fixing nodules. In cultivation fruiting is rare. Some cultivars like 'Ngawi' flower very rarely; others (e.g. 'Wulung' and 'Pantu') flower freely but seldom fruit.

Other botanical information *Derris* is placed in the tribe *Millettieae* within the subfamily *Papilionoideae*. It seems closely related to *Millettia* and *Lonchocarpus*, and to *Aganope* (or *Ostryocarpus* when this originally African genus is considered as congeneric). It is characterized by the winged sutures of the pods. The genus is often subdivided into 3 sections: section *Derris* with about 50 species including *D. elegans* and *D. trifoliolata*, section *Brachypterum* (Wight & Arn.) Benth. with 3 species including *D. robusta* and *D. scandens*, and section *Paraderris* Miq. with 6 species including *D. elliptica* and *D. malaccensis*. The latter two sections have been raised to generic level, differing from the first one particularly in the the inflorescences and in the pods. However, new combinations for the *Derris* species involved have often not yet been made. Sometimes, a fourth section *Dipteroderris* Benth. is separated from section *Derris*. The 4 South American species closely related to *Derris* are usually classified in *Deguelia*.
Several other *Derris* species not discussed above have been mentioned as a fish poison and are occasionally used as an insecticide: *D. acuminata* Benth. (synonym: *D. pubipetala* Miq.), *D. multiflora* Benth. and *D. montana* Benth. for Indonesia, *D. philippinensis* Merr. for the Philippines, and *D. amoena* Benth. and *D. polyantha* Perk. for Peninsular Malaysia. *D. ferruginea* (Roxb.) Benth. is used in India as an insecticide.
Several cultivars of *D. elliptica* have been selected of which 'Sarawak Creeping', 'Changi No 3' and 'Ngawi' are reportedly commercially superior. Other cultivars include 'Pantu', 'Wulung', 'Putih' and 'Kotari'. They differ mainly in hairiness and leaflet shape, but also in rotenoid content, yield and susceptibility to diseases. 'Sarawak Erect' has been reported as the *D. malaccensis* cultivar with the highest content of rotenoids.

Ecology *Derris* grows best in regions with an annual precipitation of 2300–3300 mm and a mean annual temperature of 29°C. *D. elliptica* can survive dry periods of up to 4 months. This species is often confined to low altitudes, but locally (e.g. in Java) it can be found up to 1500 m altitude. *Derris* can be grown on a range of soils varying from coarse sand to heavy clay, but swampy and stony soils are unsuitable. *Derris* is sensitive to waterlogging. It prefers a rich friable loam and tolerates a pH 4.3–8. It is often found on river banks, in brushwood, forest borders and secondary forest. *D. trifoliata* occurs near the coast in or near mangroves.

Propagation and planting Ripe dry seeds cannot be stored for long without losing their viability. They germinate immediately after sowing. For commercial production, however, woody stem cuttings 30–45 cm long and 0.5–1.5 cm in diameter and with 3 or more buds are used. In tests in Central America cuttings from mature stems with a diameter of 2 cm and a length of 20–30 cm with at least 2 nodes gave the best results in rooting. Single-node cuttings can be employed if treated with root-inducing substances such as naphthalene acetic acid (0.2%). The cuttings are often first planted in nursery beds, to a depth of 15–20 cm. Shading and regular watering are needed during the dry season, and during the first weeks the beds should be kept free from weeds. When cuttings have 2 normal leaves, the shade is gradually removed. The cuttings are ready for transplanting into the field when about 6 weeks old, and are preferably transplanted in the rainy season. They are planted either in furrows 10 cm deep or in separate planting holes. The planting distance is 0.7–1 m × 0.7–1 m. Direct planting into the field is sometimes also practised, and should also be done in the rainy season. In Indonesia, *Tephrosia noctiflora* Bojer ex Baker is sometimes used as a shade during the first year, then pulled out and applied as a soil cover.

When planted specially for the production of cuttings, *Derris* is trained on a fence. Each year, these plantations produce enough material to plant an area at least ten times larger. The area to be planted can easily be enlarged at harvest by using cuttings from the branches of an established plantation.

In tests in the Philippines, tissue culture of *D. elliptica* was found to be not viable due to low explant decontamination, retarded shoot regeneration for alcohol propagation and unsuccessful shoot regeneration from calli.

In vitro production of active compounds Tissue culture to obtain rotenoids appears to be rather difficult. When leaves of *D. elliptica* were used for callus induction, only trace amounts of rotenoids (3 μg/g on dry weight basis) were detected in the tissue subcultured for 4 months. Rotenoid biosynthesis decreased with frequent subcultures of callus tissue, and was finally lost. Callus with imperfectly differentiated rootlets induced from the leaves or stems by regulating plant hormones contained rotenoids which were identified as rotenone and deguelin. The rotenone content was 160 μg/g on dry weight basis. In other experiments in the Philippines root regeneration from calli induced from internodes, nodes and axillary buds of *D. elliptica* was obtained 3–5 weeks after inoculation on Shenck and Hildebrandt's medium supplemented with naphthalene acetic acid. Using Durham's test for rotenone, 60–100% of the calli and regenerated roots showed a positive reaction.

Husbandry *Derris* can be raised as a sole crop, or as an intercrop e.g. with rubber, kapok, coconut and cocoa. It needs full sunlight, however, so shading by the main crop should be avoided. Fertilizer application should be during the rainy season. The crop requires high K and P but low N. Trellising considerably increases the number of usable cuttings and the yield of roots.

The crop remains in the field for two years if the trailing cropping method is used. As the crop does not cover the soil completely during the first year, great care should be taken to prevent soil erosion. Hillsides are not suitable and the soil should be covered. To facilitate harvesting, soils must not be too heavy.

Diseases and pests Some fungal diseases are reported to damage planted *D. elliptica*: a rust (*Ustilago derrides*), a *Gloeosporium* sp. that causes the shoot tips to die, and an unidentified fungal disease that attacks cuttings in nursery beds. Pests are not serious and are easily controlled.

Harvesting In cultivation, the roots are often harvested before the plants flower, usually 2 years after planting. They generally grow no deeper than about 50 cm and are dug out carefully, taking care to minimize damage to the bark. On large plantations, the harvested area is cleaned and then replanted. In small plantings with trellised plants all roots are removed, except for those directly under the plants, leaving the top part intact. This root-pruning practice enables several harvests from the same plant. Regeneration, however, is slow.

Yield The yield of dried *D. elliptica* roots is 1100–1800 kg/ha, occasionally up to 3000 kg/ha, particularly when plants are trellised. The weight of a fresh *D. malaccensis* root is up to 900 g. Yields of rotenoids reported in literature vary widely, depending on species and cultivar, age of the plants and ecological conditions.

Handling after harvest After harvesting, the roots are cleaned, preferably in running water, and rapidly dried in the sun or in an oven at approximately 50°C to about 10% moisture content. Drying can be speeded up by cutting the roots into pieces up to 5 cm long. The roots can be stored in a cool and dry place. However, drying the roots seems to degrade the active constituent, particularly when stored too wet.

Rotenoid content is highest in roots 2–10 mm in diameter. So it is advisable to sort the roots into two groups before packing, those smaller and those larger than 1 cm in diameter. The roots are pressed into blocks of 100 kg or, if cut into chips, packed in bags of 50 kg. The packing material should be waterproof because a high moisture content will cause rapid deterioration. *Dinoderus minutus* and *Sinoxylon anale* beetles feed on the dried roots and can cause considerable damage. Protection is possible by fumigation. If the product is to be used in dusting or spraying, the dried roots are ground into a fine powder. The powder remains effective for a long time if it is protected against air, sunlight and moisture.

Proper ventilation, the use of masks and strict attention to hygiene are a prerequisite when manufacturing *Derris* insecticides to prevent complaints such as dermatitis and irritation of mucous membranes.

Fresh roots are usually fermented with water for 24 hours to obtain an aqueous solution of the toxic principle. For application against snails in wet rice *Derris* roots are chopped and crushed, and then scattered over the field for at least 24 hours. This procedure is suitable for rice fields without fish. Often a solution is prepared for spraying. For this, chopped and crushed roots are first soaked in water (90 kg of roots per ha in 200–300 l water) with 0.1% soap solution and subsequently sieved and squeezed. The solution is boiled for one hour and immediately sprayed. It should not be kept for more than 24 hours. If it rains or the water level increases, the treatment should be repeated after 3–5 days.

For use in ponds against predatory fish, roots are chopped into pieces of 2–3 cm and ground (e.g. with a laboratory pulverizer) and then sieved to obtain the root powder, which can be used to selectively poison fish without killing prawns.

To use *Derris* as a fish poison in the Solomon Islands, leaves are put into a hole together with an equal amount of sand and pounded. The resulting granular green mixture is then spread under water, and poisoned fish exhibiting extreme disorientation are speared or collected from the surface of the water.

Genetic resources and breeding In South-East Asia, several *Derris* species are widely distributed as wild plants, but some species (particularly *D. elliptica* and, to a lesser extent, *D. malaccensis*) have been cultivated in gardens since antiquity. This has resulted in the present situation where, e.g. in Java, wild plants of *D. elliptica* vary widely but have a low rotenone content (about 0.5%), whereas the cultivated plants vary little but have a high rotenone content (12–13%). Collections of both provenances are available. Hybrids between *D. elliptica* and *D. malaccensis* have shown promising results. Breeding trials have been hampered by the almost total self-incompatibility or cross-incompatibility of most cultivars of *D. elliptica*.

Prospects There is a renewed interest in the use of *Derris* as a pesticide because of the problems arising from repeated application of synthetic chemical insecticides, which are, however, often cheaper and more effective. Preparing a solution for use in the field is a simple procedure that can be done by the farmer. Moreover, the active compounds are completely detoxicated within one week and the effect on the environment is limited. *Derris* roots and their extracts are cheaper and more potent than pyrethrum, and are simple and convenient to apply. It has been reported that they have low toxicity for higher animals. However, determination of the toxicity of the insecticide to mammals and other non-target organisms needs further investigation. Because of the lack of convincing data, *Derris* insecticide has been banned in some countries (in the Netherlands, for instance) since about 1980.

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Selection of species

Derris elegans Graham ex Benth.

Miq., Pl. jungh.: 252 (1852).

Vernacular names Malaysia: akar tuba (Peninsular). Papua New Guinea: imora (Kabali, Central Province).

Distribution India, Indo-China, Thailand, throughout Malesia, the Solomon Islands and the New Hebrides.

Uses *D. elegans* has been employed as a fish poison in New Guinea and possibly Peninsular Malaysia. A solution of crushed leaves in (green) coconut water is used in Papua New Guinea to wash snake bites.

Observations A liana or scandent shrub up to 10 m long, branches purplish-brown; leaflets 3–5(–7), glabrous or adpressed hairy below; inflorescence axillary or fascicled on older branches; flowers with brown, pink or red calyx and white corolla, standard without callosities at base, glabrous or pubescent at extreme tip; fruit elliptical or oblong-elliptical, with a narrow wing along one side, finally orange-brown. Three varieties are distinguished: var. *elegans* (synonym: *D. rufula* Lauterb. & K. Schumann) occurring throughout the area of the species, var. *gracillima* (Hemsley) Verdc. (synonyms: *D. cauliflora* Pulle, *D. momiensis* Kanehira & Hatusima, *D. papuana* Pulle) from the Moluccas, New Guinea, the Solomon Islands and the New Hebrides, and var. *vestita* (Baker) Prain (synonym: *D. vestita* Baker) from Malesia. *D. elegans* occurs in forest along the coast, on coastal plains, in sago swamps and in secondary and riverine forest, up to 600 m altitude; often on alluvial soils, but also on limestone soils.

Selected sources 202, 597, 1520.

Derris elliptica (Wallich) Benth.

Journ. Linn. Soc. 4, Suppl.: 111 (1860).

Vernacular names Derris, tuba root (En). Touba (Fr). Brunei: tuba (Dusun, Malay). Indonesia: tuba, oyod tungkul (Javanese), tuwa leteng (Sundanese). Malaysia: tuba, akar tuba. Philippines: tubli, tugling-pula (Tagalog), upei (Bontok). Burma (Myanmar): hon. Cambodia: ca bia, k'biehs. Thailand: hang lai daeng, lai nam (northern), kalamphoh (Phetchaburi). Vietnam: d[aa]y m[aaj]t, d[aa]y thu[oos]c c[as].

Distribution Bangladesh, Burma (Myanmar), Indo-China, Thailand, the Nicobar Islands and Malesia (apparently not wild in Borneo, Sulawesi and the Moluccas); cultivated in South-East Asia, India, tropical Africa and America.

Uses The powdered root of *D. elliptica* is widely used as an insecticide and fish poison. In Thailand, the roots are also used as an emmenagogue and the stems as a blood tonic. An extract of the root is reported to be used as an ingredient of dart poison in Borneo.

Observations A liana up to 16 m long, root reddish-brown, apical shoots often leafless for several m and rusty pubescent; leaflets 7–15, mostly densely rusty hairy on both surfaces when young; inflorescence axillary or fascicled on older branches; flowers with rusty pubescent calyx and pinkish corolla, standard with basal callosities, rusty silky hairy; fruit oblong or oblong-elliptical, with a narrow wing along both sides. *D. elliptica* is common-

Derris elliptica (Wallich) Benth. – 1, root system; 2, leaf; 3, inflorescences and young leaves; 4, pod.

ly found in forest edges, roadsides and along rivers, in Java up to 1500 m altitude.

Selected sources 56, 97, 190, 202, 287, 377, 494, 514, 580, 756, 782, 887, 1035, 1062, 1116, 1178, 1205, 1226, 1277, 1471, 1504, 1520, 1563.

Derris malaccensis (Benth.) Prain

Journ. Asiat. Soc. Bengal 66: 107 (1897).

Synonyms *Deguelia malaccensis* (Benth.) Blake (1929).

Vernacular names Malaysia: tuba merah (Peninsular). Vietnam: c[os]c k[ef]n.

Distribution Throughout Malesia; cultivated outside Malesia in India, southern China and tropical America.

Uses The roots of *D. malaccensis* are used as insecticide and fish poison.

Observations A liana up to at least 15 m long, root greyish-brown, young shoots adpressed pubescent; leaflets 5–9, glabrous above, adpressed pubescent beneath; inflorescence axillary; flowers with glabrous pink calyx and whitish or pinkish corolla, standard with basal callosities, glabrous; fruit oblong, with a narrow wing along both sides, rarely without wings. *D. malaccensis* often occurs in riverine rain forest, up to 250 m altitude.

Selected sources 202, 287, 377, 1226, 1277, 1520.

Derris robusta (Roxb. ex DC.) Benth.

Journ. Linn. Soc. 4, Suppl.: 104 (1860).

Synonyms *Derris polyphylla* (Miq.) Benth. (1860), *Brachypterum robustum* (Roxb. ex DC.) Dalz. & Gibs. (1861).

Vernacular names Indonesia: bekel, kedusan, wedusan (Javanese). Thailand: khang sai chang (Phitsanulok), kheemoot (Saraburi), haang khaao (northern). Vietnam: c[os]c k[ef]n m[aj]nh.

Distribution India, Burma (Myanmar), Thailand, Vietnam and Java.

Uses *D. robusta* is occasionally used as a shade tree and a green manure. The wood is used in India for e.g. tea chests, and locally in Java for handles of axes. The leaves may serve as fodder. Although it is chemically well investigated, no medicinal, insecticidal or piscicidal uses are known.

Observations A tree up to 20(–25) m tall, with bole up to 30(–65) cm in diameter, tops of branches finely pubescent; leaflets (7–)11–31, puberulous on both surfaces when young but often glabrescent above; inflorescence axillary; flowers with densely adpressed pubescent calyx and whitish or pale pink corolla, standard without basal callosities; fruit strap-shaped, with a wing along one side. In Java, *D. robusta* occurs in deciduous forest, especially teak forest, up to 300 m altitude.

Selected sources 97, 287, 580.

Derris scandens (Roxb.) Benth.

Journ. Linn. Soc. 4, Suppl.: 103 (1860).

Synonyms *Brachypterum scandens* (Roxb.) Benth. (1838).

Vernacular names Hogcreeper (En). Indonesia: bendan, gobul (Javanese), sobi (Madura). Philippines: malasaga (Tagalog), lapak (Bikol). Thailand: khruea khao nang (Nakhon Ratchasima), thaowan priang (central), phan sanai (Chumphon). Vietnam: c[os]c k[ef]n leo.

Distribution From India to northern Australia; throughout Malesia, but apparently absent in New Guinea.

Uses *D. scandens* is used as a fish poison. In Thailand, the stems are used as a diuretic, laxative, expectorant, emmenagogue and in the treatment of common cold and backache. It is sometimes cultivated as an ornamental.

Observations A liana up to 20 m long or scandent shrub with drooping branches, young branches finely pubescent; leaflets (7–)9–13(–19), puberulous beneath; inflorescence axillary; flowers with pubescent purplish calyx and whitish or pinkish corolla, standard without basal callosities, glabrous or hairy on the back; fruit narrowly oblong or strap-shaped, with a broad wing along one side. *D. scandens* occurs in light forest and brushwood in the lowland (up to 200 m altitude in Java).

Selected sources 97, 202, 287, 580, 1009, 1542.

Derris trifoliata Lour.

Fl. cochinch.: 433 (1790).

Synonyms *Derris uliginosa* (Willd.) Benth. (1852), *Derris heterophylla* (Willd.) Backer ex K. Heyne (1927).

Vernacular names Indonesia: areuy ki tonggeret, tuwa areuy (Sundanese), gadel (Javanese). Malaysia: tuba bekut (Peninsular). Papua New Guinea: gamo (Zimanki, Western Province). Philippines: silasila, asiasimanan (Tagalog), butong (Bisaya). Thailand: khwaep thale, phak thaep (central), thopthaep thale (Phetchaburi). Vietnam: long k[es]n, c[os]c k[es]n n[uw][ows]c, d[aa]y c[os]c.

Distribution Eastern Africa, Madagascar, Mascarene Islands, South and South-East Asia including the whole of Malesia, the Pacific and Australia.

Uses *D. trifoliata* is used in local medicine in India as a stimulant, antispasmodic and counter-irritant, and against rheumatism, chronic paralysis and dysmenorrhoea, and in Papua New Guinea a decoction of the roots is used externally against fever and internally against sores. Thai traditional doctors use roots or stems as a laxative, carminative and anti-arthritis treatment. It serves as a fish poison. The leaves are sometimes used as fodder.

Observations A liana up to at least 15 m long, sometimes an erect shrub, branches soon becoming glabrous, dark red; leaflets 3–5(–7), variably glabrous; inflorescence terminal and axillary; flowers with glabrous, green calyx and white, pale pink or pale mauve corolla, standard without basal callosities, glabrous; fruit oblong or elliptical to broadly oval, with a narrow wing along one side. *D. trifoliata* grows near the coast in swampy scrub vegetation and forest behind beaches, on muddy foreshores and estuaries, and in edges of mangroves, sometimes in pure stands.

Selected sources 97, 202, 580, 597, 1035, 1178, 1520.

Auzay Hamid

Desmodium Desv.

Journ. Bot. appl. 1: 122 (1813).

LEGUMINOSAE

$x = 10, 11$; *D. adscendens*, *D. gangeticum*, *D. microphyllum*, *D. triflorum*: $2n = 22$

Major species *Desmodium adscendens* (Sw.) DC., *D. gangeticum* (L.) DC., *D. styracifolium* (Osbeck) Merr., *D. triflorum* (L.) DC.

Vernacular names Tick clovers (En). Vietnam: h[af]n the.

Origin and geographic distribution *Desmodium* consists of about 300 species found in the tropical and subtropical regions of Africa, Central and South America, East Asia and Oceania; some species occur in temperate regions. The centre of origin of the genus is South-East Asia. The highest species diversity is found in an area stretching from India eastward to western and south-western China and Malesia (25 species reported). Mexico is a second centre of diversity.

Uses *Desmodium* shows a wide range of medicinal uses. In South-East Asia, they are considered diuretic (*D. gangeticum*, *D. repandum*, *D. styracifolium*); other prominent uses are the treatment of diarrhoea, dysentery and stomach-ache (*D. diffusum*, *D. gangeticum*, *D. heterophyllum* (Willd.) DC., *D. triflorum*, *D. velutinum*), wounds, ulcers and other skin problems (*D. gangeticum*, *D. triflorum*, *D. sequax*), stones in the gall bladder, kidneys or bladder (*D. gangeticum*, *D. styracifolium*) and headache, toothache or other pains (*D. gangeticum*, *D. microphyllum*, *D. ormocarpoides*, *D. sequax*).

In the Philippines, a decoction of *D. triflorum* is used as a mouthwash and as an expectorant. In India, fresh leaves of *D. triflorum* are used internally as a galactagogue; and in Taiwan, the whole plant is used against fever, rheumatism, jaundice and gonorrhoea.

D. auricomum Grah. ex Benth. and *D. caudatum* (Thunb. ex Murray) DC. are reportedly used in local medicine in Indo-China, but no specific uses are mentioned. *D. adscendens*, *D. incanum* DC. (synonym: *D. canum* Schinz & Thell.) and *D. renifolium* Schindler do occur in South-East Asia, but reports of medicinal use are only available from outside the region. *D. incanum* is used as a diuretic, stomachic, febrifuge and hemostatic in Central America. *D. renifolium* is used as a febrifuge in Taiwan.

D. heterocarpon (L.) DC. and *D. heterophyllum* are primarily forages, but are also used medicinally in Malesia. The boiled roots of *D. heterocarpon* are used in Malaysia to poultice sore breasts, and a decoction of the plant is regarded as a tonic and a bechic. In Cambodia, the stems of *D. heterocarpon* subsp. *angustifolium* H. Ohashi are applied to fractures and snake bites. In Taiwan, a decoction of the roots is used against rickets in children. *D. heterophyllum* is applied in Malaysia to treat sores, earache, stomach-ache and abdominal complaints. In India, the roots are considered carminative, tonic and diuretic, the leaves are used as a galactagogue, and a decoction of the whole plant is used to treat stomach-ache and abdominal problems.

Desmodium contains a considerable number of species used as pasture and fodder crops, species used for ground cover and green manure; some of these have medicinal applications as well.

Properties *Desmodium* is very rich in alkaloids and related amino compounds, biosynthetically derived from different precursors.

From *D. gangeticum*, the following alkaloids and nitrogen-containing compounds have been isolated: hypaphorine, N,N-dimethyltryptamine, N,N-dimethyltryptamine-N_b-oxide, 5-methoxy-N,N-dimethyltryptamine, 5-methoxy-N,N-dimethyltryptamine-N_b-oxide (alkaloids, all derived from the amino acid tryptophan), N_b-methyl-tetrahydroharman, 2-methyl-6-methoxy-β-carbolinium cation (harman-type alkaloids, derived from the amino acid tryptophan), hordenine (= N,N-dimethyltyramine), N-methyltyramine, candicine (alkaloids derived from the amino acid tyrosine), β-phenylethylamine (amine, structurally related to tyramine) and choline (quaternary nitrogen compound). Of these alkaloids, hordenine is known to increase the urinary flow, and to be a remedy for diarrhoea and dysentery.

Other reported constituents are the pterocarpanoids (isoflavonoids) gangetin, gangetinin and desmodin. Gangetin isolated from the roots of *D. gangeticum* has been found to adversely affect the fertility and reproductive system of male rats. Gangetin caused a dose-dependent impairment of fertility, reduced the vaginal sperm count and enhanced pre-implantation losses. Aqueous root extracts have shown mild diuretic action, relaxant effects on intestine muscles of rats and dogs, and antibacterial, antifungal and anti-inflammatory activity. The alkaloid fraction of stems and leaves has shown relaxant (curariform) effects on frog rectal muscles. Methanolic extracts of Nigerian *D. gangeticum* plants have shown in vitro anti-leishmanial activity.

D. styracifolium contains triterpenoid saponins, of which soyasaponin I has been found to be effective against kidney stones. In a study with rats the extract inhibited the formation of calcium oxalate stones in kidneys by increasing the output of urine, decreasing the excretion of calcium and increasing the urinary excretion of citrate. Aqueous extracts have shown in vivo hypotensive action in rats through cholinergic receptor stimulation and autonomic ganglion and α-adrenoreceptor blockade. Furthermore, the extract relaxed isolated methoxamine preconstricted helical tail artery strips and was positive chronotropic without apparent effect on the contractile force. The flavonoid fraction exhibited hypotensive activity.

From the leaves of *D. adscendens*, alkaloids (tetrahydroisoquinolones, derived from tyrosine), amines (β-phenylethylamines, indole-3-alkylamines) and triterpenoid saponins (dehydrosoyasaponin I, soyasaponin I and soyasaponin III) have been isolated. The three saponins, especially dehydrosoyasaponin I, are potent potassium channel openers. This may be related to the reported use of *D. adscendens* against asthma and dysmenorrhoea, because opening of K-channels is expected to cause smooth muscle of the lung and uterus to relax. *D. adscendens* extracts have also been reported to inhibit the synthesis and release of histamines, prostaglandins and arachidonic acid. A hot water extract causes a dose-dependent reduction in the amount of spasmogens released anaphylactically and in anaphylactic-induced contractions of ileal muscle in guinea-pigs. Ethanolic leaf extracts have shown analgesic and hypothermic activity in mice. In addition, they delayed the onset of pentylenetetrazole forelimb clonus, and general seizures induced by kainic acid.

Alcoholic extracts of *D. triflorum* showed good in vitro anthelmintic activity against human *Ascaris lumbricoides*. Alkaloids and related nitrogen-containing compounds reported from *D. triflorum* (roots and/or leaves) include: hypaphorine, hypaphorine-methylester, N,N-dimethyltryptamine-N_b-oxide, S-(+)-N,N-dimethyltryptophan-methylester (alkaloids derived from tryptophan), hordenine (= N,N-dimethyltyramine), 3,4-dihydroxyphenylethyl-trimethyl-ammoniumhydroxide (alkaloids derived from tyrosine), trigonelline, S-(−)-stachydrine, tyramine, β-phenylethylamine, choline and betaine. The total alkaloid fraction has shown anti-spasmodic, sympathomimetic, central nervous system stimulant and curare-mimetic activity. Other reported constituents of *D. triflorum* include: indole-3-acetic acid, the flavonoid-C-glycosides vitexin, isovitexcin and 2'-O-glucosylvitexin, the flavone apigenin, and the polyhydric alcohol (+)-pinitol.

From *D. caudatum* N,N-dimethyltryptamine, bufotenine, bufotenine-N-oxide (alkaloids derived from tryptophan), swertisin (flavonoid-C-glycoside) and the flavone desmodol have been isolated. From ethanolic root extracts of *D. incanum*, three anti-microbial isoflavones (desmodianones A, B and C) have been isolated, which have shown in vitro activity against *Bacillus subtilis*, *Mycobacterium smegmatis*, *Staphylococcus aureus* and *Streptococcus faecalis*.

Description Herbs, shrubs or subshrubs, rarely trees, mostly erect or ascendent, but frequently decumbent or subclimbing. Leaves alternate, 3-foliolate in most species, but frequently 1- and 3-foliolate, occasionally exclusively 1-foliolate and rarely 5–7-foliolate, petiole pulvinate, stipulate; leaflets variously shaped, lateral leaflets usually smaller than terminal one, chartaceous to coriaceous, reticulately veined, with 1 stipel at the base of lateral and 2 at the base of terminal leaflets. Inflorescence mostly racemose or paniculate, rarely fasciculate, terminal or terminal and axillary; bracts dimerous or rarely monomerous, early deciduous, primary bracts larger than secondary ones, usually narrowly ovate, secondary bracts mostly subulate or narrowly ovate; bracteoles present or absent. Flowers pedicellate, calyx usually broadly campanulate, 4–5-lobed; corolla variously coloured, often pink to pale purple, papilionaceous, standard usually broadly obovate to almost orbicular, rounded or emarginate at the apex, not auriculate, sometimes short-clawed, wings short-clawed, with oblong lamina, rounded to obtuse at the apex, keel acute or obtuse at the apex; androecium monadelphous or diadelphous, stamens 10, anthers basifixed; ovary superior, narrowly oblong, sessile or stipitate, often many-ovuled, style inflexed or incurved, stigma terminal or lateral, capitate or minute. Fruit a jointed pod, often narrowly oblong or linear, flat or rarely turgid, mostly indehiscent, usually with straight or hooked hairs; articles usually elliptical to quadrangular. Seeds transversely broadly elliptical or broadly ovate to elliptical or depressed ovate, flat or turgid, hilum lateral. Seedling usually with epigeal germination; cotyledons thin leaf-like; first two leaves opposite and simple, subsequent ones alternate and similar to leaves of adult plants.

Growth and development *Desmodium* appears to be predominantly self-pollinating. However, when flowers are touched, they spring open and release pollen, which makes outcrossing possible. *D. diffusum*, *D. gangeticum*, *D. microphyllum*, *D. repandum*, *D. sequax*, *D. styracifolium*, *D. triflorum* and *D. velutinum* are reported to have nodulating ability.

Other botanical information *Desmodium* belongs to the subtribe *Desmodiinae* of the tribe *Coronilleae* within the subfamily *Papilionoideae*. The genus *Desmodium* in the broad sense has been divided into seven genera: *Codariocalyx*, *Dendrolobium*, *Desmodium* s.s., *Dicerma*, *Hegnera*, *Phyllodium* and *Tadehagi*. It is difficult to classify *Desmodium* s.s., because of the morphological variation and the continuity of morphological features across species borders; further taxonomic studies are needed. Here, the narrow sense of *Desmodium* is assumed.

Ecology *Desmodium* is mainly found in humid to sub-humid regions of the tropics and subtropics, on acid soils (pH < 6.5). The usual habitats are open woodland and forest clearings. In equatorial regions, *Desmodium* species are found from sea-level up to 3000 m altitude. The photoperiod sensitivity varies with the species.

Propagation and planting In general, propagation of *Desmodium* is by seed. The degree of scarification necessary for successful germination varies between species. The information available concerns species used as a forage or cover crop, and no detailed information is available on species used for medicinal purposes.

Diseases and pests *Desmodium* is affected by a range of diseases. On a worldwide base, important pathogens are the fungi *Synchytrium desmodii* and *Phanerochaeta salmonicolor*, causing wart and pink disease respectively, the root-knot nematodes *Meloidogyne arenaria*, *M. hapla*, *M. incognita* and *M. javanica*, and the stem gall nematode *Pterotylenchus cecidogenus*. South-East Asian reports include the sooty moulds *Meliola bantamensis*, *M. bicornis* and *M. scabriseta* var. *integra* on *D. gangeticum*. A very wide range of diseases has been reported for *D. gangeticum* in India. *D. adscendens* has been reported to be resistant to attacks of *Meloidogyne* species.

Genetic resources and breeding The major germplasm collections of *Desmodium* in the world are found in Australia (CSIRO), Brazil (EMBRAPA and IRI), Colombia (CIAT) and the United States of America (University of Florida). In these collections, only a quarter of the known *Desmodium* species are present, and many of these with only a single entry. There have been only a few plant breeding efforts in *Desmodium*, and knowledge of the extent of heritable variation is limited. Interspecific hybridization is possible, but the degree of success depends on how closely related the parent species are.

Prospects *Desmodium* shows a broad range of traditional medicinal uses, some of which have already been related to the presence and activity of specific compounds. Further research on possible uses of the various *Desmodium* species seems worthwhile. Further taxonomic studies and germplasm collection are needed to exploit the potential of this genus.

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Selection of species

Desmodium adscendens (Sw.) DC.

Prodr. 2: 332 (1825).

Synonyms *Hedysarum adscendens* Sw. (1788), *Desmodium oxalidifolium* G. Don (1832), *Desmodium trifoliastrum* Miq. (1855).

Vernacular names Papua New Guinea: roabe (Kurtachi, Bougainville). Philippines: pega pega. Vietnam: bai ngai.

Distribution Native in South America and Africa; introduced throughout South and South-East Asia and Melanesia.

Uses The leaves of *D. adscendens* are used in Papua New Guinea to treat stomach-ache. It is used against asthma and other diseases associated with smooth muscle contraction in Ghana, against fever, pain, epilepsy and stomach-ache in Congo. In Central America a decoction of the plant is used as a laxative and to treat convulsions, and to soothe urinary disorders in cases of venereal diseases. It was originally introduced in Asia as a cover crop in plantations.

Observations A creeping or ascending perennial herb or low shrub, up to 100 cm tall, stems terete, glabrescent; leaves 3-foliolate, stipules obliquely ovate-lanceolate, persistent; terminal leaflet elliptical-obovate, (1.5–)2–4(–5.5) cm × 1–3 cm, larger than the lateral leaflets, upper surface glabrous, lower surface pilose, lateral veins 4–7, not reaching the margin; inflorescence a terminal or axillary raceme, 4–20 cm long, lax-flowered; flowers in pairs, calyx 5-lobed, covered in hairs, corolla white or purple to violet, androecium diadelphous; pod 10–25 mm × 3–4 mm, 3–6-jointed, dehiscent, densely covered in hairs; seeds flattened ellipsoid, 2.5–5.0 mm × 1.5 mm. *D. adscendens* is found in humid locations, provided that they are shady, e.g. on stream banks and bunds of rice fields, at 200–1000 m altitude.

Selected sources 14, 15, 16, 17, 97, 407, 979, 1069, 1120, 1520.

Desmodium diffusum DC.

Ann. Sci. nat. 4: 100 (1825).

Synonyms *Desmodium recurvatum* (Roxb.) Wight & Arn. (1834), *Desmodium laxiflorum* DC. subsp. *parvifolium* H. Ohashi & Chen (1983), *Desmodium laxiflorum* auct. non DC.

Vernacular names Laos: nha tük hma. Thailand: nieo maa. Vietnam: nha khau mau ri.

Distribution From India eastward to Burma (Myanmar), Thailand, Indo-China, China, Taiwan and throughout the Malesian region.

Uses In Laos, a decoction of the roots is used to treat stomach-ache in children. In India, it is used as a fodder and has been tried as a green manure.

Observations A prostrate or erect undershrub, 30–100 cm tall, branches hairy in the upper parts; leaves 3-foliolate, sometimes mixed with 1-foliolate leaves at the base of the branches, stipules narrowly triangular, 6–11 mm long, terminal leaflet ovate to broadly ovate, 2.5–11 cm × 1.5–6 cm, larger than the lateral ones, chartaceous, upper surface rather hairy, lower surface covered with silky hairs, lateral veins 7–9, extending to the margin; inflorescence a terminal and axillary raceme, 10–30 cm long; flowers in clusters of 3–5, calyx 4-lobed, hairy, corolla blue or violet, androecium diadelphous; pod linear, 3–3.8 cm × 0.2 cm, 5–9-jointed, articles asymmetrically oblong, covered with hooked hairs; seeds 2.5–3 mm × 1.1–1.3 mm. *D. diffusum* is found along roadsides, in grassland and forest margins, up to 2000 m altitude.

Selected sources 97, 287, 389, 629, 921, 1069.

Desmodium gangeticum (L.) DC.

Prodr. 2: 327 (1825).

Synonyms *Hedysarum gangeticum* L. (1753), *Meibomia gangetica* (L.) O. Kuntze (1891).

Vernacular names Indonesia: daun bulu ayam (Malay, Manado), daun picah (Sundanese), waliketupa (Javanese). Malaysia: akar katah, serengan, kemani bali. Philippines: dikit-dikit (Tagalog), pega-pega (Cebu Bisaya), andudukut (Sulu). Laos: tük hma:, do:yz tük hma:, ph'è:ng kh'am h'o:yz. Thailand: i-nio, yaa tuet maeo, nuut phra phuu (Trang). Vietnam: c[aa]y th[os]c l[es]p, c[or] ch[as]y, b[af]i ng[af]i.

Distribution Tropical Africa, tropical and subtropical Asia, throughout the Malesian region and Oceania; introduced in the West Indies.

Uses In Java, a decoction of the leaves is used against stones in the gall bladder, kidneys or bladder. In Malaysia, a decoction of the root is employed to treat diarrhoea or as a sedative for children. The roots are applied to the gums against toothache, and the leaves to the head against headache. In Vietnam, the roots are considered diuretic and prescribed in case of oedema. A decoction is used externally to clean wounds and ulcers. It is also used in Indo-China to treat coughs, swellings, dysentery and kidney problems. In Thailand, the roots are used as a diuretic and the whole plant as an anthelmintic. In India, the roots are reported to be applied as a febrifuge, bitter tonic, expectorant, alterative, diuretic and astringent, and in the treatment of diarrhoea, chronic fever, biliousness, snake bite and poisoning. The fibrous stems are reported to be useful for paper production, and in the Philippines they are used to make prawn traps. Conflicting information exists on its usefulness as a green manure.

Observations A much branched, erect shrub, or a prostrate to ascending subshrub 30–200 cm tall, rootstock thickened, young stems hairy; leaves 1-foliolate, stipules narrow and tapering to a point, 7–15 mm long, leaflet (1–)2.5–18 cm × (0.8–)2–8 cm, very variable in shape and size, chartaceous, upper surface variously hairy, lower surface densely hairy, lateral veins 6–12, usually extending to the margin, persistent; inflorescence a terminal or axillary raceme or panicle, 10–30 cm long; flowers in clusters of 2–4, calyx 4-lobed, densely covered with minute hooked hairs and longer straight hairs, corolla white to pale yellow or rose to violet, androecium diadelphous; pod linear, variably incurved, 1.2–2.5 cm × 2–2.5 mm, (4–)6–8-jointed, covered with minute hooked hairs, articles broadly oblong; seeds pale yellow, reniform, 1.5–1.8 mm × 2–2.5 mm. *D. gangeticum* is a very common weed in Malesia, mainly found in anthropogenic habitats in the lowlands, under everwet or seasonal conditions. In Indo-China it is found in savannas and deforested terrains, in hedges and along forest paths, up to 1900 m altitude.

Desmodium gangeticum (L.) DC. – 1, plant habit; 2, branch with infructescence; 3, flower; 4, mature pod.

Selected sources 97, 119, 202, 287, 389, 481, 533, 580, 629, 661, 752, 819, 820, 921, 1035, 1069, 1120, 1168, 1178, 1393, 1476, 1520.

Desmodium microphyllum (Thunb. ex Murray) DC.

Prodr. 2: 337 (1825).

Synonyms *Hedysarum microphyllum* Thunb. ex Murray (1784), *Desmodium parvifolium* DC. (1825).

Vernacular names Laos: hnha:z phak kè:b. Vietnam: tr[af]ng qu[ar] ba hoa.

Distribution From India and Sri Lanka eastward to China, Taiwan and Japan and southward to Malesia and Australia; throughout and common in the Malesian region.

Uses In Indo-China the whole plant is used in the treatment of eye problems and headache.

Observations A slender, much branched, erect or creeping undershrub, up to 150 cm tall, stems glabrescent, terete; leaves 3-foliolate, usually partly 1-foliolate, stipules narrowly triangular to narrowly ovate, 2.4–4.5 mm long, terminal leaflet elliptical or obovate, 3–25 mm × 1–7 mm, larger than the lateral ones, thinly chartaceous, upper surface almost glabrous, lower surface sparsely hairy, lateral veins 4–5 on either side of the midrib, not extending to the margin; inflorescence terminal, racemose, 1–5 cm long, lax-flowered; flowers solitary, calyx very deeply 5-lobed, densely hairy, corolla variably coloured, keel longer than the wings, androecium diadelphous; pod 5–13(–25) mm × 2.5–3(–4) mm, (1–)3–4-jointed, flat, nearly glabrous or moderately hairy, articles obliquely broadly rhombic or elliptical, length 1–1.5 times the width; seeds 1.2–1.5 mm × 2–2.1 mm, arillate. *D. microphyllum* is a very common weed in the Malesian region, and is indifferent to rainfall distribution. In Indo-China it is found at 0–2000 m altitude.

Selected sources 97, 389, 629, 752, 1120, 1126, 1520.

Desmodium ormocarpoides DC.

Prodr. 2: 327 (1825).

Synonyms *Hedysarum adhaerens* Poir. (1817), *Hedysarum ormocarpum* Desv. ex Poir. (1817).

Vernacular names Papua New Guinea: agagil (Yunamami, East New Britain), digambi (Gaulim, East New Britain).

Distribution Sulawesi, the Moluccas, the Lesser Sunda Islands, New Guinea, Australia (Queensland), the New Hebrides and New Caledonia.

Uses In Papua New Guinea, the leaves are macerated in water and the solution is drunk to treat malaria and tuberculosis. The solution is also reported to be effective against pains and itches. Roots are chewed to prevent vomiting.

Observations A climbing shrub or undershrub, up to 150 cm tall, young stems covered with hooked hairs; leaves 1-foliolate, stipules narrowly triangular, 3.8–4.3 mm long, leaflet elliptical or ovate, 8–20 cm × 3.5–8 cm, chartaceous to coriaceous, both surfaces glabrous, lateral veins 6–8, prominent, not extending to the margin; inflorescence a terminal or axillary raceme, usually 15–70 cm long, lax-flowered; flowers in clusters of 2–4, calyx 4-lobed, minutely hairy, corolla white, androecium diadelphous, style spirally twisted; pod linear, stalked, 3–5-jointed, article length 4 times the width, separated by very narrow necks, covered with minute hooked hairs; seeds linear-oblong, 12 mm × 2 mm. In New Guinea, *D. ormocarpoides* is found at altitudes up to 1800 m, in savanna, scrubland, forest edges, plantations and roadsides.

Selected sources 533, 597, 752, 1069, 1126, 1520.

Desmodium repandum (Vahl) DC.

Prodr. 2: 334 (1825).

Synonyms *Hedysarum repandum* Vahl (1791), *Desmodium scalpe* DC. (1825), *Meibomia repanda* (Vahl) O. Kuntze (1891).

Vernacular names Indonesia: waliketupa sapi (Javanese), potong kujang (Sundanese), leng-elengan (Madura). Laos: kh'üa s'a:thwa'.

Distribution Africa, Asia from Sri Lanka and India eastward to China and southward to Malesia, and some Pacific Islands; a common species throughout the Malesian region.

Uses In Indonesia, *D. repandum* is used in combination with other diuretic substances. It has also been used as a green manure and ground cover.

Observations An erect suffrutescent herb, usually 30–150 cm tall, often woody at the base, stems simple or branched, variously hairy, rootstock woody; leaves 3-foliolate, stipules narrowly ovate, (10–)15–20 mm long, terminal leaflet rhombic to obovate, (2–)5–8(–11) cm × (2–)3.5–6(–9) cm, lateral leaflets smaller than the terminal ones, chartaceous, upper surface variously hairy, lower surface densely hairy, lateral veins 4–5, extending to the margin, strongly oblique; inflorescence terminal or frequently terminal and axillary, racemose or sometimes paniculate, 15–30(–60) cm long, lax-flowered; flowers in clusters of 2–4, calyx 4-lobed, rather densely hairy, corolla orange to red, androecium diadelphous; pod (2–)3–4(–5)-jointed, article length 2 times the width, densely hairy on lateral surfaces, glabrescent or sparsely pubescent on sutures; seeds 2.5–3.5 mm × 5–5.6 mm. In Malesia and Indo-China, *D. repandum* is found in light forests and thickets at 700–2000 m altitude, almost always under everwet climatic conditions, also along roadsides.

Selected sources 97, 389, 580, 752, 921, 1069, 1120, 1520.

Desmodium sequax Wallich

Pl. asiat. rar. 2: 46, t. 157 (1831).

Synonyms *Desmodium sinuatum* (Miq.) Blume ex Baker (1876), *Desmodium ancistrotrichum* K. Schumann & Lauterb. (1901).

Vernacular names Papua New Guinea: ufi pata (Kabiufa, Eastern Highlands).

Distribution From India eastward to China and Taiwan and southward to Malesia; in Malesia common throughout the region.

Uses In Papua New Guinea, the chewed leaf is spat onto wounds, apparently for its antiseptic properties. The root is included in mixtures used to alleviate toothache. In China, it is considered a diaphoretic.

Observations A shrub, up to 200 cm tall, young branches hairy; leaves 3-foliolate, stipules lanceolate, 4–7 mm long, terminal leaflet ovate to obovate or rhomboid, 3.5–14 cm × 2.3–8 cm, larger than the lateral ones, subcoriaceous, upper surface glabrescent, lower surface hairy; inflorescence a raceme, rarely branched; flowers in pairs, calyx 4-lobed, hairy, corolla pink, purple to violet-red, androecium monadelphous; pod 30–40 mm × 2.5–3.5 mm, (6–)8–13-jointed, articles 3–4 mm long, densely covered with hooked hairs; seeds 1.9–2.2 mm × 1.5–1.8 mm, rim-arillate. In Malesia, *D. sequax* is confined to higher altitudes, at 500–2400 m, mostly in open places, not in dry regions. In Vietnam it is found along water courses, in grassland, open places and forest margins at 200–1600 m altitude.

Selected sources 97, 389, 597, 629, 752, 1069, 1126, 1393, 1520.

Desmodium strigillosum Schindler

Engl. Bot. Jahrb. 54: 57 (1916).

Vernacular names Cambodia: trôm sva:. Laos: taum pauv hmab.

Distribution Burma (Myanmar), Cambodia, Laos and Vietnam.

Uses Macerated and crushed roots are applied as a poultice on swellings of the limbs.

Observations An erect shrub or subshrub, up to 60 cm tall, stems glabrescent; leaves 3-foliolate, stipules narrowly triangular, 7–8 mm long, terminal leaflet elliptical or obovate, 2–3.5(–4) cm × 1–1.7(–2) cm, larger than the lateral ones, thickly chartaceous to subcoriaceous, upper surface glabrous, lower surface densely hairy, lateral veins 5–7, not extending to the margin; inflorescence terminal, racemose, 3–6(–8) cm long, densely flowered; flowers in pairs, calyx 4-lobed, sparsely hairy, corolla blue, androecium diadelphous; pod narrowly oblong, compressed, 15–20 mm × 2–2.5 mm, 6–8-jointed, articles broadly oblong, densely covered with hooked and straight hairs; seeds 1.1–1.3 mm × 1.5–1.8 mm, rim-arillate. *D. strigillosum* is found on dry slopes and wasteland up to 800 m altitude. It may well be grown in the Malesian region.

Selected sources 389, 1069.

Desmodium styracifolium (Osbeck) Merr.

Amer. Journ. Bot. 3: 580 (1916).

Synonyms *Hedysarum styracifolium* Osbeck (1757), *Desmodium capitatum* Burm.f. (1825), *Desmodium retroflexum* (L.) DC. (1825).

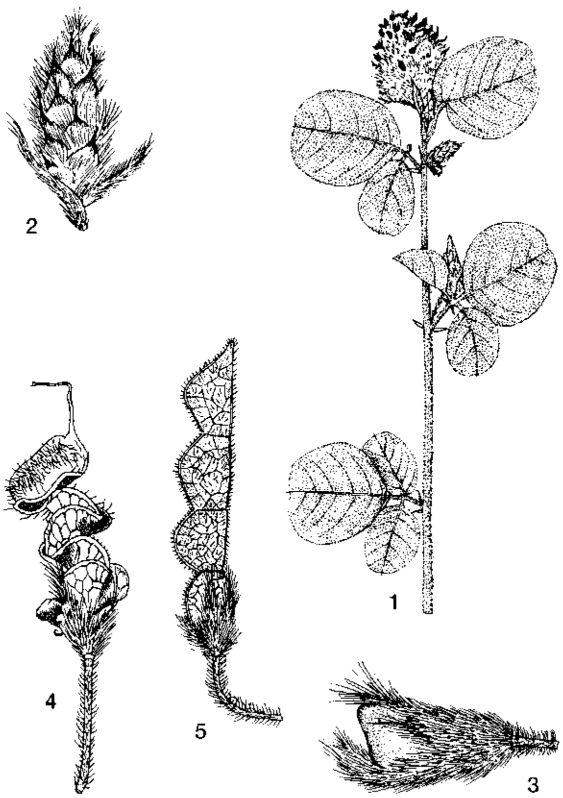
Vernacular names Indonesia: katepan, melikan (Javanese), susuukan (Sundanese). Malaysia: korat nasi. Cambodia: voë vè:t (general), smau srâlâb pôpôôk, srâka: niëk (Battambang). Laos: kéng no:yz ngwà liaz, pâdông fai. Thailand: ruk ku ning taa no, phee suea nam (Lampang). Vietnam: d[oof]ng ti[eef]n (l[oo]ng), kim ti[eef]n th[ar]o, v[ar]y r[oof]ng.

Distribution From India and Sri Lanka eastward to China, and southward to Malesia and Micronesia. Commonly found throughout the Malesian region, but no records from New Guinea.

Uses In Malaysia, *D. styracifolium* is used against colic, together with the central part of maize cobs. In Vietnam, the whole plant is considered diuretic, and applied against gall bladder and kidney stones and oedema. In southern China, it is also used to treat gall bladder and kidney stones. *D. styracifolium* is reported to be a good green manure, which covers the soil fast and produces numerous roots, nodules and seeds.

Observations A much branched, erect shrub or prostrate to ascending subshrub, 60–200 cm tall, young stems hairy; leaves 1- or 3-foliolate, stipules narrowly triangular, 8–11 mm long, terminal leaflet broadly elliptical or broadly obovate to orbicular, (1–)2–4.5(–5.5) cm × (1–)2–4.5(–5) cm, larger than the lateral ones, thick chartaceous to subcoriaceous, upper surface glabrous, lower surface densely hairy, lateral veins 8–10, not extending to the margin; inflorescence terminal and axillary, short racemose, 1–3(–5) cm long, very densely flowered; flowers in pairs, calyx 4-lobed, densely hairy, corolla purple or violet and fragrant, androecium diadelphous; pod narrowly oblong, compressed, (12–)15–20 mm × 2.5–3 mm, plicate-retroflexed when young, later straight, (4–)5–6-jointed, article quadrate or transversely broadly oblong, densely covered with hairs; seed reniform, depressed obovate or transversely elliptical, 1.3–1.8 mm × 2–2.2 mm. *D. styracifolium* is found in rather open habitats, in full sunlight as well as in shade. It grows on periodically wet and dry terrain, as well as in grasslands and abandoned rice fields from sea-level up to 600 m altitude.

Selected sources 50, 97, 202, 389, 580, 591, 593, 752, 1035, 1069, 1120, 1393, 1476, 1602.



Desmodium styracifolium (Osbeck) Merr. – 1, flowering stem; 2, young inflorescence; 3, flowerbud; 4, young pod; 5, mature pod.

Desmodium triflorum (L.) DC.

Prodr. 2: 334 (1825).

Synonyms *Hedysarum triflorum* L. (1753), *Desmodium parvifolium* Blanco (1845).

Vernacular names Indonesia: daun mules (general), semanggen (Javanese), jukut jarem (Sundanese). Malaysia: rumput barek sisek putih, sisek tenggiling. Philippines: kaliskis-dalag (Tagalog), himbispuyo (Visaya), gumadep (Ifugao). Cambodia: smau kaè lolook. Thailand: ya-klethoi, ya-tanhoi (central), ya-tansai (northern). Vietnam: h[af]n the.

Distribution Pantropical; a common species throughout the Malesian region, Australia and the Pacific Islands.

Uses A decoction of *D. triflorum* is commonly used to treat diarrhoea and dysentery in Indonesia, Malaysia, the Philippines, Thailand, as well as China, India and Sri Lanka. In the Philippines, a decoction is also used as a mouthwash and as an expectorant. In Thailand, the whole plant is used as an antipyretic and to quench thurst. In Indonesia, Malaysia, the Philippines, Laos and India the crushed plant or a poultice of the leaves is externally applied on wounds, ulcers, and for skin problems in general, apparently for its antiseptic properties. It is also used as a forage, as a green manure and ground cover.

Observations A much branched, mat-forming, prostrate, annual or perennial herb, 8–50 cm long, covered with hairs, rootstock woody; leaves 3-foliolate, stipules obliquely lanceolate, 3.5–6 mm long, persistent, terminal leaflet obovate-oblong, obovate or obcordate, 4–14 mm × 4–12 mm, larger than the lateral ones, variably hairy beneath; flowers 1–3 in leaf axils, calyx 5-lobed, hairy, corolla pink to purple, androecium diadelphous; pod flat, 6–18 mm × 2–3 mm, 3–5-jointed, constricted between the rectangular articles; seed quadrangular, 1.2 mm × 1.7 mm. *D. triflorum* is found on a wide range of soils, and most commonly in heavily grazed or closely cut areas.

Selected sources 20, 97, 119, 389, 482, 483, 629, 921, 1120, 1178, 1393, 1434, 1520.

Desmodium velutinum (Willd.) DC.

Prodr. 2: 328 (1825).

Synonyms *Desmodium lasiocarpum* (P. Beauv.) DC. (1825), *Desmodium latifolium* (Roxb. ex Ker.) DC. (1825).

Vernacular names Thailand: yaa song plong (central, northern), nieo yai (southwestern).

Distribution Africa, Asia from India and Sri Lanka eastward to China and Taiwan and southward to Malesia; common throughout the Malesian region.

Uses In Papua New Guinea, squeezed leaves are chewed with salt to treat diarrhoea. Leaves and roots may be chewed (not swallowed) to relieve toothache.

Observations An erect shrub, usually 100–300 cm tall, branches often dark red, young parts densely hairy, rootstock thickened; leaves 1-foliolate, sometimes mixed with 3-foliolate leaves, stipules narrowly triangular, 2–15 mm long, leaflets very variable in size and shape, 4–20 cm × 2.5–13 cm, chartaceous to coriaceous, upper surface continuously appressed-pubescent, lower surface densely velutinous, lateral veins 8–10, extending to the margin; inflorescence terminal and axillary, racemose or paniculate, up to 20 cm long; flowers in clusters of 2–5, calyx 4-lobed, densely hairy, corolla pink, purple, blue or reddish-violet, androecium diadelphous; pod (1–)1.6–2.5 cm × 2.2–3.5 mm, (3–)5–7-jointed, articles broadly oblong, densely covered with hairs; seeds very broadly or depressed ovate, 1.3–1.6 mm × 1.8–2.5 mm. *D. velutinum* is subdivided in subspecies and varieties, of which *D. velutinum* subsp. *longibracteatum* (Schindler) H. Ohashi and *D. velutinum* subsp. *velutinum* are found in South-East Asia. *D. velutinum* is found in rather open habitats, savanna, secondary forest margins and as a garden weed from sea-level up to 1000 m altitude.

Selected sources 97, 389, 608, 612, 629, 752, 921, 1069, 1120, 1393, 1520.

N. Setyowati-Indarto & M. Brink

Elephantopus L.

Sp. pl. 2: 814 (1753); Gen. pl. ed. 5: 355 (1754).

COMPOSITAE

$x = 11$; *E. mollis*: $2n = 22, 44$, *E. scaber*: $2n = 22$, *E. spicatus*: $n = 10, 11, 13, 14$, $2n = 22, 26$

Major species *Elephantopus mollis* Kunth, *E. scaber* L.

Vernacular names Elephant's foot (En). Pied d'éléphant (Fr). Indonesia: tapak liman. Malaysia: tutup bumi. Vietnam: c[us]c ch[ir] thi[ee]n.

Origin and geographic distribution *Elephantopus* comprises approximately 30 species and is mainly of tropical American origin. Some species have been introduced in South-East Asia. *E. scaber*, which is the most widespread in South-East Asia, is possibly indigenous there.

Uses In South-East Asian countries and India, *Elephantopus* species are well known in traditional medicine. Their primary use is as a diuretic and febrifuge, but other applications include as an anthelmintic (e.g. filariasis), antibiotic, anti-inflammatory, emollient, diaphoretic, emmenagogue and galactagogue. The plant is known as a remedy for coughs, headache, anaemia, dyspepsia, dysentery, colic pains, diarrhoea and leucorrhoea, and also reported to be beneficial during parturition: to speed birth and expulsion of the placenta, and afterwards to prevent inflammations. These uses are not confined to a certain part of the plant; preparations (such as decoctions or hot water extracts) of the (dried) roots, entire plants or leaves are mentioned in the literature.

Elephantopus preparations are also applied externally to heal wounds (astringent properties are attributed to the plant) and in cases of rheumatism (as a paste made from the entire plant).

In Africa and South America, elephants's foot has similar ethnomedical applications. In Chinese traditional medicine *Elephantopus* is used to treat influenza, colds, tonsillitis, pharyngitis, conjunctivitis, epidemic encephalitis, hepatitis, cirrhosis, ascites and eczema.

Production and international trade *Elephantopus* spp. are commonly collected from the wild, but there is no information on production and trade. A drug derived from *E. scaber* is available in China as tablets; it is marketed as a Chinese patent medicine.

Properties *Elephantopus* plants taste bitter. Most species (e.g. *E. mollis* and *E. scaber*) contain elephantopin and/or its related compounds (e.g. molephantin, molephantinin, phantomolin, deoxyelephantopin, isodeoxyelephantopin and 11,13-dihydrodeoxyelephantopin). These elephantopin derivatives (sesquiterpene lactones of the germacrane type, or germacranolides) have been found to be very characteristic of *Elephantopus*, and have attracted considerable interest because of their reported cytotoxic (anti-cancer) activities.

Molephantin, molephantinin and phantomolin (obtained from the ethanolic extract of *E. mollis*) have been shown to be active in various tumour assays in vitro (human epidermoid carcinoma of the larynx, human carcinoma of the nasopharynx) and in vivo (Ehrlich ascites carcinoma, Walker 256 carcinosarcoma, Lewis Lung carcinoma, P-388 lymphatic leukaemia). Deoxyelephantopin (from *E. scaber*) significantly inhibited the growth of Walker 256 carcinosarcoma in rats. Furthermore, dihydroelephantopin inhibited the growth of leukaemia tumour cells, and tomenphantopin-A and -B (from *E. tomentosus* L.) displayed cytotoxic activity in the in vitro human nasopharynx carcinoma assay. Research has revealed the importance of an α-methylene lactone function for the biological activity of sesquiterpenoid lactones.

Phytochemical investigations for the germacranolides have also revealed the presence of several other compounds. The guaianolides deacylcyanaropicrin, glucoazulanin-C and deacylcyanaropicrin-3β-glucopyranoside (= crepiside E) were isolated from the aqueous fraction of the total ethanolic extract of *E. scaber*. Stigmasteryl-3β-glucoside (a sterol) was isolated from the chloroform fraction. The triterpenes β-amyrin acetate, lupeol (acetate) and epifriedelanol, and the phytosterol stigmasterol were identified from ethanolic extracts of *E. mollis*.

Studies on the hepatoprotective effects of water extracts of *E. mollis*, *E. scaber* and *E. spicatus* against acute hepatic damage in rats induced by β-D-galactosamine and paracetamol (acetaminophen) demonstrated that these crude extracts

(500 mg/kg intraperitoneally) decrease the levels of serum glutamate-oxalate-transaminase (SGOT) and serum glutamate-pyruvate-transaminase (SGPT). This suggests that treatment with these extracts improves the induced hepatic lesions. In another analogous study, using CCl_4, it was furthermore found that hepatic fatty metamorphosis and necrosis of the central lobules were significantly improved after treatment with *E. mollis* and *E. scaber* extracts, but less after treatment with *E. spicatus* extract.

A preliminary pharmacological evaluation was conducted with aqueous and water/ethanol extracts of *E. scaber*. Doses of 0.3–6 g/kg induced writhing, loss of muscle tone, ataxia, prostration and death in mice. No analgesic effects of these extracts were detected using the mouse hot-plate (≤30 mg/kg intraperitoneally (i.p.), ≤600 mg/kg peroral (p.o.)) or the acetic acid-induced writhing (mouse, ≤300 mg/kg p.o.) tests. Both extracts failed to modify diuresis in the rat (≤300 mg/kg p.o.), to reduce carrageenan-induced rat paw oedema (≤600 mg/kg p.o.) or to reduce yeast-induced hyperthermia in rats (≤600 mg/kg p.o.). Aqueous extracts administered at doses of 25–100 mg/kg intravenously reduced blood pressure and heart rate in rats. Absence of diuretic effects was furthermore shown in a placebo controlled trial carried out on 10 healthy human volunteers.

Studies showed that *E. scaber* exhibits considerable antibacterial activity against the cariogenic bacterium *Streptococcus mutans* and against *Staphylococcus* sp. In general, *E. scaber* markedly inhibits the growth of both gram-positive and gram-negative bacteria. *Elephantopus* extract exhibits antiviral activity against e.g. polio virus and HIV. Protease and reverse transcriptase inhibition are also reported.

Adulterations and substitutes Sesquiterpene lactones are common in *Compositae*, but compounds of the elephantopin type seem characteristic for *Elephantopus*. In other genera of the tribe *Vernonieae*, such as *Vernonia*, the sesquiterpene lactones are mostly of the germacranolide type, and some of these compounds have also shown significant in vitro activity against cells derived from carcinomas (e.g. vernolepin from *Vernonia hymenolepis* A. Rich.).

Description Perennial herbs up to 120 cm tall, with a creeping rhizome or strong taproot; stems scabrous or pubescent. Leaves alternate, often rosulate or basal and cauline, becoming smaller upwards, simple, variously toothed, pinnately veined, cuneately tapering or long-attenuate at base to a winged petiole, exstipulate. Inflorescence consisting of sessile, few-flowered, homogamous heads aggregated into a globose capitate cluster or glomerule each of which is subtended by 2–4 foliaceous bracts; glomerules in corymbs or panicles or spicately arranged in the axils of small cauline leaves; involucre of head 2-seriate and consisting of about 8 narrowly oblong bracts. Flowers all tubular, bisexual, 5-merous; pappus of 4–5(–6) scabrid bristles; corolla with unequal, somewhat palmately spreading lobes, white, bluish or purplish; anthers connate and forming a tube around the style, obtuse at base and acute at apex; ovary inferior, 1-celled, style bifid with filiform, hairy arms. Fruit a truncate, 10-ribbed achene tipped by the 4–5 scabrid pappus bristles, which are dilated at base and equally long or with 2 longer ones sigmoidal at apex.

Growth and development *Elephantopus* can be found flowering throughout the year, but there is often a main flowering season (e.g. for *E. scaber* in Java from April to September). Flowers remain hidden in the involucre until shortly before anthesis. Within a head the usually 4 flowers expand almost simultaneously between 1 and 2 p.m., and close at about 5 p.m. The fruits are often distributed by mammals and people, when the scabrid bristles become caught in the fur or clothes.

Other botanical information *Elephantopus* is classified in the tribe *Vernonieae*, which includes about 70 genera and 1500 species. There is no modern comprehensive review of the tribe and consequently the affinity of *Elephantopus* is still obscure.

Pseudelephantopus is often kept separate from *Elephantopus* on the basis of the heads which are clustered in the axils of small cauline leaves and of 2 larger, sigmoid pappus hairs (in *Elephantopus* s.s. glomerules of heads terminal and usually long-pedunculate, all pappus hairs equal and straight). *E. spicatus* has been treated here and not separately because some recent publications have again treated *Pseudelephantopus* as if it is synonymous with *Elephantopus* (even though it is sometimes considered as a separate subgenus *Pseudelephantopus* (Rohr) C. Jeffrey). *Orthopappus* is nowadays also often included in *Elephantopus*.

Ecology Elephant's foot usually occurs in waste places, grasslands, roadsides and forest fringes. *E. scaber* is also found in the undergrowth of teak forest in Java. *Elephantopus* spp. are usually not noxious weeds, although they may occur on paths in tea plantations, and in lawns, where they are sometimes considered as troublesome. In Hawaii, *E. mollis* and *E. spicatus* are classified as noxious weeds, which rapidly invade pastures but have no forage value. In South-East Asia, *Elephantopus* may occur up to 2000 m altitude.

Diseases and pests In the Philippines, a mosaic virus may cause mild chlorosis and prominent veins in *E. mollis*. There are indications that the disease can be transmitted by aphids to coconut and Manila hemp (*Musa textilis* Née), where symptoms can be more serious.

Harvesting Elephant's foot is collected from the wild.

Handling after harvest After collecting, the plants are washed, dried and stored until use. In general, they are collected fresh when needed.

Genetic resources and breeding *Elephantopus* spp. are widespread in anthropogenic habitats and seem not to be at risk of genetic erosion. No breeding work has been done to date.

Prospects Elephant's foot is considered to be an interesting medicinal plant resource with promising prospects for becoming a valuable adjunct in e.g. cancer research or treatment.

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Selection of species

Elephantopus mollis Kunth

Humb., Bonpl. & Kunth, Nov. gen. sp. 4, ed. fol. 4: 20 (1818).

Synonyms *Elephantopus tomentosus* auct. non L.

Vernacular names Philippines: malatabako (Tagalog), tabtabako (Iloko), kaburon (Igorot).

Distribution Tropical America; introduced and widely naturalized in tropical Africa and Asia. Reported for Peninsular Malaysia, Borneo, Sulawesi and the Philippines.

Uses In the Philippines, the leaves (fresh and crushed or dried and powdered) are applied to wounds as a vulnerary. A decoction of the plant is prescribed as diuretic and febrifuge. It is also reported to act as an emetic. In Hong Kong, the entire plant is used for its diuretic, antihepatic and antibronchitis properties.

Observations A herb up to 100 cm tall, stems whitish pilose; leaves basal and cauline, elliptical-ovate or elliptical-obovate to elliptical-lanceolate, 8–22 cm × 3–7 cm; glomerules terminal, generally long-peduncled, glomerule bracts generally shorter than the involucral bracts; flowers with corolla about 5 mm long, whitish or sometimes pinkish or purplish; fruit 2.5–3 mm long with pappus bristles equal and 3.5–4 mm long. *E. mollis* occurs in open waste places and grasslands up to 2000 m altitude.

Selected sources 121, 202, 564, 668, 833, 852, 861, 862, 925, 1126, 1162, 1178, 1539.

Elephantopus scaber L.
Sp. pl. 2: 814 (1753).

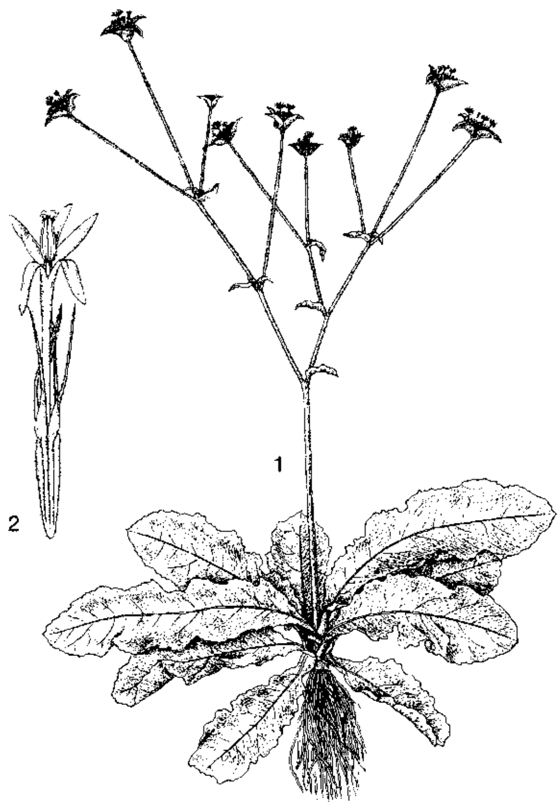
Vernacular names Prickly-leaved elephant's foot (En). Indonesia: tapak liman, tutup bumi (general), talpak tana (Madurese). Malaysia: tutup bumi, tapak leman (Peninsular), pepalut (Sabah). Philippines: dila-dila, tabatabakohan (Tagalog), kabkabron (Iloko). Thailand: do mai ruu lom (central), kee fai nok khuun (Loei), naat me khlaen (Surat Thani). Vietnam: c[us]c chi thi[ee]n, c[or] l[uw][owx]i m[ef]o, dia d[ar]m th[ar]o.

Distribution Widespread in tropical America, Africa, Asia and Australia; throughout South-East Asia.

Uses *E. scaber* is widely used as a diuretic, febrifuge and emollient throughout South-East Asia. In Malaysia, a decoction of the leaves or roots is additionally used as a tonic and anthelmintic, and to treat coughs, asthma and venereal diseases. The fresh roots are prescribed to arrest vomiting, and the leaves are recommended for application to the abdomen to treat dropsy. In Indonesia, the roots, either pounded or in decoction, are also used as a remedy for leucorrhoea, anaemia and as a tonic during parturition, whereas the leaves are used as anthelmintic and aphrodisiac, and to treat cough, sprue and diarrhoea. In Indo-China, a decoction of the plant is used as tonic, diaphoretic and emmenagogue and to treat dyspepsia. In Thailand, besides being used as a diuretic and febrifuge, the roots are used to treat cough, malaria and parasites. In India, China, Africa and South and Central America, a decoction or infusion of the roots and leaves is used as an emollient, to treat diarrhoea, dysentery, pulmonary diseases, scabies, urethral discharges, epistaxis, jaundice, oedema and to relieve anuria and blennorrhoea.

Observations An erect herb up to 80 cm tall, stems rigid, appressed long-haired or scabrous; leaves in a radical rosette, if cauline much smaller, oblong-obovate to spatulate, 5–38 cm × 1–6 cm; glomerules terminal, generally long-peduncled, glomerule bracts generally longer than the involucral bracts; flowers with corolla 7–9 mm long, bluish or purplish, sometimes white; fruit about 4 mm long with pappus bristles equal and 4–6 mm long. *E. scaber* occurs in grasslands, wasteland, roadsides, along fields and in forest borders, up to 1500 m altitude.

Selected sources 27, 29, 97, 202, 244, 333, 350, 539, 580, 592, 815, 852, 861, 862, 1035, 1126, 1148, 1178, 1539.



Elephantopus scaber L. – 1, plant habit; 2, flower.

Elephantopus spicatus Juss. ex Aublet
Hist. pl. Guiane 2: 808 (1775).

Synonyms *Pseudelephantopus spicatus* (Juss. ex Aublet) Rohr (1792).

Vernacular names False elephant's foot (En). Philippines: dilang-aso (Tagalog), maratabako (Iloko), kalkalapikap (Bontok). Vietnam: ch[aa]n voi gi[es].

Distribution Native to tropical America; introduced in tropical Africa and Asia. In South-East Asia, reported very locally for Java and widespread for the Philippines; also in Vietnam, southern China and Taiwan.

Uses In the Philippines, the leaves are used topically to treat eczema, and as a vulnerary.

Observations An erect herb up to 120 cm tall, usually branched and with a strong taproot, stems slightly hairy to glabrous; leaves in a radical rosette and cauline, oblong-obovate to oblong-lanceolate, lower ones 5–25 cm × 1–7 cm, upper ones smaller; heads clustered in the axil of small cauline leaves, combined into a long, lax terminal spike, involucral bracts 2-seriate, the outer ones shorter than inner ones; flowers with corolla about 7 mm long, white; fruit 6–7 mm long with pappus bristles unequal, the 2 largest sigmoid near the apex. *E. spicatus* is common in waste places in the Philippines.

Selected sources 97, 852, 861, 862, 1178.

Ng Lean Teik

Embelia Burm.f.

Fl. indica: 62, t. 23 (1768).

MYRSINACEAE

x = unknown

Major species *Embelia ribes* Burm.f.

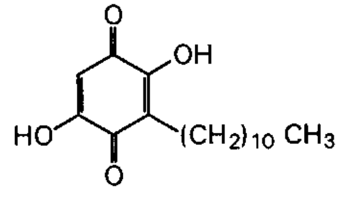
Origin and geographic distribution *Embelia* comprises approximately 130 species and occurs in Africa, Asia including Malesia, the western Pacific and Australia. Most species are found in Asia. In Indo-China 11 species have been found, in Peninsular Malaysia 17, in Sumatra 6, in Java 6, in Borneo more than 15 and in New Guinea 10. However, no recent overview is available for the Malesian region.

Uses Several *Embelia* species are well known for their anthelmintic and taeniafuge uses. The active principles primarily act as a purgative. *E. ribes* has been known since ancient times in Ayurvedic medicine under the Sanskrit name 'vidanga'. The dried fruit is considered anthelmintic, astringent, carminative, alterative and stimulant. In China, roots and leaves of *E. laeta* are used to treat dysentery, indigestion and eczema, while the fruits are used to treat anaemia, gum bleeding and anorexia. In eastern Africa, *Embelia* (e.g. *E. schimperi* Vatke) fruits either fresh or dried are a popular anthelmintic. The roots are used as a purgative and vermifuge. In Thailand, the roots of *E. ribes* are used as expectorant and in the treatment of internal inflammations. In Papua New Guinea, squeezed sap of *Embelia* stems and young leaves is drunk to treat malaria or as a general febrifuge. In East Kalimantan, the crushed fresh bark of *E. ribes* is used as a fish poison. In Java the young leaves, shoots and immature fruits of *E. ribes* are consumed cooked as a sour vegetable or condiment. *E. philippinensis* A. DC. is used in a similar way in the Philippines. The ripe sour-sweet fruits of both species are also eaten as a delicacy. The fruits of *E. coriacea* Wallich ex A.DC. are reported to be poisonous. When dissolved in alcohol, embelin (a major constituent of *Embelia*) can be used as a yellow dye for silk and wool.

Production and international trade Although fruits of *Embelia* were traded from Malesia to Europe at the beginning of the 20th Century, at present no commercial trade is reported.

Properties Embelin (2,5-dihydroxy-3-undecyl-1,4-benzoquinone) is recognized as the main active principle of *Embelia* species. The fruits of *E. ribes* contain 2.5–3.1% embelin and about 1% of the sugar quercitol, those of *E. tsjeriam-cottam* about 1.6% embelin and no quercitol. The fruits of the African *E. schimperi* yield 4.8–7.5% embelin and about 1% quercitol. Embelin is also isolated from *E. robusta*. Embelin can be isolated as golden yellow needles, insoluble in water, but clearly soluble in ethanol, chloroform and benzene.

The best known pharmacological action of embelin is its effect on reproduction: male antifertility, anti-implantation and abortifacient activity has been shown in tests with various animals. Ethanolic (90%) extracts of *E. ribes* fruits administered orally to female rats at 250 mg/kg during early pregnancy showed 66% anti-implantation activity, and the abortifacient activity in late pregnancy was about 25%. A daily subcutaneous administration of embelin at a dose of 20 mg/kg body weight to male albino rats for 15 or 30 days inhibited the motility of epididymal sperm, fertility parameters (such as pregnancy attainment and litter size) and the activities of enzymes of glycolysis and energy metabolism. However, all changes were reversible, as seen after 15 and 30 days of recovery. Addition of embelin to epididymal sperm suspensions caused a dose and duration-dependent inhibition of spermatozoal motility and inhibited the activities of carbohydrate metabolism enzymes. Light and scanning electron microscopy showed that both in vitro and in vivo treatment with the substance causes profound morphological changes in spermatozoa such as decapitation of the spermatozoal head, discontinuity of the outer membranous sheath in the mid-piece and the tail region, and alteration in the shape of the cytoplasmic droplet in the tail. In another experiment, sixty 3-month-old pregnant mice were treated with a suspension of embelin (50 mg/kg body weight) in carboxymethylcellulose (CMC, 0.5 ml) from days 3



embelin

to 8, days 6 to 9 or days 10 to 16 of gestation. A control group was treated with distilled water and CMC (0.5 ml). In a second experiment, males and virgin females were treated with embelin (50 mg/kg body weight) for 15 and 30 days respectively. Treated males were than mated with untreated females, and treated females were mated with untreated males. A distilled water and CMC control was maintained during the experiment. Embelin treatment resulted in a significant increase in resorptions (maximum of 18.5% in females treated from days 3 to 8) and skeletal abnormalities (maximum of 26% in females treated from days 3 to 8). Furthermore, embelin treatment resulted in changes in the sex ratio of litters, with 132 females to 100 males occurring in females treated from days 3 to 8 compared with 96 females to 100 males in the distilled water control. Treatment with embelin prior to mating significantly increased the incidence of dead foetuses and increased the occurrence of physical and skeletal abnormalities and resorption. Histochemical and biochemical investigations of male rats, treated for 35 days with doses of 0.3–0.5 mg/kg bodyweight (subcutaneously), revealed a picture of the testis with arrest of spermatogenesis, a marked diminution in the cell population and deformation of the seminiferous tubulus at all doses. Necrobiosis and nuclear degeneration of varying degrees were observed. The weight of testes, epididymis, vas deferens, seminal vesicle, coagulating gland, ventral prostate, dorso-lateral prostate, adrenal gland and levator and muscle were reduced considerably, just like the biochemical parameters in the tissues, such as glycogen in testis and fructose in seminal vesicle, prostate and coagulating glands. These observations may be due to a hormonal imbalance, caused by embelin; an anti-androgenic nature is suggested. A significant anti-oestrogenic and weak progestational activity was also found in female rats.

Oral administration of embelin (75 mg/kg body weight, daily for 15 and 30 days) to male rats caused a significant increase in the uptake of D-glucose, L-alanine, L-leucine and calcium in small intestine segments. Embelin also produced significant increases in intestinal brush border membrane-associated enzymes (invertase, lactase, maltase, alkaline phosphatase and leucine aminopeptidase) in both intestinal homogenates and partially purified brush border membrane preparations. Significant increases were also noted for microsomal glucose-6-phosphatase and cytosolic lactate dehydrogenase. Increases in brush border membrane-associated total lipids, phospholipids, cholesterol, triacylglycerol, unesterified fatty acids and ganglioside sialic acid were seen but there was little change in the cholesterol-phospholipid molar ratio. All changes returned to control or near control levels following withdrawal of the drug.

Embelin (isolated from the fruits of *E. ribes*) and administered to male albino rats with fibrosarcoma at doses of 50 or 100 mg/kg, orally, for 20 days, prolonged survival time and induced significant tumour regression. To evaluate the possible mode of action of embelin, the anti-oxidant status of the drug was studied. Embelin exhibited significant free radical scavenging properties. The biological defence system constituting the superoxide dismutase, catalase, glutathione peroxidase, glutathione-S-transferase and glutathione was significantly enhanced, whereas lipid peroxidation was greatly restricted. In vivo studies in rats and mice indicated an analgesic effect of potassium embelate. It was found to be effective by oral, intramuscular, subcutaneous and intracerebro ventricular routes (doses ranged from 5–40 mg/kg), and the results compared well with morphine (a mainly μ receptor agonist) as reference. Potassium embelate acts centrally to produce analgesia (binding studies indicate that mixed μ and κ receptor sites may be involved), and its effect is not strongly antagonized by naloxone (a pure μ receptor antagonist), indicating that other central sites are also of importance. Furthermore, there is no precipitation of abstinence syndrome as observed with morphine. A toxicity evaluation which included subacute, chronic, reproductive testing and teratological investigations in laboratory animals (mice, rats and monkeys; doses 10–100 mg/kg per day, orally) did not indicate adverse effects, suggesting the compound is safe.

'Pestoban' is a mixture of 3 plant extracts, only 2 of which (*Cedrus deodara* Loud. and *Azadirachta indica* A.H.L. Juss. oils) show toxicity against the mollusc species *Lymnaea acuminata* and *Indoplanorbis exustus*. The third plant extract, that of *E. ribes*, is non-toxic, but when all three are mixed, the toxicity of the mixture is about 100 times more active than either of the two toxic components. The toxic effect against the snail *Lymneae acuminata*, an intermediate host for both *Fasciola hepatica* and *F. gigantica* is time- as well as dose-dependent. The molluscicidal activity is higher than synthetic molluscicides, and the dose levels used against the snail are safe for fish. 'Ectozee' is a herbal preparation containing the same combination of plants, which is used against mites.

Application of a seed extract of *E. ribes* results in a high mortality of the nematodes *Meloidogyne incognita* and *Rotylenchulus reniformis*.

Adulterations and substitutes Dried fruits of *E. ribes* and *E. tsjeriam-cottam* have been used as an adulterant of black pepper (*Piper nigrum* L.).

Description Dioecious scandent shrubs or lianas up to 20 m long. Leaves alternate, distichous or spirally arranged, simple, entire to serrate, glabrous, dotted with red-brown or black glandular dots or streaks, petioled. Inflorescence axillary or terminal, fascicled or solitary, racemose or paniculate, sometimes subumbellate. Flowers functionally unisexual, small, 4–5(–6)-merous; calyx deeply lobed, lobes imbricate; petals free or slightly connate at base, imbricate or contorted, usually papillate inside and glabrous outside; stamens and staminodes inserted towards the base of the petals, filaments short to rather long, anthers dorsifixed; ovary superior, in male flowers minute, in female flowers globose or ovoid, few-ovuled, style short, persistent, stigma broad, disciform. Fruit a subglobose to ovoid drupe, usually drying black, 1-seeded. Seedling with epigeal germination; cotyledons emergent, leafy with finely toothed margins, hypocotyl elongated.

Growth and development The various *Embelia* species do not flower simultaneously, and fruit maturation takes several months. The juicy fruits are probably dispersed by birds.

Other botanical information The closely related genus *Grenacheria* differs primarily in the connate petals. No recent taxonomical revision of the genus *Embelia* is available and the existing revision from the beginning of the 20th Century is based on a limited number of specimens. Numerous species have been described with a high degree of endemism, and this causes considerable taxonomic difficulties. The species are rather difficult to distinguish in the field. For example *E. robusta* and *E. tsjeriam-cottam* are often confused.

Ecology *Embelia* can be found from sea-level up to 2000(–2800) m altitude. Some species prefer primary forest, but others are common along forest margins and in secondary forest.

Propagation and planting *Embelia* can be propagated by seed or cuttings. Most species are common in secondary vegetation and not propagated or planted deliberately. Occasionally some *Embelia* are grown on a small scale in home gardens.

Harvesting *Embelia* fruits are simply picked when ripe. Young shoots to be used as a vegetable are harvested shortly before use or sale. For collecting the roots, plants are uprooted.

Handling after harvest Fruits of *Embelia* are either used fresh or dried for medicinal purposes. Sometimes the fruit pulp is removed by washing and threshing the fruits, and the seeds are dried and stored. Dried fruits and seeds guarantee a year-round supply in the market. Stems harvested to be used as a fish poison are simply bundled, and the bark is later pulverized at the spot to release the toxic agents.

Genetic resources and breeding Some species like *E. ribes* and *E. tsjeriam-cottam* have a wide distribution, but most *Embelia* species have a very local occurrence. The latter species are theoretically more vulnerable to extinction.

Prospects The application of embelin in herbal molluscicides and against mites appears promising. Other applications of embelin, e.g. as analgetic, antifertility or free radical scavenging agent deserve more attention.

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Selection of species

Embelia laeta (L.) Mez.

Engler, Pflanzenr., Heft 9 (IV 236): 326 (1902).

Synonyms *Choripetalum benthamii* Hance (1853), *Embelia obovata* Hemsl. (1889).

Vernacular names Vietnam: th[uf]n m[ux]n, c[aa]y m[ux]n, d[aa]y ng[os], chua ng[us]t, chua m[es]o.

Distribution Vietnam, southern China and Taiwan.

Uses The fruits are used as a vermifuge (taeniafuge) in Vietnam. The sap of the leaves is reported to be taken orally against snake bites, whereas the leaves are applied as a poultice on the bite. In China, roots and leaves are used to treat dysentery, indigestion and eczema, and the fruits are used to treat anaemia, gum bleeding and anorexia.

Observations A small shrub 1–2 m tall; leaves obovate to oblong, 3.5–9 cm × 1.5–3 cm, chartaceous, base acute, apex obtuse, glabrous, petiole 3–10 mm long; inflorescence a lateral or axillary raceme, 6–10 mm long, few-flowered, with numerous bracts at the base; flowers 4-merous, yellowish-green. *E. laeta* generally occurs at higher elevations in mountainous regions. In Indo-China it flowers in December and mature fruits are present in April. It may well be grown at higher elevations in the Malesian region.

Selected sources 364, 849, 940, 1128, 1140.

Embelia ribes Burm.f.

Fl. indica: 62, t. 23 (1768).

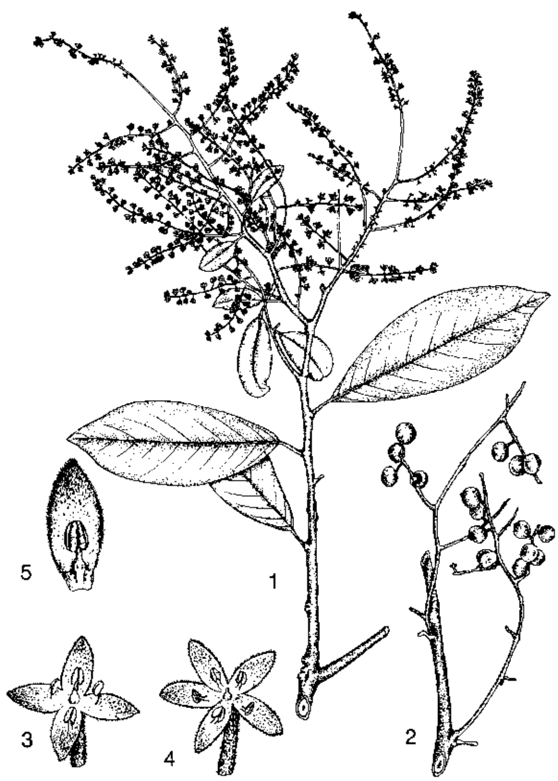
Synonyms *Embelia garciniifolia* Wallich ex Miq. (1853).

Vernacular names Indonesia: kacembang (Sundanese). Malaysia: akar sulur kerang. Cambodia: chou pruc. Laos: reut jeum bang. Thailand: som kung (peninsular). Vietnam: th[uf]n m[ux]n, c[aa]y m[ux]n, d[aa]y ng[us]t.

Distribution From Sri Lanka and India eastward to Indo-China, Thailand and southern China and southward to Peninsular Malaysia, Sumatra, Java and Borneo.

Uses The seeds or fruits are widely used as a vermifuge. An infusion of the roots is given to treat coughs and diarrhoea in Java. In East Kalimantan, the crushed fresh bark is used to repel leeches and as a fish poison. The young leaves, shoots and young fruits are consumed as a (cooked) vegetable or condiment. The ripe sour-sweet fruits are also eaten as a delicacy, mostly by children.

Observations A scandent shrub or liana up to 20 m long, young shoots densely pubescent; leaves lanceolate to oblanceolate, 3–9 cm × 1.5–3.5 cm, chartaceous, base round or acute, apex acuminate, glabrous, petiole 5–10 mm long; inflorescence a terminal panicle, 10–17 cm long; flowers (4–)5-merous, petals inside and outside pubescent, white. *E. ribes* occurs from sea-level up to 1500 m altitude, in forest or at forest borders. In Indo-China it flowers in February–March and mature fruits are present in March–October.



Embelia ribes Burm. f. – 1, flowering twig; 2, infructescence; 3, 4-merous flower; 4, 5-merous flower; 5, petal with stamen.

Selected sources 25, 97, 287, 565, 580, 687, 741, 829, 886, 940, 1035, 1066, 1128, 1140, 1156, 1361, 1364, 1512.

Embelia robusta Roxb.

Hort. bengal.: 16 (1814).

Synonyms *Samara robusta* (Roxb.) Kurz (1877).

Vernacular names Vietnam: r[ef] d[oos]m.

Distribution From India eastward to Indo-China.

Uses In India the fruits are widely used as an anthelmintic.

Observations A scandent shrub or liana; leaves elliptical to obovate-elliptical, 4–9 cm × 2–5 cm, membranous, base rounded to cuneate, apex obtuse to shortly acuminate, initially pubescent below but soon glabrescent, petiole 4–7 mm long; inflorescence axillary, capituliform, 2–3 cm long; flowers 5-merous, anthers rotundate. *E. robusta* generally occurs at higher elevations. It may well be grown at higher elevations in the Malesian region.

Selected sources 202, 940, 1140.

Embelia tsjeriam-cottam (Roemer & Schultes) A. DC.

Trans. Linn. Soc. 17: 131 (1834).

Synonyms *Embelia robusta* C.B. Clarke (1882) non Roxb.

Distribution From India and Sri Lanka eastward to Indo-China and Peninsular Malaysia.

Uses The dried fruits are used as a taeniafuge, antispasmodic and carminative. The bark of the root is reportedly used to treat toothache.

Observations A small shrub 1–2 m tall; leaves elliptical to obovate-elliptical, 6–9 cm × 3.5–5 cm, membranous, base rounded to shortly cuneate, apex shortly acuminate, petiole 8–12 mm long; inflorescence an axillary, cylindrical raceme, 3–6 cm long; flowers 5-merous, anthers acuminate or mucronate. *E. tsjeriam-cottam* generally occurs at lower elevations. In Indo-China it flowers in June–August.

Selected sources 287, 741, 940, 1140.

L.S.L. Chua & J.L.C.H. van Valkenburg

Erythroxylum P. Browne

Civ. nat. hist. Jamaica: 278 (1756).

ERYTHROXYLACEAE

$x = 12$; *E. coca*: $2n = 24$, *E. novogranatense*: $2n = 24$

Major species *Erythroxylum coca* Lamk, *E. novogranatense* (Morris) Hieron.

Vernacular names Coca (En, Fr).

Origin and geographic distribution *Erythroxylum*, which has about 250 species, is pantropical and its centre of diversity is in the Andes and the Amazon basin in South America. There are 6 indigenous species and 2 cultivated species in the Malesian region. The two species that are medicinally most important, *E. coca* and *E. novogranatense*, contain cocaine. They are native to South America, and were introduced into South-East Asia by the end of the 19th Century.

Uses The dried leaves of *Erythroxylum* spp. have been used in South America for at least 5000 years as a masticatory to allay hunger and fatigue, and as an element in religious rituals. Many medicinal applications have been recorded for coca in South America: infusions of coca leaves are used to treat indigestion and other stomach complaints, and altitude sickness. Coca is also reported to be effective against respiratory problems, teeth and gum complaints, malaria, eye irritations and sore throat, and it is valued as an aphrodisiac and a means of ensuring longevity. In some countries, e.g. Bolivia, the leaves are also used in infusions ('maté de coca') which are consumed like coffee or tea.

E. coca and *E. novogranatense* are a source of cocaine, which is used medicinally or as a narcotic. The therapeutic importance of cocaine has declined considerably. Cocaine (in its form as a hydrochloride) has long been used as a local anaesthetic in ear, nose and throat surgery. Although it is applied locally, systemic absorption may be marked, giving side effects (e.g. tachycardia, euphoria). It has been replaced by less toxic agents at present. Cocaine (hydrochloride) also used to be the sole active component in analgesic potions, or was added to oral solutions containing salts of morphine in order to potentiate the analgesic effect. These applications, however, are considered obsolete today. As a narcotic, cocaine is consumed in various ways. Coca paste, the initial product of extraction of the leaves, contains 40–70% cocaine (base), and is smoked. Cocaine (hydrochloride) is usually inhaled through the nose. 'Crack' or 'rock', a pure form of cocaine base, obtained by treating cocaine hydrochloride with bicarbonate, is smoked too ('freebasing').

The cola soft drink originally included coca extracts and caffeine-rich extracts from *Cola nitida* (Vent.) Schott & Endl., but nowadays coca leaves are only used to flavour the syrup after the cocaine has been removed from them.

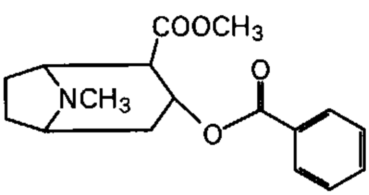
The leaves of *E. cuneatum* (Miq.) Kurz are reported to be used as fish poison in the Philippines (Luzon). *E. cuneatum* is also planted as an ornamental. The leaves of *E. ecarinatum* Burck are used medicinally, known as 'obat jaguar' in Sulawesi. In Papua New Guinea (Morobe Highlands), leaves are chewed and the sap ingested with traditional wood-ash salt against an upset stomach.

The wood of *Erythroxylum* has been used for fence posts and poles, flooring and sometimes for local house building, bridges, boat building and tool handles.

Production and international trade Coca is cultivated extensively in South America (Peru, Argentina, Bolivia, Colombia and Brazil), but also in Java, Sri Lanka, Taiwan, India and the United States. Few statistics are available on coca production. In South America, most of the coca leaves produced are consumed locally; very little is exported. Part of the coca leaves are used to make cocaine for illegal trafficking. Illegal imports of cocaine into the United States and Europe in 1988 were estimated at 100 t and 50–60 t, respectively.

Properties The most important constituent of *E. coca* and *E. novogranatense* is the tropane-ester alkaloid cocaine (methylbenzoyl ecgonine). The tropane part of the molecule, ecgonine, is biosynthetically derived from the amino acid ornithine. In the plant, cocaine occurs alongside other derivatives of tropine, e.g. cis- and trans-cinnamyl cocaine and tropa cocaine, and pyrrolidines e.g. hygrine, hygroline and cuscohygrine.

Cocaine and cinnamyl cocaine are considered to be the naturally occurring alkaloids of the coca plant, and have been identified in the roots, bark and leaves of several species and varieties. The younger leaves seem to accumulate cinnamyl cocaine as the main alkaloid, but the older leaves contain mainly cocaine. In an extensive study, the cocaine content in leaves of *E. coca* var. *coca* (30 samples) was found to range from 0.23–0.96%, with a mean of 0.63%, while the cocaine content in *E. coca* var. *ipadu* (6 samples) was lower: 0.11–0.41%, with an average of 0.25%. *E. novogranatense* var. *novogranatense* (3 samples) contained 0.55–0.93% cocaine, with an average of 0.77% and *E. novogranatense* var. *truxillense* (14 samples) 0.42–1.02%, with a mean of 0.72%. Cocaine (0.0003–0.3%) was detected in the leaves of 13 out of 29 wild *Erythroxylum* species, but no cocaine was detected in Old World species. The drug 'Cocae Folium' is also known to contain α-and γ-truxilline and benzoyl ecgonine. These components are probably formed during harvesting and processing of coca leaves: truxillines are dimers of cinnamoyl cocaine, and hydrolysis of cocaine leads amongst others to benzoyl ecgonine.



cocaine

Cocaine was first isolated around 1859. The compound displays several pharmacological activities, the best known being its local anaesthetic action. In this respect, cocaine acts by blocking Na^{+} ion channels in the neuron membranes, slowing down impulse conduction, and finally interrupting the propagation of action potentials. Because of cocaine's toxicity and addictive properties, a search for synthetic substitutes began. This is why the general molecular structure of cocaine can be found in several well-known local anaesthetics, e.g. procaine and tetracaine. Besides being a local anaesthetic, cocaine also acts as an adrenergic stimulant, by blocking the re-uptake of catecholamines (noradrenaline (= norepinefrine), dopamine) in both the peripheral and central nervous systems. Its euphoric properties are primarily due to inhibition of catecholamine uptake, particularly that of dopamine, at central nervous system synapses.

The chewing of coca leaves is a well-known practice in several South American countries. Alkalis added to the coca leaves facilitate the release of cocaine in its basic form. As a base, the ester is also volatile and can be smoked. Occasional use of cocaine results in feelings of mood elevation, vitality, mental clarity, sexual stimulation and reduction in appetite. However, chronic use can lead to anxiety, confusion, insomnia and impotence, and long-term heavy use can lead to paranoid psychosis. There are also indications that cocaine can be detrimental to fetal development. Regular use of cocaine finally leads to psychic dependence, but in contrast to heroin, not to physical dependence.

Adulterations and substitutes Although cocaine itself has never been synthesized, this has been done with similar compounds, of which procaine is the most important. Synthetic alkaloids with a similar action have almost completely replaced cocaine in medical use in the United States.

Description Shrubs or small trees. Leaves simple, alternate, distichous, entire; stipules intrapetiolar, inserted semi-amplexicaulously, mostly entirely connate, rarely bifid, sometimes emarginate or 2-toothed at the apex, often bicarinate, long-persistent or early caducous, leaving a distinct scar, involute in bud, the margins leaving a subpermanent trace as 2 longitudinal lines on the upper leaf surface ('areolate'). Flowers in axils of leaves, solitary or in clusters, bisexual, 5-merous, actinomorphic, often heterodistylous, or even heterotristylous; pedicel slightly thickened, often only under the calyx, with 2 bracteoles at the base; calyx campanulate, persistent; petals free, alternating with the calyx lobes, caducous, quincuncial in bud, nearly always provided with an emarginate or 3-lobed ligule inserted on the apex of the claw; stamens in 2 whorls of 5, persistent, filaments towards the base connate into a staminal tube, anthers ellipsoid, basifixed, cordate at the base, 2-celled; ovary superior, (1–)3-celled, normally only 1 cell fertile, each cell with 1 ovule, ovules pendulous, anatropous, with a ventral raphe, styles 3, erect, free or partly connate or stigmas sessile. Fruit a drupe. Seed with or without endosperm, embryo oblong, erect, cotyledons flat to plano-convex, plumule absent, radicle distinct.

Growth and development *E. novogranatense* seed starts to germinate in 2–3 weeks after planting. Three months after germination the plants may have attained a height of 15 cm. The first harvest, usually 1–3 years after transplanting into the field, consists of the main shoot that is pruned to promote frame formation as in tea (*Camellia sinensis* (L.) Kuntze). Consecutive pruning is carried out when coca develops flower buds; this coincides with a maximum in harvestable leaves. Leaf harvesting brings *E. coca* plants from the vegetative into the reproductive development phase.

Other botanical information Cocaine-rich leaves are obtained from 4 taxa: *E. coca* var. *coca* (Bolivian or Huánoco coca), *E. coca* var. *ipadu* Plowman (Amazonian coca), *E. novogranatense* var. *novogranatense* (Colombian coca) and *E. novogranatense* var. *truxillense* (Rusby) Plowman (Trujillo coca). *E. coca* var. *coca* is considered the ancestor, while *E. novogranatense* var. *truxillense* is derived from it, and *E. novogranatense* var. *novogranatense* derived from *E. novogranatense* var. *truxillense*. Cultivation and selection has probably been the main selective force. *E. coca* var. *ipadu* is considered to be a cultivar selected by man from *E. coca* var. *coca*. Wild populations of *E. coca* var. *coca* are found in the eastern Andes, but the other 3 taxa are only known as cultivated plants. Crosses between *E. coca* var. *coca* and *E. novogranatense* var. *novogranatense* have failed. Crosses between *E. coca* and *E. novogranatense* var. *truxillense* have been made, but gave abnormal, dwarfed progenies.

In the past *Erythroxylum* has been incorporated in different families, i.e. *Malpighiaceae*, *Linaceae* and *Erythroxylaceae*. In recent systems of classification it is widely accepted that the *Erythroxylaceae* differ from the *Malpighiaceae* by their unwinged fruits that do not split into 3 nut-like parts at maturity, and from the *Linaceae* by their ligulate petals and 3-locular ovary with only one fully developed locule.

Ecology *E. coca* var. *coca* is well adapted to the eastern Andes of Peru and Bolivia, an area of humid, tropical montane forest, whereas *E. coca* var. *ipadu* is cultivated in the lowland Amazonian basin. *E. novogranatense* is cultivated in drier regions in South America. However, *E. novogranatense* var. *novogranatense* is very adaptable to varying ecological conditions, and grows well in both humid and dry areas, and at low and higher altitudes. In Java, *E. novogranatense* has been cultivated from sea-level to 1000 m altitude, with best results at 400–600 m. In controlled environment studies, the optimum average daily temperature for leaf growth for both *E. coca* and *E. novogranatense* var. *novogranatense* was found to be around 27°C, whereas leaf growth was generally higher at photosynthetic photon flux densities of 250 or 400 $\mu mol.m^{-2}.s^{-1}$ than at 155 $\mu mol.m^{-2}.s^{-1}$. Environmental effects on the cocaine concentration in the leaves were smaller, so that total cocaine production per plant was largely a function of leaf mass, with environmental conditions that stimulated leaf growth giving higher cocaine yields. Both species grow on soils with low pH, and a greenhouse study has shown that the optimum pH for biomass accumulation of *E. coca* and *E. novogranatense* is as low as 3.5 and 4.7–6.0, respectively.

Propagation and planting *E. novogranatense* var. *novogranatense*, *E. novogranatense* var. *truxillense* and *E. coca* var. *coca* have to be reproduced by seed, because vegetative propagation is difficult. However, *E. coca* var. *ipadu* does not produce seed and is propagated by stem cuttings. It cannot reproduce without human interference. Cultivated *E. novogranatense* var. *novogranatense* produces abundant seed and is easy to propagate.

Seed viability decreases rapidly. Germination percentages of *E. coca* and *E. novogranatense* seed were found to decrease from around 95% and 89% directly after harvesting to 29% and 0%, respectively, after 24 days' storage at 4°C. Coca seedlings are usually sown in shaded nurseries and transplanted to the field when they are about one year old and 20–25 cm tall. In the field, they are planted at a spacing of 1–2 m. The actual time of transplanting and the spacing of the plants varies with climatic factors and whether coca is interplanted or cultivated as a sole crop.

In vitro production of active compounds It is possible to obtain cocaine and other alkaloids from *E. coca* var. *coca* shoot tissue cultures. The levels of cocaine produced have been found to be 50% of that produced by the parent plant, but within the range of the species. Whereas in *Solanaceae* the tropane alkaloids are biosynthesized in the roots, in *E. coca* tropane alkaloids (e.g. cocaine) can be produced from rootless explants.

Husbandry In mountain areas, coca is often grown on terraced fields. The fields are often manured with ash or plant material to sustain production. Older plants are severely pruned when leaf production decreases, after which regrowth occurs, but coca plantings are usually renewed after 20 years. *E. coca* var. *ipadu* is grown by semi-nomadic Amazonian tribes in isolated small plots, and constitutes an important part of their shifting cultivation system.

Diseases and pests *Erythroxylum* spp. are susceptible to Fusarium wilt, caused by the host-specific fungus *Fusarium oxysporum*, which is considered a potential mycoherbicide to combat illegal coca production. Symptoms are vascular wilt and permanent defoliation.

Harvesting The first harvest of coca takes place at 1–3 years after transplanting. In Java, a first harvest can be expected within a year after transplanting. The leaves have to be stiff and easily detachable to be harvested. Leaves can be harvested every 50–60 days in the rainy season, but when it is drier, they are usually harvested every 3–4 months. The leaves should be pinched from the plant, not ripped off.

Yield Annual yields of 1.7–2.2 t dry coca leaves per ha have been reported. The highest yields are obtained between 3 and 10–15 years after transplanting. In the Asian coca plantations, yields are about 700 kg dry coca leaves per ha, with the leaves containing up to 1.4% cocaine.

Handling after harvest When the leaves of coca are used for cocaine production, they are dried in the sun or artificially. Temperatures should not exceed 40°C, because the cocaine content of the leaves decreases at higher temperatures. The leaves are considered dry when they can be broken. In Asia, dried leaves are ground, pulverized and packed in plastic bags, while in South America they are pressed into bales of about 50 kg for transport. Leaves intended for chewing in South America must keep their form and colour and are dried more carefully.

Genetic resources and breeding The gene pool of cultivated *E. coca* has changed little over 5000 years, and wild or abandoned *E. coca* shows no morphological and genetic differences from cultivated *E. coca*. No germplasm collection and breeding programmes are known to exist.

Prospects The chewing of coca leaves is very important in Indian culture in parts of South America, and therefore coca will remain important there in the future. Elsewhere, the crop will only be important in regions where illegal production of narcotics is possible, because the world market for cocaine for medical use is limited, as synthetic agents have almost completely replaced the use of cocaine as a local anaesthetic.

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Selection of species

Erythroxylum coca Lamk

Encycl. méth. Bot. 2: 393 (1786).

Synonyms *Erythroxylum peruvianum* Prescott (1847), *Erythroxylum bolivianum* Burck (1890).

Vernacular names Coca, Peru coca, Peruvian coca (En).

Distribution *E. coca* var. *coca* (Bolivian or Huánoco coca) is widely cultivated in the Andean region, where it locally also occurs wild. It is not easy to cultivate elsewhere, and it is little known in other parts of the world. In South-East Asia, it is only grown in botanical gardens, not as a crop. *E. coca* var. *ipadu* (Amazonian coca) is only found as cultivated plant in Amazonian lowland rain forest areas.

Uses *E. coca* is the most important commercial coca species, cultivated for the legal or illegal production of cocaine. The leaves are used as a masticatory by millions of Indians in South America.

Observations A shrub or small tree, with very prominent, sometimes warty lenticels on the branches; leaves mainly at the end of the twigs, early caducous, broad-elliptical, 3–8 cm × 2–4 cm, base cuneate, apex acuminate or rounded with a mucronate tip; flowers in clusters of 6–12, rarely more, in the axils of leaves or ramenta, pedicel 4–6 mm, calyx with a 0.2–1 mm long tube and 5 lobes, triangular-ovate, 1–2 mm long, acute, green, petals oblong, 4–4.5 cm × 2 mm, yellow or yellowish green; fruit oblong-ovoid, pointed, 7–10 mm × 3–4.5 mm, red. *E. coca* has heterodistylous flowers, and self-pollination or pollination between plants of the same flower type gives few seeds. In Bogor it produces abundant fruit but not much foliage.

Selected sources 193, 379, 432, 466, 549, 555, 682, 683, 684, 880, 1119, 1145, 1146, 1147, 1167, 1178, 1277, 1278, 1301.

Erythroxylum novogranatense (Morris) Hieron.

Bot. Jahrb. 20, Beibl. 49: 35 (1895).

Synonyms *Erythroxylum coca* Lamk var. *novogranatense* Morris (1889), *Erythroxylum coca* Lamk var. *spruceanum* Burck (1890), *Erythroxylum truxillense* Rusby (1900).

Vernacular names Java coca, Truxillo coca (En).

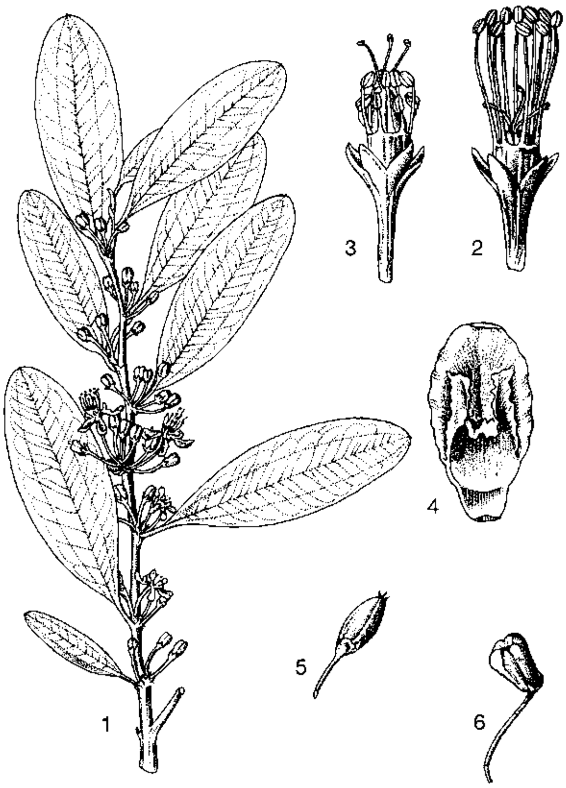
Distribution *E. novogranatense* var. *novogranatense* (Colombian coca) is native to Colombia and Venezuela, but its adaptability and easy propagation has led to a wide distribution over the Old and New World tropics. *E. novogranatense* was introduced in the Bogor Botanical Gardens in 1875, and by 1888 large quantities of seed were already being distributed. In South-East Asia, it has been grown in Peninsular Malaysia, western and eastern Java, northern Borneo, northern Sulawesi (Minahasa) and the Philippines (Luzon). *E. novogranatense* var. *truxillense* (Trujillo coca) is grown in arid areas in northern Peru. Neither of these varieties is known from wild populations.

Uses The medicinal uses of *E. novogranatense* are similar to those of *E. coca*. It used to be grown as a hedge plant in Malesia, up to 750 m altitude, for its bushiness and the contrast of its light green foliage with the bright red berries, but its cultivation is now prohibited. Although of importance as a plantation crop for the Malesian region in the past, it has since long lost its importance. *E. novogranatense* var. *truxillense* is highly regarded for its flavour and cocaine content, and has long been used for coca-flavoured beverages.

Observations A shrub of 1–3 m tall, with minute lenticels on the branches; leaves abundant along the twigs, rather persistent, obovate-oblong, (2–)3–6(–7) cm × 1–3 cm, base attenuate, apex rounded or sometimes emarginate, always with a mucronate tip or notch; flowers in clusters of 1–4(–8), pedicel 5–10 mm, calyx with a 1–1.5 mm long tube and 5 lobes, triangular-ovate, 1.5–2 mm × 1 mm, acuminate, petals oblong, convex, (3.5–)4(–5) mm × 2 mm, white or greenish-white; fruit ellipsoid-oblong, red. *E. novogranatense* has heterodistylous flowers, but, in contrast to *E. coca*, at least the long-styled type is self-compatible.

Selected sources 193, 202, 284, 328, 466, 549, 555, 580, 682, 683, 684, 1119, 1145, 1146, 1147, 1167, 1277, 1278.

R.C.K. Chung & M. Brink



Erythroxylum novogranatense (Morris) Hieron. – 1, flowering twig; 2, short-styled flower with petals removed; 3, long-styled flower with petals removed; 4, petal showing 3-lobed ligule-like appendage; 5, fresh fruit; 6, dried fruit.

Euphorbia L.

Sp. pl. 1: 450 (1753); Gen. pl. ed. 5: 208 (1754).
EUPHORBIACEAE

x = 9, 10, 11; *E. antiquorum*: $2n$ = 60, *E. barnhartii*: $2n$ = 40, *E. heterophylla*: $2n$ = 54, 56, *E. hirta*: n = 8, 9, 10, *E. neriifolia*: $2n$ = 60, 80, 90, 180, *E. prostrata*: n = 9, $2n$ = 20, *E. thymifolia*: n = 9, *E. tirucalli*: $2n$ = 20

Major species *Euphorbia antiquorum* L., *E. hirta* L., *E. thymifolia* L.

Vernacular names Spurge (En). Euphorbe (Fr).

Origin and geographic distribution *Euphorbia* comprises over 2000 species and occurs worldwide, though most species are found in tropical, subtropical and warm temperate regions. There are 35 species native to South-East Asia: Vietnam has 24 species, Thailand 25, Sumatra 6, Java 5, Borneo 5, the Philippines 6, Sulawesi 5, the Lesser Sunda Islands 11, the Moluccas 7 and New Guinea 15. Australia has 45 species.

Uses The latex of many *Euphorbia* species is used medicinally as a purgative, has antidiarrhoeal and antibacterial properties, and is used to treat boils, warts, wounds and other skin disorders. It is also often used as a fish poison and has insecticidal and fungicidal properties. The woody central part of the stem of some succulent species is applied as a remedy for dysentery. The leaves of several *Euphorbia* species are used to treat asthma. Traditional pharmacies often include material from several *Euphorbia* species.

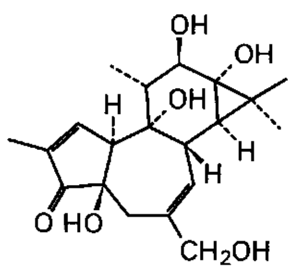
Some species are cultivated as ornamentals or living fences. The latex of some species can be converted into fuel and has been investigated as a possible energy source.

Properties Phytochemical investigations of the lipophilic constituents of *E. tirucalli* has revealed the presence of steroids (sitosterol, stigmasterol, campesterol) and fatty acids (palmitic acid, linoleic acid).

A lectin isolated from the latex of *E. neriifolia* agglutinated trypsinized human and rabbit erythrocytes. Untreated sheep erythrocytes did not agglutinate, but sialidase-treated sheep erythrocytes did. Galactose and sugars containing galactose inhibited the haemagglutination with increased β-anomeric specificity. The lectin possesses mitogenic activity with murine spleen lymphocytes but it does not inhibit protein synthesis in the rabbit reticulocyte lysate assay. The lyophilized aqueous extract of *E. hirta* has central analgesic properties. A dose of 20 mg/kg produced action against chemical stimuli, whereas one of 25 mg/kg produced action against thermic stimuli; the effects were inhibited by a pretreatment with naxolene, a specific morphinic antagonist compound. At the sedative doses of 100 and 400 mg/kg an antipyretic activity was obtained on the yeast-induced hyperthermia model. Significant and dose-dependent anti-inflammatory effects were also observed on an acute inflammatory process in a carrageenin-induced oedema test in rats from a dose of 100 mg/kg.

The ethyl acetate fraction of the ethanol extract of *E. prostrata* administered orally to rats at 200 mg/kg inhibited 76% of acute carrageenin-induced paw oedema. The ethyl acetate extract and a fraction (KSE-23) isolated chromatographically from it, showed significant anti-inflammatory activity when applied topically in a murine model of carrageenin-induced footpad oedema in mice. KSE-23

was found to be more potent than indomethacin given by the same route.
The extracts of *E. tirucalli* have markedly enhancing effects on the activation of latent Epstein-Barr virus (EBV) genomes in the EBV carrying lymphoblastoid cells and also on EBV-induced transformation of human lymphocytes. Soil and drinking water taken around the plants have the same enhancing effects and are a serious risk to humans in Africa. Various doses of powdered *E. prostrata* administered orally to male albino rabbits produced significant hypoglycaemic effects in normal rabbits, but had no effect in alloxan-diabetic rabbits. The methanol extract also decreased the blood glucose of normal rabbits. The methanol extract of *E. hirta* was effective against dysentery-causing *Shigella* spp. using the vero cell line, and it had no cytotoxic effects. This is attributable to quercitrin, a flavonoid, isolated from a lyophilized decoction of *E. hirta*. At doses of 50 mg/kg quercitrin is known to show preventive activity against diarrhoea induced by castor oil and prostaglandin E2 in mice, but not when magnesium sulphate is used as a cathartic agent. The aqueous extract of *E. hirta* has been found to strongly reduce the release of prostaglandins. Additionally, the extracts exerted an inhibitory effect on platelet aggregation. In organ bath tests with ileum preparations shikimic acid and choline extracted from the aerial parts of *E. hirta* had relaxing and contracting properties, respectively. The methanol extract of leaves and stems of *E. hirta* inhibited the activity of angiotensin-converting enzyme by 90% at 500 μg and 50% at 160 μg. The effect of the extract on thirst was examined in Wistar rats. The extract (10 mg/100 g, intraperitoneally) significantly decreased the amount of water the rats consumed. Extracts of whole plant material are also reported to have oestrogenic activity. Extracts of *E. hirta* showed anti-microbial activity against *Candida albicans*, *Escherichia coli*, and *Staphylococcus aureus*. Leaf extracts of *E. hirta* severely inhibited sporulation in the hyphomycete *Helminthosporium* sp. Finally, drying



phorbol

E. hirta prior to extraction considerably reduces the cytotoxic activity of certain of its extracts.
The latex of *Euphorbia* is often highly irritant to the eyes and must be washed away immediately. It can cause irritation and vesication from contact and emesis and purgation from ingestion. These effects are caused by a large number of different esters of the tetracyclic diterpenoid phorbol, many of which have also been shown to act as tumour promoters (cocarcinogens). The latex of *E. tirucalli* contains the irritant and/or cocarcinogenic constituents ingenane and tigliane-type diterpene esters derived from the parent alcohols ingenol, phorbol and resiniferonol. Furthermore, the latex is an emulsion of about 30% terpenes in water.
The latex hydrocarbon is largely a C_{30} triterpenoid which can be cracked to make high octane gasoline. The gross energy value of *E. tirucalli* biomass is 17 600 kJ/kg. Biomass can be converted into gas, liquid fuels and solid fuels such as pellets, briquettes and charcoal.
Rubber production from the latex of *E. tirucalli* was investigated early in the 20th Century, but continuous latex production proved difficult and its high resin content limited the profitability of the rubber production.

Description Monoecious or rarely dioecious, annual, biennial or perennial herbs, shrubs or trees, sometimes succulent, armed or unarmed, with latex. Leaves alternate, opposite or verticillate, sometimes much reduced, simple, uniform or heterophyllous, margin entire, toothed or lobed; stipules present or absent, sometimes modified into spines. Flowers unisexual, one female flower together with several male flowers enclosed within a small, cupuliform, glanduliferous involucre, the whole structure termed a 'cyathium', functioning as a single, bisexual flower; cyathia solitary or combined into corymbs or cymes, occasionally unisexual; bracteoles usually ligulate and fringed. Male flowers reduced to single stamens; anthers with 2 cells. Female flowers pedicellate, reduced to single pistils or with a minute perianth; ovary superior, during maturation on an accrescent pedicel and often nodding outside the cyathial cup, 3-locular with 1 ovule per locule, styles 3, partly fused, entire to 2-fid. Fruit a smooth to tuberculate, sometimes fleshy capsule, splitting open elastically, first dehiscing septicidally and then loculicidally. Seeds with endosperm, with or without caruncle. seedling with epigeal germination; cotyledons leafy, usually elliptical to ovate, glabrous; hypocotyl elongated, glabrous, epicotyl absent or very short; first two leaves opposite.

Growth and development In Java, *E. atoto*, *E. hirta*, *E. prostrata* and *E. thymifolia* flower throughout the year, *E. barnhartii* usually in September–November, whereas *E. tirucalli* rarely flowers in October but never sets fruit. In most *Euphorbia* the capsules dehisce with force and ejaculate their seeds which are thus dispersed over some distance. Ants may act as a dispersal agent of some *Euphorbia*, for example in *E. hirta* and *E. heterophylla*. *E. hirta* produces up to 3000 seeds per plant which show a high germination rate. *E. tirucalli* is one of the very few known plants combining a Crassulacean acid metabolism (CAM) pathway of its branches and twigs with the C_3 metabolism pathway of its leaves. Consequently it is very drought-resistant and very efficient in photosynthesis.

Other botanical information Some authors have separated *Euphorbia* into a number of distinct genera, usually based upon peculiarities of the cyathial structure. Others recognize these entities at infrageneric level. In South-East Asian and Australian literature one may, for example encounter the genus *Chamaesyce* next to *Euphorbia*; here, however, *Chamaesyce* is regarded as a subgenus.

Some of the American *Euphorbia* species that have been introduced into South-East Asia are sometimes referred to as members of the genus *Poinsettia*, or of the subgenus *Poinsettia*. All tree-like, succulent, spinose species belong to the subgenus *Euphorbia*. *E. cyathophora* and *E. heterophylla* are now regarded as two distinct species, but have not been treated as such in older literature. Therefore much of the older information cannot be referred to either of these species. Both species are strikingly variable in leaf shape. *E. buxoides* Radcl.-Sm., which closely resembles *E. plumerioides*, is widely planted as a hedge and boundary marker in the highlands throughout New Guinea. Its bark is chewed to induce vomiting and acts as a poison antidote. Leaves of *E. vachellii* Hook. & Arn. (syn. *E. serrulata* Reinw. ex Blume non Thuill.) are used internally to treat catarrh in Papua New Guinea.

Ecology The succulent, spinose *Euphorbia* species generally occur in dry places, on rocky or sandy soils, occasionally in dry forest. Most herbaceous *Euphorbia* species are commonly found in waste places and as a weed in fields and gardens.

Propagation and planting The weedy medicinal *Euphorbia* species produce seed in abundance and reproduce spontaneously. *E. tirucalli* can easily be propagated by stem cuttings, which greatly facilitates its planting as a hedge. Cuttings can best be taken from older branches; they are left to dry for 1 day before planting. A density of 10 000–20 000 plants/ha is normal when grown as fuel crop.

In vitro production of active compounds Isolation and culturing of protoplasts of *E. tirucalli* has been successful. Callus tissue of *E. tirucalli* produces the 4,4'-dimethyl sterols euphol and tirucallol. Euphol is the principal terpene in the latex of the plant, whereas tirucallol is found in intact parental tissue. The highest yield of sterol has been obtained on a Murashige and Skoog medium supplemented by indole acetic acid (IAA) and kinetin; incorporation of squalene at 1.0 mg/l enhanced sterol production.

Husbandry The herbaceous medicinal *Euphorbia* species are in general weeds. *E. heterophylla* is a shade-tolerant, pantropical weed and as such its control is more important than its husbandry. It may be troublesome in crops like maize, cotton, cowpea and soya bean. Crops need to be kept free from *E. heterophylla*, especially in the early phases of development. Well-established *E. heterophylla* can depress yields greatly, for instance by as much as 75% in cowpea. Fresh *E. heterophylla* seed germinates readily under tropical conditions, but remains dormant under temperate circumstances and then both light and temperature influence dormancy breaking. *E. prostrata* shows strong allelopathic effects on a number of crops. Its aqueous extract, decaying residues and root exudates have been found to be inhibitory to several species. Under semi-arid conditions the regrowth of coppice of *E. tirucalli* is excellent.

Harvesting In general stems or whole plants of herbaceous *Euphorbia* are harvested to be used fresh. *E. tirucalli* can be coppiced at 20–30 cm height.

Yield When planted at a spacing of 1 m × 1 m *E. tirucalli* in Thailand produced 120 t/ha fresh material and 14 t/ha dry matter after 1 year, yielding 40–88 kg of crude oil, 135–213 kg of sugar and 1.8 t of bagasse. After 1.5 years with 6 trimmings a year, 148 t/ha of biomass (i.e. 17.5 t dry weight) could be harvested. It was calculated in Japan that 1–2 t of crude oil could be obtained per ha per year from *E. tirucalli*. A daily production of biogas from *E. tirucalli* of about 31 m^3/ha (226 l/kg dry matter) is considered possible based on an annual production of 500 t biomass/ha by means of a two-phase methane fermentation process; a one-phase process yields 175–323 l of biogas per kg dry matter.

Genetic resources and breeding Given the common and widespread occurrence of most medicinal *Euphorbia* species and their weedy nature, the risk of genetic erosion appears very limited. The same holds for the succulent *Euphorbia* species planted as ornamentals. Neither germplasm collections nor breeding programmes are known of.

Prospects Phorbols and phorbol-esters are extremely harmful to the skin and mucous membranes, and also reported to be tumour promoters. Therefore, the medicinal prospects of many *Euphorbia* species are very limited. Acetylated esters of phorbols, however, may play a role in the search for possible anti-tumour compounds.
E. tirucalli may hold promise for energy production through biomass utilization or use of the crude oil extracted from the plants.

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Selection of species

Euphorbia antiquorum L.

Sp. pl. 1: 450 (1753).

Vernacular names Malayan spurge tree (En). Euphorbe des anciens (Fr). Indonesia: sudu-sudu, susudu, susuru. Malaysia: sesudu, sudu-sudu (Peninsular). Cambodia: chan bat day. Laos: lep nguak. Thailand: kalam-phak (eastern), khia phaa (northern), salatdai paa (central). Vietnam: x[uw][ow]ng r[oof]ng, x[uw][ow]ng r[oof]ng c[aj]nh.

Distribution Southern India, Sri Lanka, Burma (Myanmar), Laos, Vietnam, Thailand and Peninsular Malaysia; locally cultivated within the area of natural occurrence, in Java and possibly also in the Philippines. Also sporadically cultivated as an ornamental or hedge plant in other tropical and subtropical regions, and as an indoor plant in temperate areas.

Uses The poisonous milky latex or other plant parts (e.g. root bark) are taken as a drastic purgative and induce vomiting. The latex is applied externally to swellings, boils, warts and other skin affections. When mixed with oil, it is a rubefacient embrocation for rheumatism. It may also be used to treat toothache, earache and asthma. The dried heartwood is an antipyretic and used in applications to treat toothache, and is used in Cambodia as a febrifuge and against dysentery. In India, the plant is employed for nervine diseases and dropsy. A saline extract of the stem shows antibiotic activity. Furthermore, the plant is used as a fish poison and shows insecticidal properties. *E. antiquorum* is often planted for ornamental purposes and as a fence. In Java, young twigs that have been properly boiled, soaked in water and covered with sugar, have been eaten as sweetmeats.

Observations A spiny, succulent shrub or small tree up to 6(–9) m tall, branches tufted, ascending, 3–5-ribbed, with 3–5 mm long, persistent spines on the exsculptate ribs, young branches constricted at the joints; leaves early caducous, obovate-spathulate or subrhomboid, 0.3–1.3 cm long, cuneate to attenuate at base, rounded to emarginate at apex, sessile; inflorescence borne on the exsculptate ribs, composed of 1–7 cyathia, peduncles short, rigid, 0–2 times forked, bracts scale-like, about 2.5 mm long, pale green; cyathia with 5 pale yellow glands, 4–4.5 mm wide, anthers dark red; capsule obtusely trigonous, 8–12 mm across, smooth. *E. antiquorum* is found in dry, open, evergreen forest, in scrubby vegetation, on rocky limestone hills and on sandy soils, up to 800 m altitude.

Selected sources 97, 202, 287, 580, 921, 1035, 1126, 1128, 1135, 1181, 1185.

Euphorbia atoto J.G. Forster

Fl. ins. austr.: 36 (1786).

Synonyms *Euphorbia laevis* Poir. (1812), *Euphorbia halophila* Miq. (1852), *Chamaesyce atoto* (J.G. Forster) Croizat (1936).

Vernacular names Indonesia: jelutung laut (Java), susuan i lawanan (Sulawesi). Philippines: tairas (Filipino), lamingo (Bagobo). Thailand: ma phraao nok khao (south-western), nam nom raatchasee thale (peninsular). Vietnam: c[aa]y thu[oo]c d[of]i.

Distribution Indo-China, China, Japan, Thailand, throughout the Malesian region, northern Australia and Polynesia.

Uses In Indo-China the latex is used as an emmenagogue and an abortifacient. In New Caledonia, seawater in which the plant has been soaked and trampled is often used as a purgative.

Observations An unarmed, perennial, glabrous herb with prostrate to ascending stems; leaves opposite, slightly leathery, elliptical to ovate-oblong, 1.2–3 cm long, obliquely subcordate at base, acute at apex, margin entire, glaucous, shortly petiolate, stipules entire; bracts leaf-like; cyathia 1–3 together in terminal cymes, glands 4, transversely elliptical to oblong, yellow, with white appendages, anthers yellow; capsule obtusely trigonous, about 2.5 mm in diameter, smooth. *E. atoto* is a typical beach plant confined to sandy beaches and coral reefs.

Selected sources 97, 155, 865, 921, 1128, 1178, 1181, 1380.

Euphorbia barnhartii Croizat

Euph. antiq. offic.: 54 (1934).

Synonyms *Euphorbia trigona* Roxb. (1832) non Miller.

Vernacular names Indonesia: sudu-sudu, susudu, susuru. Malaysia: sesudu, sudu-sudu (Peninsular). Philippines: sorog-sorog (Tagalog).

Distribution Native origin possibly Java; planted in Peninsular Malaysia, Java, the Philippines, possibly also elsewhere.

Uses The latex is used to treat earache, and has been reported as poisonous. Pounded leaves are applied as a poultice to boils. *E. barnhartii* is fairly commonly cultivated for ornamental purposes and as a hedge.

Observations A spiny, succulent shrub or small tree up to 5 m tall, main stem 4–5-ribbed, branches 3-ribbed, with 3–5 mm long, readily caducous spines on the exsculptate ribs; leaves early caducous, oblong-obovate, 4–15(–30) cm long, apex rounded with a recurved mucro; inflorescence borne on the exsculptate ribs, composed of 3–7 cyathia on short, rigid, forked peduncles, bracts 2–7 mm long; cyathia with 5 shiny yellow glands, 3.5–4.5 mm broad, anthers red; capsule obtusely trigonous, ovoid, 4–7 mm in diameter, smooth. *E. barnhartii* is found as an escape from cultivation, e.g. on limestone and lava rocks, at low altitude.

Selected sources 97, 202, 296, 580, 933, 1126.

Euphorbia cyathophora Murray

Comm. Göttingen 7: 81, t. 1 (1786).

Synonyms *Euphorbia heterophylla* L. var. *cyathophora* (Murray) Griseb. (1859), *Poinsettia cyathophora* (Murray) Klotzsch & Garcke (1859), *Poinsettia graminifolia* (Michx.) Millsp. (1909).

Vernacular names Painted leaf, red milkweed, wild poinsettia (En). Philippines: pintado (Tagalog). Vietnam: tr[aj]ng nguy[ee]n ghi ta.

Distribution Native to the southern United States, Mexico and perhaps also the Greater Antilles, but now cultivated and commonly escaping and naturalizing throughout the tropics. Within Malesia occurring in Peninsular Malaysia, Java, the Lesser Sunda Islands, the Philippines and Papua New Guinea.

Uses In Peninsular Malaysia, a decoction of the roots and bark is used to treat ague. In Mexico, the stem latex is applied against erysipelas. In the West Indies, the latex is applied to corns. In Guatemala, a decoction of the flowers is taken as a pectoral. In Central America, the roots are applied as an emetic and cathartic and administered in very small doses. In Brazil, the leaves are used to produce the red dye porcetin. *E. cyathophora* is sometimes planted for ornamental purposes.

Observations An annual or facultative perennial, unarmed herb up to 1.5 m tall; leaves alternate, ovate or lanceolate to fiddle-shaped, 4–10 cm × 1–5 cm, base cuneate to rounded, apex obtuse or acute, margin entire to serrulate or dentate, glossy green, lower surface pilose, petiole up to 1.7 cm long, glabrous or sparsely pilose; inflorescence a terminal, clustered cyme of cyathia, bracts similar to the leaves but progressively smaller, with a red blotch at base or entirely red; cyathia with 1(–2) peltate, funnel-shaped glands with an elliptical, 2 mm wide opening, anthers yellow; capsule deeply 3-lobed, 4–5 mm × 3.5–5 mm, smooth; seeds ovoid, sharply tuberculate. *E. cyathophora* is found in waste places and roadsides, up to 1800 m altitude.

Selected sources 97, 217, 372, 864, 865, 979, 1178, 1183, 1185, 1186, 1582.

Euphorbia heterophylla L.

Sp. pl. 1: 453 (1753).

Synonyms *Euphorbia prunifolia* Jacq. (1798), *Poinsettia geniculata* (Ort.) Klotzsch & Garcke ex Klotzsch (1859), *Poinsettia heterophylla* (L.) Klotzsch & Garcke ex Klotzsch (1859), *Euphorbia taiwaniana* Ying (1987).

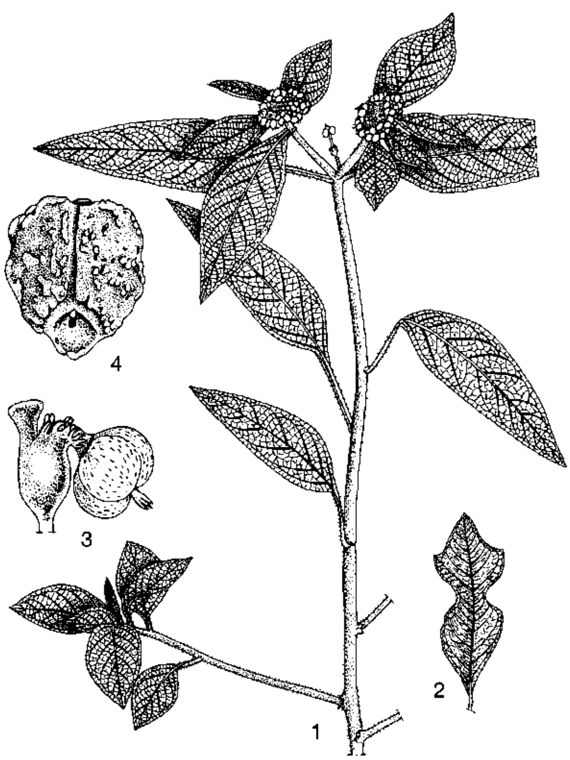
Vernacular names Japanese poinsettia, Mexican fireweed, mole plant (En). Malaysia: pekapar (Peninsular). Thailand: yaa yaang (general), bai taang dok, luuk khoei taai mae yai tham sop (Bangkok). Vietnam: c[or] m[ur].

Distribution Native to Central and South America, but nowadays naturalized throughout the tropics. Within Malesia not yet reported from the Philippines.

Uses *E. heterophylla* may cause poisoning in livestock. The young leaves are sometimes eaten as a vegetable, but may act as a laxative.

Observations An annual or facultative perennial, unarmed herb up to 110(–200) cm tall; leaves alternate, lanceolate or ovate to distinctly fiddle-shaped, 3–14 cm × 0.5–7 cm, base cuneate to rounded, apex obtuse to slightly acuminate, margin entire to serrulate, dull green, glabrous to sparsely pilose above, pilose below, petiole up to 3(–6) cm long, pilose; inflorescence composed of densely clustered cyathia in axillary or terminal cymes, bracts similar to the leaves but progressively smaller and paler green, sometimes purple spotted; cyathia with 1(–2) peltate, funnel-shaped glands with a circular, 0.5–1.2 mm wide opening, anthers yellow; capsule deeply 3-lobed, 4–5.5 mm × 3.5–4.5 mm, smooth, puberulent; seeds truncate-ovoid, bluntly tuberculate. *E. heterophylla* is a noxious weed of e.g. cocoa, tea, rice and sugar cane, also found in gardens and waste places, and on alluvial soils and sandy beaches, up to 3000 m altitude.

Selected sources 97, 202, 217, 372, 638, 864, 865, 1182, 1183, 1186, 1380, 1386, 1425, 1582.



Euphorbia heterophylla L. – 1, plant habit; 2, leaf showing variability in shape; 3, cyathium; 4, seed.

Euphorbia hirta L.

Sp. pl. 1: 454 (1753).

Synonyms *Euphorbia pilulifera* L. (1753), *Chamaesyce pilulifera* (L.) Small (1903), *Chamaesyce hirta* (L.) Millsp. (1909).

Vernacular names Asthma herb, hairy spurge, pill-bearing spurge (En). Euphorbe à fleurs en tête, euphorbe pilulifère (Fr). Indonesia: daun biji kacang (Malay, Moluccas), nanangkaan (Sundanese), patikan kebo (Javanese). Malaysia: ambin jantan, kelusan, keremak susu (Peninsular). Papua New Guinea: sip (Kurtatchi, Bougainville), kiki kana kuku (Gunantuna, New Britain). Philippines: botobotonis (Tagalog), gatas-gatas (Bisaya, Tagalog), maragatas (Iloko). Laos: mouk may, nom ra sa 'si, ungl yang. Thailand: nam nom raatchasee (central), yaa nam muek, yaa-lang-ueng (northern). Vietnam: c[or] s[uwx]ra, c[or] s[uwx]a l[ows]n l[as].

Distribution A pantropical weed of Central American origin; introduced into South-East Asia long ago and nowadays occurring throughout Malesia.

Uses The milky latex is cooling and is used as a remedy for conjunctivitis, ulcerated cornea and other eye complaints. It is also applied to cuts, sores and warts. It has a depressant action on the heart and respiration, and a decoction, infusion or tincture of the plant is used to treat asthma, chronic bronchial disorders, acute nasal catarrh, hay fever and emphysema. A decoction is also administered to allay convulsions, as an expectorant, and as a mouthwash to treat toothache. A tincture is considered useful in colic, dysentery, as a vermifuge and in diseases of the genito-urinary tract. The leaves are mixed with those of downy thorn apple (*Datura metel* L.) in preparing 'asthma cigarettes'. The plants are slightly narcotic and are reported as being haemostatic, sedative, and sudorific. They are also applied to stimulate milk secretion and to promote sweating. An infusion of the roots is taken to relieve headache, and heat exhaustion. The ground fruits are given to children as a laxative. In Java and India the tender shoots serve as famine food, raw or steamed, but these may cause intestinal complaints.

Observations An annual, unarmed, pilose herb up to 70 cm tall, stems sparingly branched near the base; leaves opposite, ovate to ovate-oblong, 1–5 cm × 0.3–2.5 cm, base obliquely cuneate to rounded, apex bluntly pointed, margin finely serrate, pale to dark green, often with purple spots, short-petioled, stipules free, subulate; inflorescence axillary or terminal, composed of peduncled, globose clusters of cyathia; cyathia with appressed-hairy involucres and 4 minute, green or purplish glands bearing a narrow appendage, anthers yellow; capsule acutely 3-lobed, broadly ovoid-pyramidal, about 1 mm × 1.2 mm, appressed-hairy; seeds oblong, with slight transverse wrinkles. *E. hirta* is a weed of waste places and in crops, occurring up to 2000 m altitude.

Selected sources 97, 287, 380, 393, 465, 531, 581, 671, 716, 814, 865, 1035, 1126, 1128, 1135, 1178, 1181, 1182, 1183, 1184, 1185, 1186, 1380, 1386, 1525, 1527, 1572, 1578.

Euphorbia hirta L. – 1, plant habit; 2, young cyathium; 3, mature cyathium; 4, seed.

Euphorbia neriifolia L.

Sp. pl. 1: 451 (1753).

Synonyms *Euphorbia ligularia* Roxb. (1832).

Vernacular names Common milk hedge, hedge euphorbia, oleander spurge (En). Indonesia: sudu-sudu, susudu, susuru. Malaysia: sesudu, sudu-sudu (Peninsular). Philippines: bait (Pampangan, Tagalog), soro-soro (Tagalog), sorog-sorog (Pampamgan, Tagalog). Thailand: som chao (central). Vietnam: x[uwl[ow]ng r[oof]ng, x[uwl[ow]ng r[oof]ng r[af]o, x[uw] [ow]ng r[oof]ng ta.

Distribution Probably of South-Asian origin, but nowadays locally cultivated and naturalizing in Sri Lanka, India, Burma (Myanmar), Thailand and throughout the Malesian region except for Borneo; also occasionally cultivated in other tropical regions.

Uses In Malaysia and the Philippines, the latex from heated leaves is applied externally to relieve earache. The latex may also be used as a purgative, diuretic, vermifuge, and to treat asthma. In Guatemala, the latex is applied on haemorrhoids. In El Salvador, it is used to relieve sore throat and cracked lips, and also to cure gonorrhoea. In the Moluccas, the bark has been used as a strong purgative. The root is considered antiseptic. In India, the latex is used to remove warts and cutaneous eruptions. The leaves and roots have been used as a fish poison. *E. neriifolia* is fairly commonly planted as a live fence and for ornamental purposes. When boiled with syrup the leaves and slices of the branches can be made into sweetmeats. The nicely figured and aromatic wood is used for small objects such as kris handles. The leaves can be eaten, even raw. In India, the latex is smeared on cuts in *Borassus flabellifer* L. made by tappers, in order to prevent attack by red weevil.

Observations An armed, succulent shrub or small tree up to 8 m tall, branches obtusely 5-angular, with pairs of spines of 4–12 mm long arising from the ribs; leaves alternate, obovate to narrowly oblanceolate, (5–)15–30 cm × (1.5–)2–7.5 cm, base cuneate to attenuate, apex rounded, margin entire, glabrous; inflorescence lateral, composed of 3–7 cyathia on short, rigid, forked peduncles, bracts ovate; cyathia with 5 oblong glands, 1.5–2 mm × 4–5 mm; capsule 10–12 mm in diameter, glabrous. *E. neriifolia* grows well in dry, often rocky places.

Selected sources 97, 202, 287, 580, 638, 979, 1126, 1128, 1135, 1178, 1181, 1183, 1184, 1185, 1186, 1311, 1380.

Euphorbia plumerioides Teijsm. ex Hassk.

Hort. bogor. descr. 1: 29 (1858).

Vernacular names Papua New Guinea: noti (Koheno, North Solomons Province), Simbu (Anji, Enga), temp (Mt Hagen, Western Highlands).

Distribution Probably native to the Moluccas and New Guinea, but now cultivated and locally naturalized in Java, the Lesser Sunda Islands, the Philippines (Gola Island), the Moluccas and New Guinea.

Uses In Papua New Guinea, the latex is mixed with water and taken to induce vomiting in cases of poisoning or sickness due to sorcery. It is also used as a purgative, vermifuge and fish poison. *E. plumerioides* is often planted as an ornamental on cemeteries and as a hedge.

Observations An unarmed shrub up to 2.5 m tall, twigs thick, terete, glabrous; leaves semipersistent, alternate, crowded towards the twig apices, almost sessile, narrowly lanceolate to obovate-lanceolate, 5–14 cm × 1.2–3.5 cm, gradually narrowed at base, apex obtuse with a long mucro, glabrous, pale glaucous below, older ones red; inflorescence terminal, umbelliform, bracts ovate; cyathia with sordidly red involucres and 5 elliptical to orbicular, green or sometimes red-margined glands, anthers yellow; capsule 3-lobed, glabrous. *E. plumerioides* is very variable and has been subdivided into 4 varieties mainly based on leaf characters. It is found on littoral cliffs.

Selected sources 97, 597, 768, 1126, 1183, 1185, 1186.

Euphorbia prostrata Aiton

Hort. kew. 2: 139 (1789).

Synonyms *Chamaesyce prostrata* (Aiton) Small (1903).

Vernacular names Trailing red spurge (En). Indonesia: gelang pasir, ki mules (Sundanese), patikan cina (Javanese). Vietnam: c[or] s[uwx]a n[awf]m.

Distribution Native to the West Indies (Jamaica), but nowadays introduced and widely naturalized throughout the tropics and subtropics. In South-East Asia reported from Thailand, Java, the Philippines, Sulawesi, the Lesser Sunda Islands, the Moluccas and New Guinea, but probably occurring elsewhere as well.

Uses In traditional medicine it is not distinguished from *E. thymifolia*; hence for its uses see under that species.

Observations An annual, unarmed, prostrate, often purplish-tinged herb, branches up to 20 cm long, pilose above; leaves opposite, ovate to obovate, up to 0.8 cm × 0.5 cm, base obliquely rounded to truncate, apex rounded, margin serrulate to subentire, puberulous on both surfaces or only below, subsessile, stipules pilose, partly fused; inflorescence terminal and pseudoaxillary, composed of solitary cyathia, bracts absent; cyathia with 4 red glands with minute appendages, bracteoles hair-like; capsule acutely 3-lobed, exserted on a reflexed pedicel, about 1.3 mm × 1.3 mm, hairy; seeds with distinct transverse ridges and grooves. *E. prostrata* is closely related to and sometimes even, incorrectly, regarded as conspecific with *E. thymifolia*. It is found in disturbed places, gardens, fields and roadsides, usually on sandy or gravelly soils, up to 2000 m altitude.

Selected sources 40, 51, 97, 217, 580, 921, 1126, 1181, 1183, 1185, 1186, 1334, 1335.

Euphorbia synadenium Ridley

Journ. Roy. As. Soc. Straits Br. 61: 36 (1912).

Synonyms *Euphorbia ridleyi* Croizat (1937).

Vernacular names Malaysia: pokok susu hutan, sesudu bukit, sesudu hutan (Peninsular). Thailand: rak luukmaa (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia; possibly also in India (Bengal).

Uses *E. synadenium* is used for poulticing burns.

Observations A slightly succulent, unarmed shrub up to 1.5 m tall, stem unbranched; leaves alternate, oblanceolate-spathulate, up to 20 cm long, apex blunt to subacute, petiole about 1.5 cm long; inflorescence composed of axillary, solitary, unisexual cyathia, bracts ovate, purple-pink; male cyathia with 10 laciniate, pink glands, female cyathia with green glands. *E. synadenium* is found locally in rocky, evergreen forest, up to 330 m altitude.

Selected sources 120, 202, 1181, 1227, 1380.

Euphorbia thymifolia L.

Sp. pl. 1: 454 (1753).

Synonyms *Chamaesyce thymifolia* (L.) Millsp. (1916).

Vernacular names Euphorbe à feuilles de thym, rougette (Fr). Indonesia: gelang pasir, ki mules (Sundanese), patikan cina (Javanese). Malaysia: gelang susu, rumput barah, rumput jangot (Peninsular). Philippines: makikitot (Iloko). Laos: nhayang ung baynoy. Thailand: namnom raatchasee lek (central). Vietnam: c[orl s[uwx]a l[as] nh[or], c[or] s[uwx]a d[aas]t, nh[ar] m[uwj]c n[oj]i.

Distribution Throughout the Old World tropics, apparently not widespread in tropical East Africa, but advancing there; throughout the Malesian region.

Uses *E. thymifolia* has stimulant, astringent, diuretic, anthelmintic and laxative properties, and shows antispasmodic and antifungal activity. It is used as a remedy in earache, eye infections, herpes, gonorrhoea and asthma. In India, *E. thymifolia* is administered to cure ringworm. A poultice is applied to wounds, skin complaints and dislocated bones. A decoction is used in cases of diarrhoea, dysentery, prolapsed rectum, and other abdominal troubles. In the Philippines, a poultice is applied for snake bites, whereas the latex is used to dissipate corneal opacity. In India, whole plants are used as a fish poison, whereas an essential oil can be extracted and applied as an insecticide.

Observations An annual, unarmed, prostrate herb, branches up to 25 cm long, often reddish, subglabrous to pubescent especially on the upper side; leaves opposite, elliptical or ovate to obovate-oblong, 0.2–0.9 cm × 0.1–0.4 cm, base obliquely rounded to subcordate, apex subacute to rounded or truncate, margin crenate to serrate, glabrous above, sparsely pilose below, subsessile, stipules free, pilose; inflorescence terminal and pseudo-axillary, composed of solitary cyathia, bracts absent; cyathia with 4, minute, red glands bearing minute appendages, bracteoles hair-like; capsule 3-lobed, short-stalked and only barely protruding from the involucre, 1–1.5 mm in diameter, hirsute; seeds with shallow transverse ridges and grooves. *E. thymifolia* is a common weed of cultivated and waste ground, often on sandy or gravelly soils, up to 1650 m altitude.

Selected sources 97, 202, 217, 287, 363, 531, 580, 1035, 1126, 1128, 1130, 1135, 1178, 1181, 1182, 1183, 1184, 1185, 1186, 1380, 1572.

Euphorbia tirucalli L.

Sp. pl. 1: 452 (1753).

Synonyms *Euphorbia rhipsaloides* Lem. (1857), *Euphorbia media* N.E.Br. (1911), *Euphorbia scoparia* N.E.Br. (1911).

Vernacular names Finger tree, pencil tree, rubber euphorbia (En). Euphorbe effilé, tirucalli (Fr). Indonesia: patah tulang (general), kayu urip, tikel balung (Javanese). Malaysia: kayu patah tulang, tulang-tulang, tentulang (Peninsular). Philippines: bali-bali (Panay Bisaya), suelda-consuelda (Bikol), suerda (Tagalog). Laos: 'khi[2] hai bai. Thailand: khia cheen, khia thian, phayaa rai bai (northern). Vietnam: x[uw][ow]ng c[as], c[aa]y x[uw][ow]ng kh[oo], san h[oo] xanh.

Distribution Native to tropical Africa, but widely planted and naturalized throughout the tropics and subtropics. Within Malesia not yet reported from Borneo and New Guinea.

Uses In traditional medicine, poultices from the stem or bark of *E. tirucalli* are applied to heal broken bones. The latex is used for similar purposes as that of *E. antiquorum* and *E. neriifolia*, but is poisonous, corrosive, and emetic. In Peninsular Malaysia, a poultice of the roots or stems has been applied to ulceration of the nose, haemorrhoids and swellings. Root scrapings, mixed with coconut oil, are given to cure stomach-ache. An extract of the plant shows antibiotic activity. *E. tirucalli* has also been used as a fish poison. It is widely planted as a hedge and for ornamental purposes, especially in dry regions. During the Second World War the latex was tested in South Africa as a rubber substitute, but it proved to be unstable. An oil obtained from the latex appeared useful for application in linoleum, oilskin and leather cloth industries. The white, close-grained and fairly hard wood is used for rafters, toys and veneer. It yields charcoal suitable for use in gunpowder.

Observations An unarmed, succulent shrub or small tree up to 10(–15) m tall, branches often in whorls, terete, 5–8 mm in diameter, finely longitudinally striate; leaves alternate, early caducous, linear-lanceolate, 0.7–1.6 cm × 0.1–0.3 cm, narrowing at base, apex obtuse to subacute, glabrous throughout or puberulent below, sessile or subsessile, stipules minute, glandular; inflorescence on the stem apices and in bifurcations, generally composed of unisexual cyathia, bracts rounded, small; cyathia with 5 subglobose to transversely elliptical, bright yellow glands; capsule exserted on a tomentose pedicel, subglobose, 7–8 mm in diameter, glabrescent; seeds smooth, buff speckled with brown and with a dark brown ventral line. *E.*

tirucalli easily naturalizes in brushwood, open woodland and grassland, up to 2000 m altitude.

Selected sources 97, 134, 154, 202, 217, 287, 337, 453, 531, 580, 638, 647, 828, 864, 865, 960, 979, 1035, 1074, 1126, 1128, 1135, 1178, 1181, 1184, 1185, 1186, 1380, 1402, 1499, 1525, 1547, 1610.

Nguyen Nghia Thin & M.S.M. Sosef

Eurycoma Jack

Mal. Misc. 2: 45 (1822).
SIMAROUBACEAE
x = unknown

Major species *Eurycoma apiculata* A.W. Bennett, *E. longifolia* Jack.

Vernacular names Brunei: langsia siam, tungat ali, pasak bumi. Indonesia: pasak bumi (general), bidara laut, beseng (Sumatra). Malaysia: bedara merah, bedara putih, tongkat ali (Peninsular). Cambodia: antong sar, antoung sar. Laos: tho nan. Thailand: hae phan chan (northern), plaalai phuenk (central), phiak (peninsular). Vietnam: c[aa]y b[as] b[eej]nh.

Origin and geographic distribution *Eurycoma* is confined to tropical South-East Asia and consists of 3 species, with several subspecies. In the Malesian region 2 species are present: a widespread, rather variable species (*E. longifolia*), occurring from Burma (Myanmar) trough Indo-China and Thailand, to Peninsular Malaysia, Sumatra, Borneo and the Philippines; and *E. apiculata*, which is confined to Peninsular Malaysia and Sumatra.

Uses Where *E. apiculata* and *E. longifolia* occur sympatrically, the uses are the same for both, and no actual distinction is made. The roots, in particular the bark, are used as a febrifuge, and also as a tonic after childbirth. In Malaysia pounded roots are applied externally as a poultice to treat headache, and also on wounds, ulcers and syphilitic sores. A decoction of the leaves is also sometimes used as a febrifuge. An infusion of the root bark of *E. longifolia* is used to treat stomachache and fever by the Kenyah Dayak in Borneo. In Kalimantan, Banjarese men drink a decoction of the root as an aphrodisiac, in peninsular Thailand it is used as a traditional remedy against malaria. 'Babi kurus' is the vernacular name used in Java for the imported drug.

In Vietnam *E. longifolia* is reputed to cure a variety of diseases ('c[aa]y b[as] b[eej]nh' means the plant for hundred diseases). The bark is prescribed against indigestion, fever and lumbago, the fruits against dysentery. A decoction of the leaves is used as a wash to treat itch. In Cambodia, the root is employed as a vermifuge and as an antidote for intoxication, including drunkenness. A large enough dose of the bitter constituents will provoke vomiting, thereby acting as an antidote for poisoning. Furthermore, roots are used against malaria, as an antipyretic, anti-inflammatory and diaphoretic. The fruits are used against dysentery.

Production and international trade No statistics are available on the production and trade of *Eurycoma*. Some interinsular trade seems to exist.

Properties Antimalarial activities have been reported from *Eurycoma*. A semi-purified extract of the powdered root (mainly consisting of the quassinoids 13β,18-dihydroeurycomanol, eurycomanol-2-O-β-glucopyranoside, eurycomanol and eurycomanone) was evaluated in vitro using 6 chloroquine-resistant *Plasmodium falciparum* isolates. Results indicated complete inhibitions at 1.25–5 μg/ml extract after 3 days post-treatment, and at 0.62 μg/ml and 0.31 μg/ml after 4 and 6 days post-treatment, respectively. Subsequently, the purified compounds performed well in an in vitro test with 9 *Plasmodium falciparum* isolates from patients infected with chloroquine-resistant malaria. Eurycomanol, eurycomanol-2-O-β-glucopyranoside and 13β,18-dihydroeurycomanol possessed antimalarial activities with IC_{50} values of 1.231–4.899 μM, 0.389–3.498 μM and 0.504–2.343 μM, respectively, compared with 0.323–0.774 μM for chloroquine. Furthermore, the quassinoids eurycomanone, eurycomalactone, 6-hydroxy-5,6-dehydroeurycomalactone and 7-methoxy-β-carboline-1-propionic acid (a β-carboline alkaloid), all isolated from the roots, also demonstrated significant antimalarial activity in vitro.

In general, several constituents isolated from *E. longifolia* possess cytotoxic activity. Quassinoids (eurycomalactone, 6α-hydroxyeurycomalactone, 5,6-dehydroeurycomalactone, longilactone, 14,15β-dihydroxyklaineanone, 11-dehydroklaineanone) and tirucallane-type triterpenes (niloticin, dihydroniloticin, piscidinol, boujotinolone A, 3-episapelin A, melianone, hispidone) isolated from the wood have shown potent cytotoxicity against P388 and KB cell lines in vitro. Cathin-6-one alkaloids (biosynthetically derived from the aminoacid tryptophan) were isolated from the root. 9-Methoxy-canthin-6-one, 9-methoxy-canthin-6-one-N-oxide, 9-hydroxy-canthin-6-one and 9-hydroxy-canthin-

6-one-N-oxide were active against a panel of human and murine cancer cell lines in vitro: breast, colon, fibrosarcoma, lung, melanoma, KB and P388. Though several other cathin-6-one alkaloids (9,10-dimethoxy-, 10-hydroxy-9-methoxy-, 11-hydroxy-10-methoxy- and 5,9-dihydroxy-cathin-6-one and 9-methoxy-3-methyl-cathin-5,6-dione) are known to be present in the wood and bark, their cytotoxic effects have not been evaluated. Finally, the quassinoid eurycomanone is active against the cell lines mentioned above (except for P388) but, in addition, has significant activity against the KB-V1 (a cell line derived from KB that is resistant to several drugs).

A bioassay study of the trunk root without the root bark of *E. longifolia* led to the isolation of four quassinoids pasakbumin-A, -B, -C and -D. Both pasakbumin A (= eurycomanone) and pasakbumin B exhibited potent anti-ulcer activity on stomach ulcers in vivo in the rat, induced by indomethacin as well as by stress.

The effects of *E. longifolia* were studied in male rats. Doses of 200–800 mg/kg body weight twice daily for 10 days prior to the test intensified the orientation activities towards receptive females, supporting the aphrodisiac property of the plant.

Adulterations and substitutes *Strychnos* species are used for the same purpose as *Eurycoma*; they are also called 'bidara laut' in Indonesia.

Description Small trees or rarely shrubs up to 10 m tall, monoecious or dioecious, branches rather thick with large leaf scars. Leaves alternate, imparipinnate, usually multijugate, crowded at the tip of the branches; leaflets opposite or subopposite, slightly oblique, ovate-lanceolate to obovate-lanceolate, (nearly) sessile, with a conspicuous articulation at base, midrib slightly prominent on the upper surface, prominent beneath, secondary veins straight, ending in an intramarginal looped vein. Inflorescence an axillary panicle, mostly large and lax, puberulous. Flowers bisexual or unisexual, male flower always with a sterile pistil, female flower always with rather large but sterile stamens; calyx small, 5(–6)-lobed, lobes ovate to triangular, acute or blunt, longer than the tube; petals 5(–6), induplicate-valvate in bud, lanceolate or ovate to ovate-oblong; stamens 5(–6), alternating with petals, filaments narrowing to the top, alternating with 5(–6) small, entire, emarginate or cleft staminodes, sometimes a second row of staminodes present, stamens and staminodes sometimes connate with the petals; disk inconspicuous; carpels 5(–6), free, styles attached adaxially near the top and mutually connate or coherent, stigma peltate, 5(–6)-lobed, 1 ovule per carpel. Fruit consisting of up to 5 ellipsoid or ovoid drupes on a stalk of about 3 mm, with very thin exocarp, fleshy mesocarp and hard endocarp. Seeds exalbuminous, with 2 planoconvex cotyledons and a short plumule.

Growth and development *Eurycoma* can be found flowering and fruiting all year round, sometimes at an early age. Pollination is probably by insects, and the fleshy fruits are probably dispersed by birds.

Other botanical information *Eurycoma* is closely related to *Quassia*, another *Simaroubaceae* genus, containing similar bitter principles and also used medicinally in South-East Asia. *Eurycoma* is most often encountered as an unbranched treelet with an umbrella-like rosette of leaves. However, larger specimens with upright branches (see habit drawing) are also found but appear to be increasingly scarce in easily accessible areas.

Ecology *Eurycoma* is a common understorey plant occurring from beach forest to lower montane forest. *E. longifolia* rarely occurs up to 1000 m altitude; *E. apiculata* occurs from sea-level to about 1200 m altitude, being more common at higher elevations. *E. longifolia* shows a preference for acidic, leached, well-drained soils. Both *Eurycoma* species can be found in primary and secondary vegetation.

Propagation and planting It is assumed that *Eurycoma* can be propagated by seed.

In vitro production of active compounds Stem sections of *E. longifolia* cultured in Murashige and Skoog medium gave highest callus production when supplemented with 2.0 mg/l naphthalene acetic acid and 0.1 mg/l benzyladenine. Optimum growth of callus was obtained on medium with pH 6.0, adjusted before autoclaving. Cultures grown at 35°C produced the highest amount of biomass. At this temperature, light intensity of 610 lux was adequate and gave the highest callus yield. Callus growth was best at a photoperiod of 24 hours. The callus produced was yellowish, soft and loose. Successful production of plant biomass is the first necessary step towards the establishment of cell cultures for the in vitro production of secondary metabolites.

Husbandry In general, *Eurycoma* spp. are collected from the wild or seedlings are transplanted from the forest to the home garden.

Harvesting The small *Eurycoma* trees are usually simply uprooted, and the roots are collected and traded. Collecting only bark or leaves involves slightly less destructive harvesting methods.

Handling after harvest After harvesting, the roots, bark and leaves of *Eurycoma* are simply sold in the market. In the Kerayan area in East Kalimantan, the roots are sometimes modelled into cups and filled with water. After some time the water has taken up bitter constituents, and is drunk as a tonic.

Genetic resources and breeding There are no known germplasm collections of *Eurycoma*. As *Eurycoma* species occur in both primary and secondary forest and are in general common in their areas of distribution, the risk of genetic erosion seems limited. However, as collecting is primarily from the wild and the plants are often destroyed during collection, overexploitation can become a serious risk, especially in easily accessible areas.

Prospects The demonstrated antimalarial properties of *Eurycoma* against chloroquine-resistant *Plasmodium falciparum* strains deserves further attention. Given the increasing problem of the resistance to antimalarial agents, the development of alternative medicaments is of great importance to keep malaria under control. The crude extract of *Eurycoma* should be used with caution because of its toxic effect. Further research on the cytotoxic and anti-ulcer effects of isolated compounds seems desirable as well.

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Selection of species

Eurycoma apiculata A.W. Bennett

Hook. f., Fl. Brit. India 1: 522 (1875).

Distribution Peninsular Malaysia and Sumatra.

Uses The most common application of *E. apiculata* is as a decoction of the roots as a febrifuge.

Observations A small tree up to 5 m tall; leaves up to 40 cm long, leaflets 8–14 cm × 2–4 cm, usually rather abruptly blunt-acuminate; petals linear, rarely lanceolate, 4–9 mm × 1–1.5 mm, puberulous, with glandular hairs outside, glabrous inside, styles very short, stigma 5-lobed; fruit 10–17(–20) mm × 5–12 mm. *E. apiculata* is common in the understorey of primary and secondary forest.

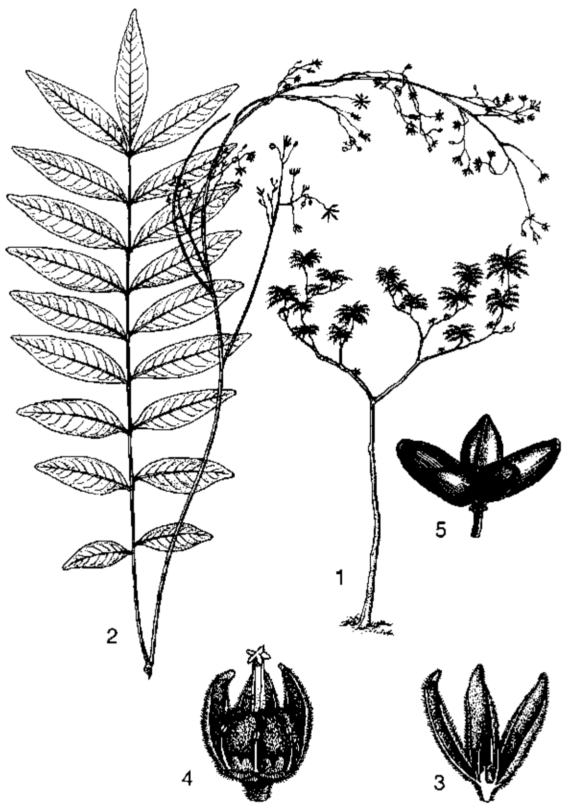
Selected sources 202, 1052.

Eurycoma longifolia Jack

Mal. Misc. 2: 45 (1822).

Distribution Southern Burma (Myanmar), Indo-China (Cambodia, Laos and Vietnam), Thailand, Peninsular Malaysia, Sumatra, Borneo and the Philippines (subsp. *eglandulosa* (Merr.) Nooteboom only).

Uses A decoction of the root is a well-known febrifuge. A poultice of the pounded root is used on wounds, ulcers and sores. The bitter constituents of the roots will in a large enough dose provoke vomiting and are employed as such. In Brunei, a decoction of the root is drunk to relieve gastric pains, reduce high blood pressure and fever. The bark is used as a blood coagulant in complications during childbirth. Also in Brunei, the leaves are reportedly eaten raw to relieve stomach-ache. Furthermore, the roots are locally popular as an aphrodisiac.



Eurycoma longifolia Jack – 1, tree habit; 2, detached leaf and inflorescence; 3, male flower in section; 4, female flower with 2 petals removed; 5, fruit.

Observations A spindly unbranched androdioecious tree or shrub up to 10 m tall, or with a few upright branches, each crowned by an umbrella-like rosette of leaves; leaves up to 100 cm long, leaflets lanceolate to obovate-lanceolate, 5–20 cm × 1.5–6 cm; petals lanceolate to ovate or obovate-oblong, 4.5–5.5 mm × 2–3 mm, puberulous on both surfaces, styles rather long with a peltate 5(–6)-lobed stigma, elevated about 1 mm above the carpels; fruit 10–17(–20) mm × 5–12 mm. *E. longifolia* is common in the understorey of primary and secondary forest on a wide range of soils and is locally abundant.

Selected sources 68, 69, 70, 202, 228, 284, 350, 822, 829, 1035, 1052, 1126, 1287, 1383, 1509.

Tahan Uji

Fatoua villosa (Thunb. ex Murray) Nakai

Bot. Mag. Tokyo 41: 516 (1927).
MORACEAE
$n = 13$

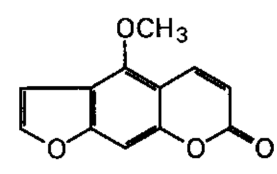
Synonyms *Fatoua pilosa* Gaudich. (1826), *Fatoua japonica* (Thunb. ex Murray) Blume (1856).

Vernacular names Indonesia: akar kuning (Malay, Timor), ranggitan (Javanese), utu guraci (Ternate). Philippines: sikir (general), malbasdamo (Tagalog), sarungkar-a-babassit (Iloko). Vietnam: d[aa]u b[is]ch, du[oos]i c[or].

Origin and geographic distribution *Fatoua* comprises 2 species, one endemic to Madagascar, the other distributed from eastern Asia to Australia. *F. villosa* occurs from Japan and China to Vietnam, Taiwan, the Philippines, Sulawesi, Java, the Lesser Sunda Islands, the Moluccas, New Guinea, the Solomon Islands, New Caledonia and northern Australia. It has escaped from cultivation and naturalized in the United States, where it is likely to become a weed.

Uses In Indonesia, the ground yellow roots of *F. villosa*, known as 'greges otot', used to be smeared on the legs of children with weak legs. In the Philippines, a decoction of the roots is given against fevers and is effective for swollen gums when used as a gargle. An infusion of the roots is prescribed for irregular menstruation and as a diuretic. In Taiwan, the chewed leaf is considered a remedy against stomach-ache. In Indo-China, the crushed and roasted roots are used to prepare a depurative medicine for women after childbirth.

Properties The methanol root extract of *F. villosa* has been found to contain phototoxins that possess a UV-A light (λ 320–380 nm) activated anti-microbial activity using *Escherichia coli* (ATCC 12407) as test organism. Subsequent high pressure liquid chromatography analysis revealed that the compound responsible was 5-methoxypsoralen (5-MOP or bergapten). 5-Methoxypsoralen belongs to the linear (or 6,7-) furanocoumarins, compounds which are known to have phototoxic activity. The isomeric angular (or 7,8-) furanocoumarins, however, appear to be inactive in



5-methoxypsoralen (bergapten)

this respect. Dermatosis may arise after plants containing linear furanocoumarins come into direct contact with the skin, if this is immediately followed by exposure to UV-A light, e.g. from the sun. The mechanism of photosensitization by linear furanocoumarins is based on interference with DNA base pairs. Energy provided by UV-A irradiation leads to the formation of additional products between the furanocoumarin and cytosine and thymine bases. This bridge-building inhibits the replication and transcription of DNA and, consequently, the synthesis of RNA and proteins and the occurrence of cell division.
Due to this mechanism of DNA synthesis inhibition, psoralens like 5- and 8-methoxypsoralen and the synthetical 4,5',8-trimethylpsoralen are used in therapy for the treatment of psoriasis. Psoriasis is a non-infectious skin disease, characterized by an abnormal production of the outermost layer of the skin, which forms scales and peels off, often in large amounts. Therapy might consist of application of psoralens orally or locally, followed by irradiation with UV-A light.

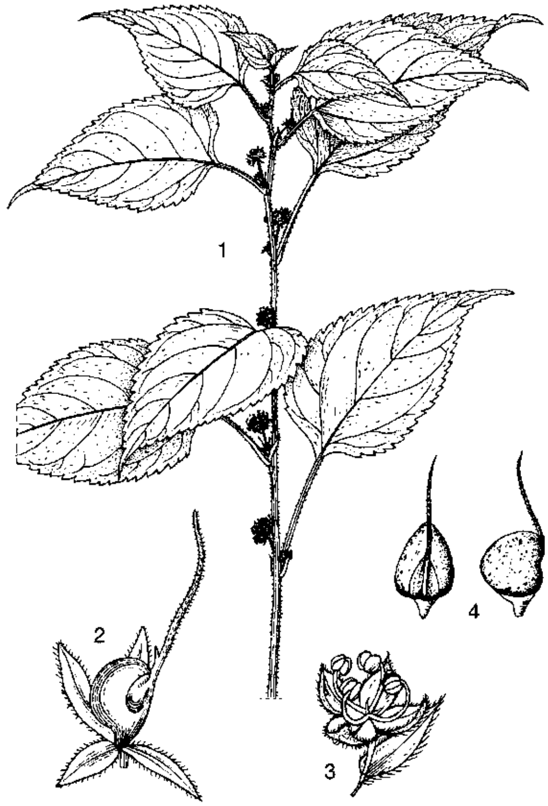
Description A monoecious, annual or perennial, ascending or erect, often half-woody herb up to 100 cm tall, without latex; stem with hooked hairs. Leaves alternate, simple, ovate to broadly ovate, 4–11 cm × 2–6 cm, cordate to cuneate at base, acute to acuminate at apex, margin dentate, hirsute, long-petioled; stipules free, lateral. Inflorescence an axillary, peduncled, bisexual, capitate cyme. Flowers unisexual, small, green, with valvate tepals; male flowers with 3–4 tepals, fused up to halfway, stamens 3–4, incurved in bud but exserted when mature, pistillode minute; female flowers sessile with 4 tepals, free or fused at base, ovary superior, 1-locular with a single ovule, style lateral, filiform. Fruit a warty, achene-like drupe, asymmetrically globular to ovoid, enclosed by the enlarged but not fleshy perianth. Seed with endosperm.

Growth and development Female flowers of *F. villosa* predominate in inflorescences positioned in the lower and middle parts of the stem, male ones in those of the upper parts.

Other botanical information Recently, some authors have recognized *F. villosa* and *F. pilosa* as distinct species, but it is doubtful whether this distinction is valid.

Ecology *F. villosa* occurs in dry thickets, grassy places, on walls, stony sites and cliffs at 0–1200 m altitude. It may form a carpet in light secondary forest.

Genetic resources and breeding *F. villosa* is common in its area of distribution and is found in various anthropogenic habitats. The risk of genetic erosion appears to be limited, in view of its rather weedy nature.



Fatoua villosa (Thunb. ex Murray) Nakai – 1, flowering stem; 2, female flower; 3, male flower; 4, fruits with perianth removed.

Prospects The furanocoumarins present in the roots of *F. villosa* merit further research on its potential as a local or industrial source of psoralens for application in the treatment of psoriasis.

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Other selected sources 190, 280, 478, 767, 1128.

M.S.M. Sosef & S.F.A.J. Horsten

Ficus L.

Sp. pl. 2: 1059 (1753); Gen. pl. ed. 5: 482 (1754).
MORACEAE
$x = 13$; $2n = 26$ for the vast majority of species (e.g. *F. hispida*, *F. religiosa*), $2n = 52$ for few species

Major species *Ficus benghalensis* L., *F. hispida* L.f., *F. religiosa* L., *F. rumphii* Blume, *F. septica* Burm.f.

Vernacular names Ficus, fig (En). Figue (Fr). Indonesia: ara, bunut, karet. Malaysia: ara, ara kelumpong (stem figs), ara tanah (geocarpic figs), nunok (strangling figs, Dusun, Sarawak), giwit (geocarpic figs, Dusun, Sarawak). Philippines: balete (Filipino). Burma (Myanmar): nyaung. Laos: hai. Thailand: sai. Vietnam: chi da, d[eef], sung.

Origin and geographic distribution *Ficus* comprises about 1000 species and occurs in all tropical and subtropical regions, with a few species in warm temperate areas. About half of the species occur in Malesia, which forms the main centre of speciation.

Uses The latex of many *Ficus* species is used medicinally, mainly to cover and cure wounds, boils and sores, but also as an antirheumatic, and it is swallowed to cure coughs and colds and to treat diarrhoea. The bark of many species has astringent properties. In India, the dried bark of *F. benghalensis* and *F. religiosa* is used as an antidiabetic.

Several of the medicinally used *Ficus* species yield useful timber, used for e.g. temporary construction, interior work, concrete formwork, small domestic articles, fruit crates, low grade plywood, and firewood. The fruits of some species are edible but are generally not sought after or prized. Some *Ficus* species have poisonous fruits. The latex has been used as a wax in dyeing batik cloth. The latex is also used as birdlime and in Papua New Guinea for sealing leaks in canoes, whereas that of some species is highly toxic and applied as dart poison. The tough and fibrous bark of a few species is a well-known raw material for rough cordage and matting and formerly for clothing; it is still used for bow strings and fish nets. Young leaves of several species are eaten raw in salads or cooked with meat wrapped in them; the latter dish is considered a delicacy in the highlands of New Guinea. They have also been used as fodder, and leaves of other species are applied as sandpaper or to scour cooking pots. Several *Ficus* species are well-known for their ornamental value, planted as wayside trees or even grown commercially as pot plants in temperate regions.

F. benjamina L., *F. elastica* Roxb. ex Hornem., *F. minahassae* (Teysm. & de Vriese) Miq., *F. racemosa* L. and *F. retusa* L.f. are also used medicinally but have other primary uses.

Properties Bark extracts of various *Ficus* species (*F. benghalensis*, *F. racemosa*, *F. religiosa*, *F. rumphii*) display hypoglycaemic effects, which are probably mainly related to the presence of β-sitosterol and its related compounds. A bark extract of *F. benghalensis* showed in vitro hypoglycaemic activity (the lowering of blood glucose) in both normoglycaemic and moderately diabetic (streptozotocin-induced) rats after oral administration. The extract also enhanced serum insulin levels in both groups of animals. Furthermore, incubating of isolated islets of Langerhans from normal and diabetic animals with the extract stimulated insulin secretion, and reduced the insulinase activity of liver and kidneys. The alcohol extract of *F. racemosa* also showed hypoglycaemic effects in rats.

The stem bark of *F. benghalensis* contains β-sitosterol and its glucoside β-sitosterol-D-glucoside. Both compounds have also been isolated from other species: the former from *F. rumphii* and the latter from the bark of *F. religiosa*. Stigmasterol and β-sitosterol (both sterols) and lupeol (a related triterpene) have been isolated from the petroleum ether extract of trunk bark of *F. religiosa*. β-Sitosterol-D-glucoside produced a hypoglycaemic effect in rabbits, which compared favourably with tolbutamide as a positive control. Although the aglycone β-sitosterol is also active, the glucoside is more potent, probably because of its better water solubility and adsorption.

Also of interest besides the sterols are the flavonoids coumarin and related compounds isolated from *Ficus* species. A dimethoxy derivative of leucocyanidin-3-O-β-galactosyl-cellobioside, isolated from the bark of *F. benghalensis* and administered orally (250 mg/kg) decreased blood glucose levels significantly in normal and moderately diabetic (alloxan-induced) rats, and increased serum insulin significantly in the latter group. Furthermore, during one month treatment of the diabetic rats orally (100 mg/kg), a significant decrease in blood and urine sugar was found, as compared with the diabetic controls. A dimethoxy ether of leucopelargonidin-3-O-α-L-rhamnoside (from the bark of *F. benghalensis*) has also been tested for antidiabetic effects. A medium effective dose (100 mg/kg) administered orally to normal and moderately diabetic (alloxan-induced) dogs, significantly reduced blood glucose and raised serum insulin. Acute and chronic administration in single doses of 0.2–1.8 g/kg to mice, and daily administration of 100–500 mg/kg to rats for a period of one month did not produce observable toxic effects. The antidiabetic effects e.g. low blood glucose levels, glucose tolerance and urinary sugars, were also found in normal and in moderately diabetic rats compared to glibenclamide as a positive control. Finally, in vitro studies showed that insulin secretion by pancreatic β-cells was greater in the presence of the leucopelargonidin derivative than in the presence of the leucocyanidin derivative.

An alcohol extract of the bark of *F. religiosa* showed parasympatholytic effects and a protective action against acetylcholine and histamine-induced asthma in guinea-pigs. The extract also showed antiprotozoal, protease inhibitor and antiviral activity. Antiprotozoal activity is furthermore reported from the alcohol extract of *F. racemosa*.

A methanolic extract of the leaves of *F. septica* displayed intense antibacterial and antifungal activities. This activity is probably related to the presence of 2 indolizidine alkaloids, ficuseptine (4,6-bis-(4-methoxyphenyl)-1,2,3-trihydroindolizidinium chloride) and antofine. A leaf extract of *F. religiosa* showed antifungal properties against *Diplodia natalensis*, the agent of stem-end rot of mango fruits. Fruit extracts of *F. benjamina*, *F. benghalensis* and *F. religiosa* also had significant antibacterial activity, but no antifungal activity. Furthermore, the extracts of *F. benghalensis* and *F. religiosa* demonstrated activity in the brine shrimp assay (*Artemia salina*) which indicates toxicity, whereas *F. benjamina* showed no activity. All the fruit extracts exhibited antitumour activity in the potato disk bioassay, and none of the tested extracts showed any marked inhibition on the uptake of calcium into rat pituitary cells (GH-4C-1). A water extract of dried fruits of *F. benghalensis* exhibited anti-HIV activity.

The anthelmintic properties of several *Ficus* species (e.g. *F. pumila*) can be ascribed to the proteolytic enzyme ficin present in the latex. Excessive amounts of this substance are toxic to humans when administered orally or intravenously. Furthermore, ficin, whether fresh or dry, is highly irritant to the skin and eyes.

Seed extracts of *F. deltoidea* have been observed to agglutinate human erythrocytes (A, B, AB, 0), and some strains of bacteria including *Chlamydia trachomatis*, a significant pathogen. Seed extracts of *F. racemosa* have been found to agglutinate white blood cells from patients with different types of leukaemia.

The popular pot plant *F. benjamina* may give rise to allergic reactions, e.g. conjunctivitis, rhinitis. Sensitization is believed to occur by inhalation of allergen-enriched dust emanating from the leaves.

Phytochemical investigations of a petroleum ether extract from dried *F. hispida* bark yielded the acetates of n-triacontanol, β-amyrin and gluanol, whereas the leaves contain bergapten, psoralen (two furanocoumarins, which might give rise to phototoxicity), β-amyrin and β-sitosterol. The leaves of *F. pachyrrachis* contain 2 tetrahydrobenzylisoquinoline alkaloids, (−)-reticuline and (+)-norreticuline.

Description Evergreen or sometimes deciduous, woody epiphytic climbers or stranglers, creepers, shrubs or small to large trees up to 40(–50) m tall, or banyans, i.e. trees whose branches send down aerial roots that thicken ('pillar roots') and function as props; bole fairly straight in tree-like species, sometimes fluted, up to 100(–190) cm in diameter, sometimes heavily buttressed; bark surface smooth, often pale grey, sometimes whitish or brown, sometimes lenticellate, inner bark yellowish, exuding white or yellow latex. Leaves arranged spirally, alternate or opposite, simple to palmately lobed, symmetrical to asymmetrical, dentate to entire, often with glands below in the axil of the lateral or basal veins or abaxial at the apex of the petiole; stipules free or connate. Inflorescence axillary or ramiflorous to cauliflorous, sometimes subterranean, solitary or clustered, monoecious or gynodioecious, with the flowers set inside an urn-shaped receptacle (syconium; a fig). Flowers unisexual; tepals 2–8, free or joined; stamens 1–7; ovary unilocular with a single ovule, style single. Infructescence a subfleshy fig; individual fruit a drupelet. Seedling with epigeal germination; cotyledons emergent; hypocotyl elongated; all leaves arranged spirally.

Growth and development The strangling figs start as epiphytic plants and send down aerial roots that eventually form a false trunk composed of a trellis-work of interlacing and anastomosing roots around the trunk of the support tree. The roots of *F. religiosa,* however, penetrate inside the support trunk, eventually splitting it from within. Many species have more than one kind of leaf (heterophylly).

The symbiotic relation of figs with specialized wasps is well-known. Figs can only be pollinated by female agaonid wasps (*Hymenoptera, Chalcidoidae, Agaonidae*). The wasp species are highly species-specific. Fig species are divided into 2 groups: monoecious species and gynodioecious ones. In the former the wasps arrive when only female flowers are receptive. They enter the fig via the osteole, a bract-covered apical pore. Once inside, they pollinate the female flowers and deposit their eggs in the ovaries. As style length varies greatly within these figs and because the wasp can only reach the ovary of short-styled flowers, only some of the flowers obtain an egg, while in others the seed develops. Male and female wasps emerge after a few weeks, and mating takes place within the fig. The females then emerge from the fig and, in so doing, pick up pollen from the newly mature anthers. On a single tree figs mature at the same time, while different trees of the same species flower out of synchrony, thus inducing cross-pollination. The gynodioecious fig species either bear hermaphrodite figs or figs with female flowers only. In hermaphrodite figs the styles are uniformly short. Wasps can oviposit every female flower and such trees rear the pollinators' offspring and function as pollen donors. All the flowers of female-flowered figs have long styles. The wasps can only deposit pollen, so such figs produce large amounts of seed.

During daytime the figs are eaten by birds (e.g. pigeons, hornbills, bulbuls, cassowaries), monkeys and squirrels. At night they are visited by bats and civet cats. Cauliflorous figs are eaten by deer and pigs. The latter also uproot the geocarpic figs. Even elephants, rhinoceros, tapir and wild cattle have been reported to feed on figs. As fig fruits are often available year-round, they constitute an extremely important forest food, a so-called keystone resource that sustains frugivorous animals at the famine period of the year when few species, if any, are fruiting.

Other botanical information In Asia and Australia the large genus *Ficus* has been subdivided into 4 subgenera, 14 sections and numerous smaller taxonomic groups.

Ecology *Ficus* species are common and form an important element of lowland rain forest, both as canopy and understorey trees. Most species prefer per-humid forest, but several are found in areas with a monsoon climate and in teak forest, including locations where the soil dries out. *Ficus* does not occur in mangrove vegetation but is often present in brackish swamps behind the mangrove. *Ficus* species are generally found below 1500 m altitude, some between 1500 and 2750 m or rarely up to 3200 m. Many are epiphytic and/or strangling.

Propagation and planting *Ficus* can be propagated from seed and vegetatively. Per kg there are about 2.1–2.5 million seeds of *F. benghalensis.* The drupelets are usually the unit of sowing. These cannot be stored without a serious decrease in viability. A 50% germination rate is achieved in 27–37 days in *F. deltoidea* and in 18–34 days in *F. microcarpa*. In India, pretreatment with hot water of 60°C for 10 minutes was found to increase the germination rate from 20% to 24% in *F. benghalensis* and from 19% to 28% in *F. racemosa*. The tiny seedlings are pricked out twice, first in clumps and later individually. The young seedlings are sensitive to excess of water. Both large and small cuttings are used in vegetative propagation, but small cuttings are less successful. Tissue culture and air layering can also be used for propagation of *Ficus*. Some species, e.g. *F. hispida*, easily regenerate naturally in abandoned fields.

Yield Information on yield of *Ficus* is rather scarce. Petrol and methanol extraction yielded a residue of 85 g from 1.7 kg powdered leaves of *F. septica*. Complete isolation yielded 500 mg of ficuseptine and 130 mg of antofine.

Handling after harvest The bark, roots or leaves of *Ficus* can be applied fresh or dried. The fresh products are used or sold shortly after harvesting. When dried in shade or sunlight the products can be stored for longer periods.

Genetic resources and breeding With the exception of some species that are widely planted (these include *F. benghalensis* and *F. benjamina*) there are no records of ex situ conservation of *Ficus*. Some of them have a high ritual or ornamental value and have been translocated within South-East Asia or even on a worldwide scale. As most *Ficus* species are fairly common and widespread, the risk of genetic erosion seems comparatively low. Breeding efforts are restricted to species with ornamental value, of commercial importance.

Prospects Some *Ficus* species are well-known medicinal plants which have been successfully used in the treatment of common illnesses. The promotion of traditionally used plant resources that are widely available or can easily be grown deserves attention from government extension workers, especially in rural areas. Ficin as found in the latex of *F. pumila* can be used for its anti-inflammatory properties. Its proteolytic activity makes it a potential meat tenderizer in industrial applications.

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Selection of species

Ficus adenosperma Miq.

Ann. Mus. Bot. Lugd.-Bat. 3: 233 (1867).

Synonyms *Ficus pauper* King (1888), *Ficus turbinata* Ridley (1916).

Vernacular names Indonesia: fangkis (Maibrat, Irian Jaya), nusu, tintinalino (Sulawesi). Papua New Guinea: simpa (Kabiufa, Eastern Highlands).

Distribution Sulawesi, the Moluccas, New Guinea, east to the Solomon Islands and Vanuatu, south to northern Australia.

Uses In Papua New Guinea, the latex from the leaves is applied to sores and scabies; fresh roots are chewed to treat malaria. The timber, which is of poor quality, has been used for house building.

Observations A small to medium-sized tree up to 20 m tall; leaves alternate, narrowly ovate to ovate or elliptical, 5–18 cm × 3–7.5 cm, base cuneate to subcordate, apex short acuminate to attenuate, margin entire, appressed hairy below when young, with 8–10 pairs of lateral veins, stipules 1–3 cm long; figs globose to pyriform, 1–1.8 cm in diameter, smooth to pustular, on a peduncle up to 1 cm long; male flowers in 1 row, with 4–5 tepals and 1 stamen, female flowers sessile, with 3–4 tepals. *F. adenosperma* is found in primary and secondary forest, up to 2500 m altitude, chiefly near rivers, often developing thickets on sandbanks and islands.

Selected sources 167, 248, 281, 597, 607, 1104.

Ficus ampelas Burm.f.

Fl. ind.: 226 (1768).

Synonyms *Ficus soronensis* King (1887), *Ficus kingiana* Hemsley (1897), *Ficus blepharosepala* Warb. (1905).

Vernacular names Indonesia: hampelas (Sundanese), rempelas (Javanese), pila (Moluccas). Philippines: upling-gubat (Tagalog).

Distribution From the Ryukyu Islands and Taiwan to the Philippines, Sumatra, Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and

New Guinea including New Britain; possibly also in Borneo.

Uses The latex is taken internally to treat diarrhoea. In Indonesia it is used as a diuretic. In New Ireland, the latex of young leaves, mixed with water, is given to babies with mouth sores. The fruits are eaten raw or cooked. The leaves have been used for sandpapering.

Observations An evergreen, small to medium-sized tree up to 15(–20) m tall, bark smooth, greyish to brown; leaves distichous, narrowly elliptical, 4–15 cm × 1.5–5 cm, base cuneate, apex acute or acuminate, margin entire, with 3–6 pairs of lateral veins, scabrid, stipules up to 8 mm long; figs axillary and clustered on twigs, stipitate, subglobose, 7–10 mm in diameter, scabridulous, ripening to red or purple; flowers with 3–5 tepals, male flowers sessile, with 1 stamen, female flowers sessile or with a short stipe. *F. ampelas* is common in primary and secondary lowland forest.

Selected sources 202, 281, 580, 606, 856, 1126, 1274, 1384.

Ficus aurantiacea Griffith

Not. pl. asiat. 4: 394 (1854).

Synonyms *Ficus callicarpa* Miq. (1867), *Ficus pomifera* Kurz (1873), *Ficus megacarpa* Merr. (1904).

Vernacular names Indonesia: oyod santenan (Javanese). Malaysia: akar jalar-jalar, akar pala-pala, tengkok biawak hitam (Peninsular). Vietnam: sung cam.

Distribution From Burma (Myanmar), the Nicobar Islands, Indo-China and Taiwan to Thailand and throughout the Malesian region except for New Guinea.

Uses In Sabah, leaf shoots are heated slowly over a fire and applied as a poultice on skin itches. In Peninsular Malaysia, the leaves are used to treat fever and toothache. The fruits are sometimes reported to be poisonous.

Observations A climber; leaves elliptical to obovate, 4.5–12 cm × 3–7.5 cm, base cuneate, apex rounded to slightly pointed, margin entire, with 3–6 pairs of veins and prominent reticulations below, stipules 3–13 mm long; figs cauliflorous, pear-shaped, 50 mm × 30 mm, glabrous or sparsely puberulous, ripening red to black with white spots; male flowers gamophyllous, female flowers with 3–4 tepals. *F. aurantiacea* is found in lowland to montane forest, up to 1700 m altitude, also in villages, coconut plantations and other anthropogenic habitats.

Selected sources 27, 202, 281, 284, 856, 1289.

Ficus baeuerleni King

Journ. Asiat. Soc. Bengal II, 55: 408 (1887).

Synonyms *Ficus mespiloides* King (1888), *Ficus hollrungii* Lauterb. & K. Schumann (1901), *Ficus laurentina* Diels (1935).

Distribution New Guinea, New Britain and the Solomon Islands.

Uses In Papua New Guinea, the latex of the inner bark is drunk to treat diarrhoea or dysentery.

Observations A large climber, stem red when cut, bark thick, corky; leaves elliptical, 10–25 cm × 4.5–10.5 cm, base subcordate to broadly cuneate, apex acuminate, margin entire, with 5–9 pairs of lateral veins, hairy on the veins below, stipules up to 12 mm long; figs axillary, solitary or paired, depressed globose, 23–30 mm in diameter, lanuginose, ripening rose-red. *F. baeuerleni* occurs in lowland forest.

Selected sources 281, 609.

Ficus benghalensis L.

Sp. pl. 2: 1059 (1753).

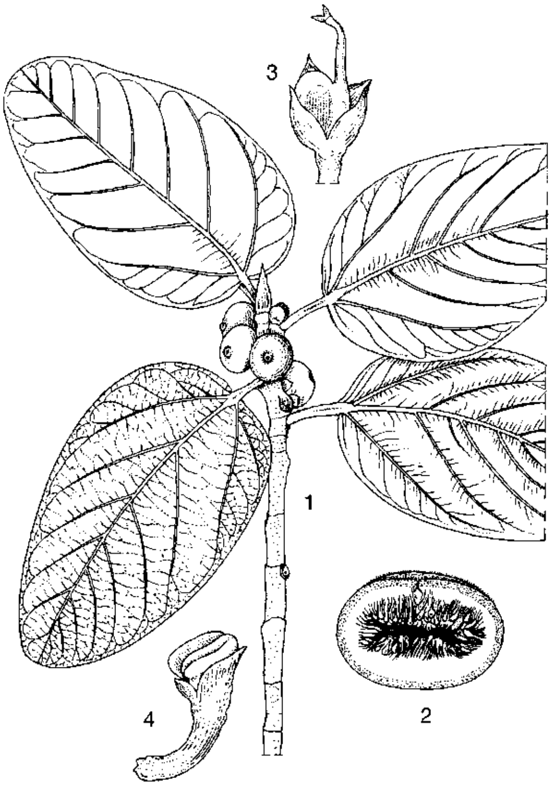
Synonyms *Ficus indica* L. (1753), *Ficus lasiophylla* Link (1822), *Ficus banyana* Oken (1841).

Vernacular names Banyan tree, Indian banyan (En). Indonesia: beringin India. Malaysia: banyan (general), ara tandok, bohdi (Peninsular). Burma (Myanmar): pyi-nyaung. Thailand: krang, ni khrot (central). Vietnam: da l[as] tr[of]n.

Distribution Originally from India and Pakistan but widely planted in Indo-China, Thailand and in the Malesian region and locally naturalized.

Uses The leaves are used to remedy dysentery and diarrhoea, and are applied to abscesses as a poultice to promote suppurations and discharge of pus. In a decoction with toasted rice, the leaves are used as a diaphoretic. The bark is tonic and diuretic, an infusion is antidiabetic and a decoction is used as an astringent in leucorrhoea. A decoction of root fibres is useful against gonorrhoea, whereas the tender ends of aerial roots are used for obstinate vomiting. An infusion of the twigs is good for haemoptysis. The milky latex is used against pains and fever, rheumatism and lumbago, toothache, and applied to cracked and inflamed soles. The concentrated latex plus fruit is aphrodisiac and used to treat spermatorrhoea and gonorrhoea. The fruit is tonic and has a cooling effect.

Observations A deciduous to evergreen, wide-spreading banyan up to 20(–25) m tall, with copious aerial roots, bark surface smooth, grey; leaves arranged spirally, ovate or broadly ovate to ellipti-



Ficus benghalensis L. – 1, fruiting twig; 2, halved fig; 3, female flower; 4, male flower.

cal, 10–30 cm × 7–20 cm, base cordate, apex blunt to rounded, margin entire, with 5–7 pairs of lateral veins, puberulous below, stipules 1.5–2.5 cm long; figs paired, sessile, globose to depressed globose, 15–25 mm in diameter, puberulous, orange to red or pinkish-red when ripe; male flowers many, shortly stipitate, with 2–3 tepals and 1 stamen, female flowers sessile, with 3–4 tepals. *F. benghalensis* occurs in evergreen to deciduous lowland forest.

Selected sources 9, 167, 248, 281, 284, 478, 795, 874, 921, 1115, 1178, 1191, 1289, 1404.

Ficus botryocarpa Miq.

Ann. Mus. Bot. Lugd.-Bat. 3: 233 (1867).

Synonyms *Ficus barnesii* Merr. (1904), *Ficus mindorensis* Merr. (1904), *Ficus linearifolia* Elmer (1907).

Vernacular names Indonesia: bali susuk, delah, tarera intalun (Sulawesi). Papua New Guinea: simbahu (Sui, Northern Province). Philippines: basikong (Manobo, Bagobo), daing-daing (Tagalog).

Distribution The Philippines, Sulawesi, the Moluccas, New Guinea and New Britain.

Uses In Papua New Guinea, the fruit latex is placed on a boil to effect healing. The leaves and fruits are edible.

Observations A small tree up to 14 m tall; leaves distichous or opposite, elliptical, 9–26 cm × 3–11 cm, base cuneate, apex shortly acuminate, margin entire, with 6–10 pairs of lateral veins, sparsely hairy below, stipules 1–2.5 cm long; figs cauliflorous, paired, subglobose, 15–27 mm in diameter, glabrescent, ripening yellowish-white; male flowers with 1 stamen, female flowers sessile or shortly stipitate. *F. botryocarpa* is found in primary and secondary lowland to montane forest, up to 1700 m altitude, often along rivers.

Selected sources 281, 597, 604, 1104.

Ficus calopilina Diels

Bot. Jahrb. Syst. 67: 212 (1935).

Synonyms *Ficus setistyla* Warb. (1905).

Distribution New Guinea.

Uses In Papua New Guinea, the fruit latex is used to cover sores; the sores are subsequently covered by a leaf of the same plant. The figs are edible but tasteless. The bark is used for twine.

Observations A small tree up to 15 m tall; leaves spirally arranged or decussate, elliptical to slightly obovate, 10–36 cm × 5.5–21 cm, base subcordate to subcuneate, apex acuminate, margin entire, with 6–9 pairs of lateral veins, hispid, stipules up to 30 mm long; figs axillary and cauliflorous, subglobose to pyriform, 30–60 mm in diameter, densely hairy but glabrescent, ripening yellow to brown; male flowers in 2–3 rings, with 1(–2) stamens, female flowers sessile or stipitate. *F. calopilina* is locally common in primary or secondary montane forest, at 1000–2400 m altitude, often along streams.

Selected sources 281, 610.

Ficus copiosa Steud.

Nomencl. bot., ed. 2, 1: 635 (1840).

Synonyms *Ficus magnifolia* F. v. Mueller (1863), *Ficus krausseana* Rechinger (1912), *Ficus longipedunculata* Rechinger (1912).

Vernacular names Indonesia: ampelas (Sulawesi), gohi (Halmahera), sosa kecil (Ternate). Papua New Guinea: kagua (Raluana, New Britain).

Distribution Sulawesi, the Moluccas, New Guinea, the Solomon Islands, northern Australia, Vanuatu, the Palau Islands and Yap.

Uses In Papua New Guinea, the unripe fruits are chewed to relieve stomach-ache, and the fruit latex is applied to boils. Fresh leaves are used in the Trobriand Islands as a poison antidote; the roots and leaves are used to treat stomach-ache. In New Britain, massaging the stomach with crushed leaves is said to relieve stomach-ache. Young leaves and figs are eaten raw or cooked. The bark is used for clothing and ropes.

Observations A small to medium-sized tree up to 20 m tall, bole muriculate, bark surface brown; leaves alternate to decussate, ovate to obovate or obpentagonal, 10–35 cm × 5–18 cm, base subcordate to subcuneate, apex acute to acuminate, margin entire, with 6–10 pairs of lateral veins, hairy, stipules 1–2.5 cm long; figs axillary to cauliflorous, slightly depressed-globose, 25–60 mm in diameter; flowers with 4–7 tepals, male flowers with 1–2 stamens, female flowers long-stipitate. *F. copiosa* is found in both coastal and inland regions, in primary and secondary forest, up to 1700 m altitude. It is also grown in villages.

Selected sources 248, 281, 576, 603, 605, 610, 1104.

Ficus dammaropsis Diels

Flora 128: 28, t. 2A, 2B (1933).

Synonyms *Dammaropsis kingiana* Warb. (1891).

Distribution New Guinea.

Uses In New Guinea, a daily drink of stem latex is said to relieve a severe cough. The figs are edible. Young leaves are used for wrapping meat and eaten as a vegetable. The bark fibre is used to make rope.

Observations A small tree up to 10 m tall; leaves arranged spirally, broadly elliptical, to 90 cm × 60 cm, base deeply cordate, apex shortly apiculate, margin sinuate, with 8–10 pairs of lateral veins, puberulous below, stipules 15–30 cm long; figs axillary, solitary, sessile, up to 60 mm in diameter, covered with large bracts; male flowers in many rows, with 2 stamens, female flowers sessile. *F. dammaropsis* occurs in montane forest, at 1000–2300 m altitude, on riverbanks and in clearings.

Selected sources 281, 607, 900, 1104.

Ficus deltoidea Jack

Malayan Misc. 2: 71 (1822).

Synonyms *Ficus diversifolia* Blume (1825), *Ficus lutescens* Desf. (1829), *Ficus motleyana* Miq. (1867).

Vernacular names Rusty-leaved bush fig, mistletoe fig (En). Indonesia: tabat barito (general). Malaysia: ara burong, ara jelateh, ara tanah (Peninsular).

Distribution Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, the Philippines (Palawan) and Sulawesi; introduced in Indo-China, India and Pakistan.

Uses In South Kalimantan, *F. deltoidea* is reported to be an effective remedy against leucorrhoea. As it promotes contraction of the vagina it is also considered an aphrodisiac. The latex may have been applied as fish poison. In Thailand, *F. deltoidea* is used as an ornamental. Various selections are commercially grown as pot plant in temperate regions.

Observations An evergreen epiphyte or small shrub up to 2 m tall; leaves obovate to elliptical or obdeltoid, 2.5–8 cm × 1.3–7.5 cm, base broadly cuneate, apex blunt to truncate or widely notched, rarely pointed, margin entire, white-spotted above, rusty or yellow-olive below, the midrib sometimes forked, stipules 8–12 mm long; figs axillary, solitary or paired, globose to oblong, 5–10 mm in diameter, ripening to orange or red; male flowers dispersed, with 2–3 free tepals and 2 stamens, female flowers sessile to subsessile, with 3–4 tepals. *F. deltoidea* is a variable species divided into many varieties. It is common in lowlands and mountains, up to 3200 m altitude, generally occurring as an epiphyte, but as a terrestrial bush on sandy shores and mountain tops and bogs.

Selected sources 202, 281, 282, 284, 478, 1230, 1289.

Ficus hispida L.f.

Suppl. pl.: 442 (1781).

Synonyms *Ficus letaqui* Lév. & Van. (1910), *Ficus poilanei* Gagnep. (1927).

Vernacular names Rough-leaved stem fig (En). Indonesia: bisoro (Sundanese), luwing (Javanese), mongmong (Sumatra). Malaysia: ara bumbing, ara sinigai, ara seniah (Peninsular). Laos: dua[1] pong[1]. Thailand: duea plong (northern, central, peninsular), duea pong (Bangkok), maduea plong (central). Vietnam: ng[as]i.

Distribution From Sri Lanka and India to Indo-China, southern China, Thailand, the Andaman Islands, Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi, the Lesser Sunda Islands, New Guinea and northern Australia (Queensland).

Uses The immature fruits are considered tonic, galactagogue and emetic. The latex of the leaves is taken internally to treat fever, diarrhoea and to relieve painful urination; the latex of the bark is regarded as an emetic. An extract of the bark is used in the treatment of jaundice, leprosy and anaemia. Boiled leaves are used to poultice boils and ulceration of the nose. The fruits are also eaten in curries, but are, however, likely to cause giddiness. Ripe fruits are made into a jam. The bark yields a rough fibre. The leaves may be used as fodder for cattle. Large cuttings have been used to establish live fences.

Observations An evergreen, small tree up to 15 m tall, bark smooth, grey; leaves often decussate, asymmetrical, pentagonal to oblong, 10–35 cm × 4–20 cm, base subcordate to broadly cuneate, apex acuminate, margin crenulate, with 5–10 pairs of veins and prominent reticulation below, hispid, stipules 1–2.5 cm long; figs on long twigs hanging from the trunk and main branches, obovoid, 25–40 mm in diameter, densely brown pubescent, pale or greenish-yellow when ripe; male flowers in 1–2 rows, with 1 stamen, female flowers sessile or stipitate. *F. hispida* is common in secondary lowland forest in per-humid to monsoon climates.

Selected sources 7, 202, 248, 281, 284, 287, 580, 766, 921, 1380, 1478, 1525, 1564.

Ficus microcarpa L.f.

Suppl. pl.: 442 (1781).

Synonyms *Ficus cairnsii* Warb. (1905), *Ficus retusiformis* Lév. (1910), *Ficus retusa* auct. non L.f.

Vernacular names Chinese banyan, laurel fig, Malayan banyan (En). Indonesia: preh (Javanese). Malaysia: jawi jawi, jejawi (Peninsular). Papua New Guinea: magi (Barakau, Central Province). Philippines: baleteng-liitan (Filipino). Thailand: sai khao (Nakhon Si Thammarat), sai rayong (Nakhon Ratchasima), sai yoi bai thu (central). Vietnam: g[uwf]a.

Distribution From Sri Lanka and India to Indo-China, southern China, the Ryukyu Islands, Thailand, and throughout Malesia towards the Solomon Islands, Australia, the Caroline and Marianas Islands, New Caledonia, the Loyalty Islands and Palau.

Uses The root, bark and leaf latex are used medicinally to treat wounds, headache and toothache. The bark and leaf latex is taken internally to treat colic and liver trouble. In the Admiralty Islands, patients with fever or headache perspire in the steam of boiling young leaves. The trees are often planted for shade and in cemeteries.

Observations An evergreen, small or medium-sized banyan up to 25 m tall, developing numerous slender aerial roots from the branches, bark surface grey; leaves usually alternate, often asymmetrical, elliptical-obovate to elliptical-ovate, 3–12 cm × 1.5–9 cm, base cuneate, apex blunt or slightly pointed, margin entire, with 5–9 pairs of veins, usually glabrous, stipules 1–1.5 cm long; figs monoecious, axillary, paired, sessile, pyriform to subglobose, 8–12 mm in diameter, glabrous, ripening purple to black; male and female flowers sessile, with 3(–4) tepals, male flowers with 1 stamen. *F. microcarpa* grows in widely varying locations, from rocky sea coasts to limestone hills, and from swampy ground near the sea to montane forest.

Selected sources 167, 248, 281, 284, 478, 608, 856, 921, 1274, 1289, 1380.

Ficus nasuta Summerh.

Hooker's Icon. Pl.: t. 3189 (1933).

Distribution New Guinea and the Solomon Islands.

Uses In Papua New Guinea, the bark latex is drunk by patients with asthma or other respiratory problems. Leaves eaten with salt are believed to increase the fertility of women.

Observations A large climber; leaves arranged spirally, ovate to suborbicular, 8–15 cm × 6–13.5 cm, base cordate to rounded, apex shortly acuminate, margin entire, with 4–5(–6) pairs of lateral veins, main veins appressed hairy below; figs axillary, depressed globose to subpyriform, to 35 mm in diameter, minutely brown velutinate, ripening dingy purple; flowers sessile. *F. nasuta* is locally common in lowland to montane forest, up to 1600 m altitude.

Selected sources 281, 609, 611.

Ficus nodosa Teijsm. & Binnend.

Natuurk. Tijdschr. Ned. Ind. 29: 245 (1867).

Synonyms *Ficus du* Lauterb. & K. Schumann (1900).

Vernacular names Indonesia: laura (Moluccas). Papua New Guinea: kem kem (New Ireland).

Distribution The Moluccas, New Guinea, east to the Solomon Islands and south to northern Australia (Queensland).

Uses In New Britain, the leaves are applied externally as a styptic and antiseptic. The fibrous bark is used to make strings and clothing. The leaves and figs are edible.

Observations A medium-sized, buttressed tree up to 30 m tall, bark surface grey to reddish-brown, inner bark fibrous; leaves alternate, broadly ovate, 15–37 cm × 10–30 cm, base rounded to cordate, apex obtuse to acuminate, margin sinuate, with 5–7 pairs of veins, glabrous, stipules silky; figs cauliflorous and ramiflorous, subglobose to subpyriform, 25–40 mm in diameter, densely lenticellate, ripening yellow to purple-brown; flowers with 3–4 laciniate-dentate tepals fused at base, male flowers in 3 rows, sessile, female flowers sessile or shortly stipitate. *F. nodosa* is found in lowland forest.

Selected sources 167, 248, 281, 576, 597, 1104.

Ficus pachyrrachis Lauterb. & K. Schumann

Fl. Schutzgeb. Südsee: 282 (1900).

Synonyms *Ficus grandis* King (1888) non Miq., *Ficus hypoglauca* Lauterb. & K. Schumann (1900), *Ficus pachythyrsa* Diels (1935).

Vernacular names Papua New Guinea: topu (Awala, Northern Province).

Distribution New Guinea.

Uses In Papua New Guinea, the latex is smeared onto an ulcer daily until cured. The leaves are edible, and the fibrous bark of saplings is used to make rope.

Observations A small to medium-sized tree up to 20 m tall; leaves arranged spirally or occasionally opposite, obovate to ovate-elliptical, 20–45 cm × 14–32 cm, base broadly cuneate to subcordate, apex shortly acuminate, margin denticulate, with 5–10 pairs of lateral veins, thinly hairy above, hispidulous velutinate below, stipules 2–4.5 cm long; figs on stout, leafless twigs, pyriform, 25–30 mm in diameter, villous but glabrescent; male flowers in 2–3 rows, subsessile, with 1 stamen, female flowers subsessile to stipitate, with cupular, short perianth. *F. pachyrrachis* is found in lowland to montane forest, up to 1500 m altitude.

Selected sources 281, 604, 723, 1104.

Ficus pachystemon Warb.

K. Schumann & Lauterb., Nachtr. Fl. Schutzgeb. Südsee: 242 (1905).

Synonyms *Ficus mangiferifolia* Lauterb. & K. Schumann (1901) non Griffith, *Ficus brassii* Summerh. (1929) non Sabine, *Ficus aechmophylla* Summerh. (1933).

Vernacular names Papua New Guinea: wawaina (Rabagi, New Britain).

Distribution New Guinea and the Bismarck Archipelago.

Uses In New Britain, leaves are chewed and swallowed to relieve diarrhoea. The bark is used for clothing.

Observations A shrub or small to medium-sized tree up to 20 m tall; leaves arranged spirally to subdigitate, lanceolate to ovate-lanceolate, 9–21 cm × 1.8–6 cm, base cuneate, apex attenuate to subacute, margin entire, with (9–)11–19 pairs of lateral veins, glabrous, stipules 2–5.5 cm long; figs axillary, paired, sessile, subglobose to ellipsoid, 12–16 mm in diameter, glabrous, ripening through white, yellow, pinkish-orange to red; flowers with 3–4 tepals, male flowers dispersed, tepals free, stamen 1, female flowers sessile, tepals fused at base. *F. pachystemon* is found in lowland forest, commonly on river banks and in stony river beds.

Selected sources 281, 603.

Ficus parietalis Blume

Bijdr. fl. Ned. Ind. 9: 462 (1825).

Synonyms *Ficus cerasiformis* Desf. (1829), *Ficus grandifolia* Wallich ex Miq. (1848).

Vernacular names Indonesia: pelas kebo, seprah (Javanese). Malaysia: ara kesinai, ara landang puteh, sepedeh (Peninsular). Thailand: ma hai (Chiang Mai), maduea khon (Nakhon Si Thammarat).

Distribution Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines (Palawan).

Uses A decoction of the roots is used to treat stomach-ache.

Observations A climber or epiphytic shrub; leaves distichous, elliptical to oblong, 9–30 cm × 4–12 cm, base rounded to cuneate, apex long tipped, margin entire, with 2–6 pairs of lateral veins and prominent reticulation below, 3-veined at base, rusty pubescent below, stipules up to 8 mm long; figs solitary or paired, globose, 10 mm in diameter, hispidulous, ripening orange to reddish-brown; flowers with 4 tepals, male flowers with free or shortly connate tepals and 1 stamen, female flowers sessile or stipitate, tepals connate to halfway. *F. parietalis* is common in lowland forest, up to 1000 m altitude, often on riversides.

Selected sources 202, 281, 284, 1289, 1380, 1564.

Ficus pumila L.

Sp. pl. 2: 1060 (1753).

Synomyms *Ficus stipulata* Thunb. (1786), *F. scandens* Lamk (1788), *F. repens* Hort. var. *lutchuensis* Koidz. (1925).

Vernacular names Creeping fig, fig ivy (En). Indonesia: karet rambat. Thailand: madueo thao, lin suea. Vietnam: c[aa]y th[awf]n l[awf]n, c[aa]y x[ooj]p x[ooj]p, bi l[eej].

Distribution Indigenous in Japan, China, the

Ryukyu Islands, Taiwan and northern Indo-China. At present widely cultivated as an ornamental and pot plant in tropical and subtropical regions.

Uses In folk medicine in Vietnam, the fruits and the leaves are considered to be tonic and are used in cases of impotence, lumbago and as a galactagogue. Furthermore, they are considered a treatment for rheumatism, anaemia, haematura, chronic dysentery and haemorrhoids. Externally the leaves are applied to carbuncles. The latex is reported to have anthelmintic properties. In cases of dropsy the plant ash is rubbed on the body. *F. pumila* is widely cultivated to cover walls and rock faces; the colourful figs add further lustre to the attractive green foliage. Various selections are commercially grown as a pot plant in temperate regions.

Observations A prostrate or climbing shrub, reaching up to 10 m or more, creeping and clinging close to walls or tree trunks by means of numerous aerial rootlets, ultimate branches 30–80 cm long, erect; leaves dimorphous, two-ranked, on sterile branches ovate, 1.5–3 cm long and shortly petioled, on fertile branches oblong, 5–10 cm long and with long petioles; figs solitary in the axils of leaves, pyriform, 40–60 mm long, yellow-brown pilose when young, ripening glabrous, red to dark blue; male flowers in many rows, filling the distal half of the fig, stipitate with 2–3 stamens, female flowers sessile or shortly stipitate. *F. pumila* is an increasingly common feature in urban areas.

Selected sources 97, 281, 287, 364, 856, 900, 921, 1035, 1126, 1178, 1289.

Ficus pungens Reinw. ex Blume

Bijdr. fl. Ned. Ind. 9: 478 (1825).

Synonyms *Ficus myriocarpa* Miq. (1867), *Ficus ovalifolia* Ridley (1916), *Ficus kalingaensis* Merr. (1922).

Vernacular names Indonesia: gososo (Ternate). Papua New Guinea: baguai (Harigen, Sepik), wopope (North Solomons Province), ohohone (Sui, Northern province). Philippines: Kalinga fig (En).

Distribution The Philippines, the Moluccas, New Guinea and New Britain.

Uses In Papua New Guinea, the root or leaf latex is swallowed to cure cough quickly. Heated leaves are applied externally to relieve body pains. In some reports the latex is reported to be very poisonous. The leaves are eaten cooked as a vegetable. The bark is used to make mats. The water that flows from a large root that has been cut obliquely can be drunk after boiling.

Observations A small to medium-sized tree up to 25 m tall, sometimes with short stilt roots, bark surface finely fissured, grey-brown; leaves arranged spirally, ovate to broadly ovate, 12–45 cm × 8–36 cm, base subcordate to subcuneate, apex with a short tip, margin serrate to denticulate, with 5–10 pairs of lateral veins, variably scabrid on both surfaces, stipules up to 7 cm long; figs on leafless twigs from the trunk and branches, paired, sessile, pyriform, 4–8 mm in diameter, puberulous but glabrescent, ripening red; flowers with 3–4 free tepals, male flowers in 1 row, sessile, with 1 stamen, female flowers sessile or shortly stipitate. *F. pungens* is locally common in primary and secondary lowland forest, up to 1700 m altitude.

Selected sources 281, 580, 604, 605, 1274, 1356.

Ficus religiosa L.

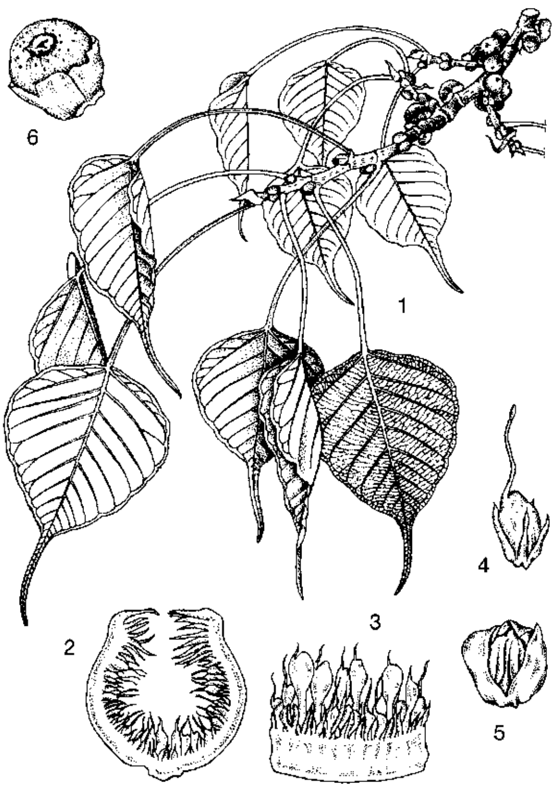
Sp. pl. 2: 1059 (1753).

Synonyms *Ficus caudata* Stokes (1812), *Ficus superstitiosa* Link (1822), *Ficus peepul* Griffith (1854).

Vernacular names Bo tree, bodhi tree, pipal tree (En). Indonesia: bodhi. Cambodia: dom pur. Laos: pho. Thailand: pho see ma haa pho (central), yong (Shan-Mae Hong Son), salee (northern). Vietnam: c[aa]y b[oof] d[eef], c[aa]y da, c[aa]y da b[oof] d[eef].

Distribution Originally from the Himalayas to southern China (Yunnan), Vietnam and northern Thailand; nowadays widely cultivated in the Malesian region but also in e.g. the Middle East, northern Africa and the United States.

Uses A decoction of the bark is used as skin wash to treat scabies, whereas the aerial roots are chewed by women to promote fertility. In India, an infusion of the bark is drunk as an antidiabetic and used externally against ulcers and skin diseases. The leaves and twigs are reputedly used against bites of venomous animals, as an astringent, antigonorrhoeal, laxative, aphrodisiac, and for the treatment of haemoptysis and fistula. Fresh sap from the leaves is used to cure diarrhoea, cholera and for wound healing. In Vietnam, the aerial roots are considered to be diuretic and used in ascites. The leaves and twigs are also applied as fodder. The fibrous bark is used to make paper. The fruits and tender leaf buds are edible though not tasty, and are considered to be cooling, alterative and laxative. The latex can be applied as birdlime. The tree is a host of the lac insect. The low-quality wood may be used for packing



Ficus religiosa L. – 1, fruiting twig; 2, fig in cross section; 3, part of receptacle with flowers; 4, female flower; 5, male flower; 6, infructescence.

cases and matches. The bark contains tannin which may be used to tan leather and for dying cloth. The tree is sacred to Hindus and Buddhists, and the trees which were brought to Sri Lanka in 245 B.C. are the oldest known trees in the world. It is regularly planted as a roadside tree.

Observations An evergreen or deciduous banyan or small to medium-sized tree up to 20 m tall, bark surface fissured, grey; leaves arranged spirally, ovate-cordate to ovate, 6–26 cm × 4–16 cm, base subcordate to truncate, apex caudate, margin often uneven or sinuous, with 6–9 pairs of lateral veins, glabrous, stipules up to 1.5 cm long; figs axillary, paired, sessile, subglobose, 10–15 mm in diameter, glabrous, ripening pink, purple or black; flowers with free tepals, male flowers in 1 row, sessile, with 2–3 tepals, female flowers sessile or stipitate, with 3–4(–5) tepals. *F. religiosa* occurs naturally in submontane forest.

Selected sources 54, 125, 202, 281, 284, 287, 478, 800, 900, 921, 1035, 1115, 1152, 1191, 1289, 1319, 1350, 1478, 1525.

Ficus rumphii Blume

Bijdr. fl. Ned. Ind. 9: 437 (1825).

Synonyms *Ficus cordifolia* Roxb. (1832), *Ficus conciliorum* Oken (1841), *Ficus damit* Gagnep. (1927).

Vernacular names Mock bodh tree (En). Indonesia: ancak (Bali), bandira (Javanese), waringin jawa (Ambon). Thailand: pho khee nok, pho prasaat, pho tua phuu (central). Vietnam: l[aa]m v[oof], da m[is]t.

Distribution India, Cocos Island, the Andaman and Nicobar Islands, Burma (Myanmar), Indo-China, Thailand, Peninsular Malaysia, Java, Sulawesi, the Lesser Sunda Islands and the Moluccas.

Uses The latex and fruits are emetic and anthelmintic, and used to treat itch. The latex is given internally as a vermifuge and for the relief of asthma. The tree is a host of the lac insect, and is also planted as a shade tree. The young leaves and ripe fruits are edible, raw or cooked. The leaves and twigs may be used as fodder for cattle and elephants. The bark yields a rough cordage. In India, the soft wood is used as fuel and for the production of charcoal.

Observations A deciduous, small to medium-sized tree or strangler up to 20 m tall, bole often fluted, bark surface flaky, silvery grey; leaves arranged spirally, ovate to broadly ovate, 7.5–17.5 cm × 5–12.5 cm, base cordate to rounded, apex acuminate, margin entire or wavy, palmately veined at base, with 4–6 pairs of lateral veins, glabrous, stipules 1–2.5 cm long; figs paired, sessile, globose, 10–15 mm in diameter, glabrous, whitish with dark spots, ripening pink or purple, then black; male flowers few, with 2(–3) free tepals and 1 stamen, female flowers sessile or shortly stipitate, with 3 fused tepals. *F. rumphii* is found on rocky coasts and is commonly planted.

Selected sources 202, 281, 284, 287, 478, 580, 900, 1289, 1380, 1564.

Ficus sagittata J. König ex Vahl

Symb. bot. 1: 83 (1790).

Synonyms *Ficus ramentacea* Roxb. (1832), *Ficus crininervia* Miq. (1861), *Ficus ramosii* Merr. ex Sata (1944).

Vernacular names Indonesia: darandan, hampelas telpe (Sundanese), lawean (Javanese). Malaysia: akar beringin, sepedeh (Peninsular). Vietnam: sung d[af]u t[ee]n.

Distribution From north-eastern India (Sikkim, Assam), the Andaman Islands to Burma (Myanmar), Indo-China, southern China, Thailand

and throughout Malesia except for New Guinea, and in the Caroline Islands (Palau group).

Uses The leaves are said to have narcotic properties. *F. sagitata* is sometimes cultivated for its ornamental value.

Observations A large climber; leaves elliptical to ovate, 6–22 cm × 4–11.5 cm, base broadly cuneate to subcordate, apex acute, margin entire, 3-veined at base, main veins sunken above, with 6–8 pairs of lateral veins, glabrous, stipules up to 17 mm long; figs solitary or paired, subglobose, 14–18 mm in diameter, ripening red. *F. sagittata* is common in lowland and montane forest, up to 1500 m altitude.

Selected sources 202, 281, 1289, 1564.

Ficus septica Burm.f.

Fl. ind.: 226 (1768).

Synonyms *Ficus hauili* Blanco (1837), *Ficus casearia* F. v. Mueller ex Benth. (1873), *Ficus kaukauensis* Hayata (1918).

Vernacular names Indonesia: awar-awar (general), ki ciyat (Sundanese), tagalolo (Sulawesi, Ternate). Papua New Guinea: omia (Kurereda, Northern Province), manibwohebwahe (Wagawaga, Milne Bay), bahuerueru (Vanapa, Central Province). Philippines: hauili (Filipino), kauili (Tagalog), sio (Bikol).

Distribution The Ryukyu Islands, Taiwan, throughout Malesia except for Peninsular Malaysia, the Solomon Islands to Vanuatu and northern Australia (Queensland).

Uses In the Moluccas and New Guinea, the roots are chewed as an antidote, the latex of the leaves and fruits is used to produce purging, and the fruits are also emetic. In Papua New Guinea, the leaves are applied to cure colds, coughs, fever and fungal and bacterial diseases, whereas root scrapings or leaves have been mixed with water and drunk to cure dysentery or diarrhoea. The crushed root, mixed with coconut water, is drunk daily to treat urinary tract infections. In the Philippines, the leaves are applied for rheumatism and used as a sudorific to treat headache. The roots are used as a poultice in boils and a decoction is prescribed as diuretic. The latex is used to cure certain varieties of herpes, and wounds caused by poisonous fish. In Java, the dried leaves were formerly used as a substitute for opium or mixed with it.

Observations A small to medium-sized tree up to 25 m tall, bark surface pale grey or white; leaves alternate or decussate, elliptical, ovate or oblong, 10–28 cm × 4–13.5 cm, base cordate to cuneate, apex acuminate, margin entire, with 6–12 pairs of lateral veins, glabrous, stipules 1–4 cm long; figs axillary or cauliflorous, paired, obovoid to depressed subglobose, to 15 mm in diameter, ripening white to yellowish; male flowers with 1 stamen, female flowers with united tepals. *F. septica* is found in secondary rain forest and scrub vegetation on various soil types, up to 1800 m altitude.

Selected sources 137, 140, 202, 248, 281, 430, 580, 597, 603, 604, 606, 856, 1178.

Ficus subcuneata Miq.

Ann. Mus. Bot. Lugd.-Bat. 3: 235 (1867).

Synonyms *Ficus stoechotricha* Diels (1935), *Ficus formosa* Summerh. (1941).

Distribution Sulawesi, the Moluccas, New Guinea and New Britain.

Uses In Papua New Guinea, the latex is applied directly to scabies or a skin rash.

Observations A small to medium-sized tree up to 30 m tall, bark surface greyish-brown to reddish or orange-brown, branches whorled; leaves arranged spirally, obovate, 12–20 cm × 4.5–9 cm, base broadly cuneate to subcordate, apex acuminate, margin entire, with (7–)9–13(–16) pairs of lateral veins, hairy below, stipules up to 22 mm long; figs axillary, solitary or occasionally paired, depressed globose, up to 40 mm in diameter, glabrescent, ripening scarlet; flowers with 4–6 free tepals, male flowers in 1 row, sessile, with 1 stamen, female flowers sessile. *F. subcuneata* is locally common in rain forest, often on riversides, from sea-level up to 1200 m altitude.

Selected sources 167, 281, 611.

Ficus sublimbata Corner

Gard. Bull. Sing. 18: 50 (1960).

Distribution New Guinea.

Uses In Papua New Guinea, the latex from the leaves is applied directly onto a sore.

Observations A small tree up to 10 m tall; leaves arranged spirally to decussate, elliptical to obovate, 10–35 cm × 4–17 cm, base rounded to subcuneate, apex acuminate, margin entire to dentate or denticulate, with 4–8 pairs of lateral veins, scabrid on both sides, stipules 1.5–4 cm long; figs cauliflorous or ramiflorous, paired, slightly depressed globose, 18–25 mm in diameter, hairy but glabrescent, ripening red-brown to purple-red; male flowers in 2 rows, with 1 stamen, female flowers sessile or stipitate, perianth a short collar. *F. sublimbata* is locally common in montane forest and grassland, at 1500–2000 m altitude.

Selected sources 281, 611.

Ficus wassa Roxb.

Fl. ind., Carey ed. 3: 539 (1832).

Synonyms *Ficus eulampra* K. Schumann (1900), *Ficus rhodocarpa* Summerh. (1929), *Ficus nubigena* Diels (1935).

Vernacular names Indonesia: gohi, wassa, wassa laki-laki (Moluccas). Papua New Guinea: avavaia (Nangananga, New Britain), gabajekni (Nyamikum, Sepik).

Distribution The Lesser Sunda Islands, the Moluccas, New Guinea, the Solomon Islands and Vanuatu.

Uses In New Britain, the bark is scraped and chewed to give quick relief in dysentery. The leaves are used as sandpaper. Young leaves are eaten raw or cooked. In Papua New Guinea, the leaves and fruits are eaten raw or cooked, and the fibrous bark is used for men's head covering. The bark is also applied to make rope.

Observations A small to medium-sized tree up to 20 m tall, bark surface brown; leaves arranged spirally or occasionally opposite, elliptical to ovate, 9–20 cm × 3–8 cm, base cuneate, apex acuminate, margin entire to denticulate, with 4–7(–8) pairs of lateral veins, scabrid on both sides, stipules 6–13 mm long; figs axillary, ramiflorous or cauliflorous, subglobose, 12–16 mm in diameter, scabridulous, ripening yellow to red and purple; flowers sessile or shortly stipitate, with 4–6 free tepals, male flowers in 2–3 rows, stamens 1–2(–3). *F. wassa* is a forest species, generally preferring open places, and can be found from sea-level to 2000(–2600) m altitude.

Selected sources 281, 576, 580, 597, 603, 900, 1104.

J.P. Rojo, F.C. Pitargue & M.S.M. Sosef

Gloriosa superba L.

Sp. pl. 1: 305 (1753).

COLCHICACEAE

$2n = 22, 66, 88$

Synonyms *Gloriosa simplex* auct.

Vernacular names Flame lily, superb lily (En). Indonesia: kembang sungsang (general), pacing tawa (Javanese), katongkat (Sundanese). Philippines: climbing lily, Turk's cap. Cambodia: var sleng dong dang. Laos: phan ma ha. Thailand: dong dueng (general), ma khaa kong (northern), waan kaam puu (central). Vietnam: c[aa]y ng[os]t ngh[ex]o, c[aa]y nh[us] nho[[as]i.

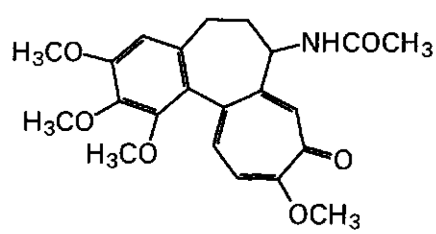
Origin and geographic distribution Flame lily is widespread in the Old World tropics, occurring from tropical and southern Africa and Madagascar to India, Burma (Myanmar) and South-East Asia as far as Java and the Lesser Sunda Islands. It is not indigenous in Sumatra and Borneo. It is commonly grown as a garden ornamental in the tropics.

Uses The use of flame lily in folk medicine in South-East Asia is rather limited, probably due to its high toxicity. This may explain the reports of its use as poison in Cambodia and as suicidal agent in Burma (Myanmar). The tubers are applied in traditional Ayurvedic medicine in India. They are used as a tonic, cholagogue, antiperiodic, alterative, anti-arthritis, antileprotic, antihaemorrhoid and purgative. In East Africa the tubers have various applications in folk medicine but their main use exploits the poisonous constituents.

The selection known as *G. rothschildiana* O'Brien is cultivated in Europe and the United States for the production of cut flowers.

Properties Flame lily seeds are valued as a commercial source of colchicine, an amino alkaloid which is biosynthetically derived from the amino acids phenylalanine and tyrosine. The tubers also contain colchicine, but the content of the seeds is reported to be up to ten times higher, hence the importance attached to good seed set when the plant is grown for colchicine production. A report from Rwanda claims that the highest colchicine content is present in the young leaves.

In medicine, colchicine is used in the treatment of gout and rheumatism. At present it is the drug of choice for acute gout. It reduces the inflammatory reaction to urate crystals deposited in the joints. Its efficacy might be due to several actions, including decreased leucocyte mobility. The substance is not an analgesic, and has no effect on blood concentration, nor renal excretion of uric acid. Because of its highly toxic nature, colchicine should be used under supervision of a physician. Diarrhoea, nausea, vomiting and abdominal pains are often the first signs of poisoning. The diarrhoea may become severe and haemorrhagic, and can



colchicine

thus lead to metabolic acidosis, dehydration, hypotension and shock. A burning sensation in the throat, stomach and skin may also be an early sign of intoxication. Severe reactions include extensive vascular damage and acute renal toxicity with oliguria and haematuria. The patients may develop convulsions, delirium, muscle weakness, neuropathy and ascending paralysis of the central nervous system. In patients who have taken an overdose of *G. superba* bulbs, death occurs as a result of respiratory depression and cardiovascular collapse.

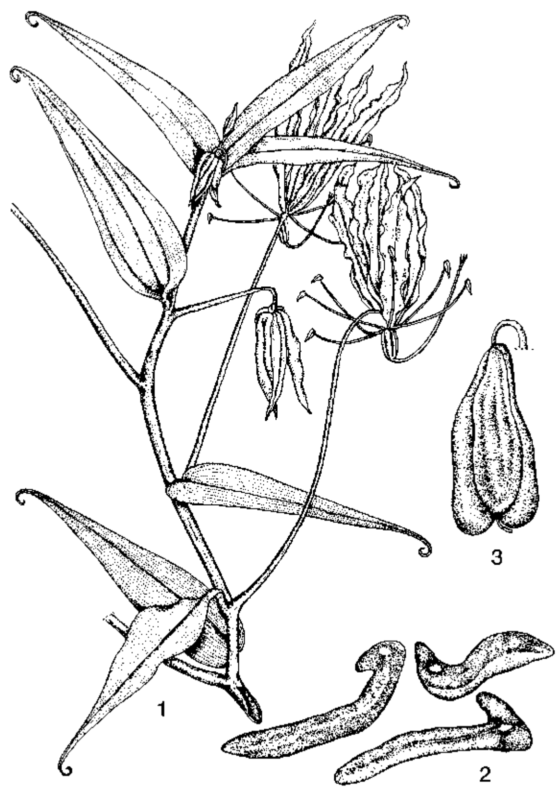
Colchicine inhibits cell division and is used in plant breeding to produce polyploidy, as it does not prevent chromosome division but inhibits formation of a mitotic spindle figure. Therefore no sister cells are formed. This so-called 'C-mitotic' activity of the alkaloid may arise from interaction with the disulphide bonds of the spindle protein, and from inhibition of the conversion of globular proteins to fibrous proteins. Once the treatment has stopped, however, the spindle figure forms again in the normal way. Colchicine also inhibits the division of animal cells, but it is too poisonous to be used to arrest tumour growth. A biosynthetic precursor of colchicine, demecolcine, has a wider margin of safety and is used for the treatment of myelogenic leukaemia and malignant lymphoma.

Extracts of the shoots and of the tubers of the plant show strong nematicidal activity, which can be largely attributed to colchicine. The chemical constituents of the tuber are known to be very poisonous to fish. Uterine stimulant properties are also reported.

Several other alkaloids have been isolated from tubers and seeds besides colchicine e.g. 1,2-didesmethyl colchicine, 2,3-didesmethyl colchicine, 3-desmethyl colchicine, N-formyl-N-deacetyl colchicine, N-deacetyl-2,3-didesmethyl colchicine, cornigerine, 2-desmethyl colchifoline and colchicoside.

Adulterations and substitutes The corms of *Colchicum autumnale* L. and *Iphigenia* (both also included in *Colchicaceae*) are traditional sources of colchicine. An increase in demand for colchicine stimulated the search for an alternative source, leading to *G. superba*.

Description A climbing or, less often, erect, glabrous herb, 3(–6) m long; tuber (corm) perennial, horizontal, roots fibrous; aerial stem annual, moderately branched. Leaves alternate, opposite or in whorls of 3(–4), sessile, lanceolate or ovate, entire, base obtuse, apex gradually narrowing in a coiled tendril (except for erect forms). Flowers solitary in the axils of leaves, bisexual; perianth segments 6, connate at the base, narrowly elliptical, 5–7(–9) cm × 1(–3) cm, with undulate margins, usually reflexed, yellow, red or 2-coloured; stamens 6, filaments spreading 2.5–5 cm long, anthers 0.7–1 cm long, dorsifixed; ovary superior, sessile, 3-celled, style filiform, bent basally almost at right angle, 3.5–5.5 cm long including short apical branches. Fruit a capsule, 4–10 cm × 1.5–2 cm. Seeds globose, about 5 mm in diameter, red or orange red, with a fleshy sarcotesta.



Gloriosa superba L. – *1, flowering stem; 2, tubers; 3, fruit.*

Growth and development The perennial organ of flame lily should be classified as a hypopodial tuber, mostly consisting of two metaphorous hypopodia with an apical bud enveloped by a prophyll, all covered in the remains of leaf bases. Two or more hypopodial tubers are left in the substrate after each growing season, while the previous season's tuber starts to shrivel. Plants propagated from seed take 3–4 years to bloom. Plants produced from tubers start flowering after 5 weeks, and continue flowering for about another 7 weeks. Development from visible flower bud to bloom takes about 2 weeks and anthesis occurs 1 day later; anther dehiscence takes another day. The same branch flowers at 3-day intervals. Terminal flowers do not usually set fruit, but if they do only a few seeds are produced. Cross-pollination generally improves seed production. Pollination is probably by butterflies and sugar birds. Fruit is mature 6–10 weeks after pollination. The dimensions of the plants are strongly correlated with tuber weight, whereas the plants's dimensions determine the size of the next season's tuber.

Other botanical information *Gloriosa* has often been included in *Liliaceae*, but is nowadays considered as belonging to *Colchinaceae*, differing from the bulbous *Liliaceae* s.s. in having a tuber or corm, i.e. a thickened underground stem part which is stoloniferous in *Gloriosa*. *G. superba* is very variable and is sometimes considered to consist of several species. Only one species, *G. superba* s.s., is indigenous to Malesia. Several selected forms in cultivation are traded under a 'specific rank', e.g. *G. rothschildiana*.

Ecology In general, flame lily prefers a pronounced monsoon climate, avoiding per-humid tropical areas. It is locally common in brushwood, hedges and open forest up to 300(–600) m altitude. It can be found flowering and fruiting throughout the year, although flowering is most abundant during the rainy season.

Propagation and planting Chemical scarification (e.g. with 1% hypochlorite) or removal of the sarcotesta reduces seed dormancy in flame lily from 6–9 months to about 4 months, and accelerates germination from 29–30 days to 11–15 days. Germination rates as high as 97% were reached for seeds incubated at 20–25°C for a period of 31 days. Higher temperatures have adverse effects.
Vegetative propagation by tubers is common practice, but not very suitable for the establishment of large plantings. The maximum number of daughter corms produced per plant is two. Separating the bilobed hypopodial tubers produces a higher percentage of flowering plants than leaving the tubers undivided (about 97% versus about 63%). Tuber dormancy can be overcome by soaking in continuously aerated water. Small tubers have been found to have a higher multiplication rate than bigger ones. Seed yield could be obtained from tubers heavier than 7 g.
Experiments with clonal propagation, using a Murashige and Skoog medium supplemented with 0.1 mg/l indole acetic acid have given promising results. However, the cloned plants did not flower at the first vegetative phase but produced small tubers that could be used as vegetative propagules.
For small-scale plantings, tubers of 50–60 g are planted 30–45 cm apart in well-tilled soil at a depth of 6 cm in furrows 45–60 cm apart. A closer spacing gives a higher percentage of cross-pollination resulting in improved fruit set. The best seeding medium is a 1:1:2 mixture of soil, sand and compost. In Thailand, the optimum fertilizer (13-13-21) rate for optimal seedling growth and tuber weight was found to be about 250 kg/ha.

In vitro production of active compounds In vitro production of colchicine is feasible. Levels of colchicine extracted from *G. superba* callus, malformed roots, and entire plantlets show an increase that can be directly related to the amount of differentiation in culture. To derive levels of colchicine in vitro equal to those found in complete plants, entire plantlet regeneration is necessary.

Husbandry Although considerable information is available on the cultivation of flame lily under greenhouse conditions, the techniques used are not applicable to field conditions in tropical regions.
At the time of planting a dose of 40 kg N, 50 kg P_2O_5 and 75 kg K_2O per ha should be applied with a top dressing of 80 kg N per ha, 8 weeks after planting. The top dressing should coincide with staking of the growing vines. Irrigation is needed at dry weather during the initial stages of growth. Irrigation applied after flowering may cause the tubers to rot.
Poor fruit set resulting in low yield of seed is a problem in plantings in southern India. This may be attributed to inadequate pollination, which can be overcome by artificial hand pollination.

Diseases and pests Leaf blight (*Curvularia lunata*) and tuber rot (*Sclerotium* spp.) are two important fungal diseases of flame lily under per-humid situations. Lily caterpillar (*Polytela gloriosae*) and green caterpillar (*Pulsia chalcites*) attack foliage and flower buds.

Harvesting Mature fruits of flame lily are hand picked, and the tubers are dug out manually.

Yield In Tamil Nadu, India, small-scale plantings, raised from tubers, yield on average 250–300 kg of seed per ha from the second year onwards. In South Africa the seed production of 'wild-type' plants is positively correlated with height of the plant, and is on average 258 seeds per plant for plants 60–65 cm tall compared with about 30 seeds per plant for plants 30–40 cm tall.

Handling after harvest After harvesting, mature fruits of flame lily are left in the shade to dry for 7–10 days. The fruits are then split open and the seeds removed, dried for a week in the shade and subsequently sun dried for another week.

Genetic resources and breeding *G. superba* has a wide natural distribution, and many selections are cultivated in the tropics as well as in greenhouses in temperate regions. Although local depletion of the resource may occur, the species is not threatened and the diversity still offers opportunities for further selection either for chemical constituents or as an ornamental.

Prospects Flame lily shows interesting potential as a source of colchicine, which is highly valued as a medicament for gout. As it is commonly grown as a garden ornamental in the tropics, there might be possibilities for the local production of drugs.

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Other selected sources 277, 402, 893, 1035, 1058, 1287, 1447.

N. Bunyapraphatsara
& J.L.C.H. van Valkenburg

Heliotropium L.

Sp. pl. 1: 130 (1753); Gen. pl. ed. 5: 164 (1754).
BORAGINACEAE
x = 7, 8, 9, 11, 13; *H. curassavicum*: $2n$ = 26, 52, *H. indicum*: $2n$ = 22, *H. ovalifolium*: $2n$ = 22

Major species *Heliotropium indicum* L.

Vernacular names Heliotrope (En). Héliotrope (Fr).

Origin and geographic distribution *Heliotropium* consists of about 250 species, and is distributed in tropical, subtropical and warm temperate regions of all continents. A total of 11 species are recorded for the Malesian region: 7 species can be considered indigenous and 1 naturalized; 3 species are known solely from cultivation, though they occasionally occur as a weed.

Uses The leaves of various *Heliotropium* species are generally applied in poultices throughout the Malesian region, and in other parts of the world. They are used to cure ulcers, wounds and local inflammations. A decoction of the leaves of *H. indicum* is reported to be applied in the treatment of urticaria. A decoction of various parts of the plants is used as an emmenagogue or even abortifacient in Indo-China and the Philippines. *H. arborescens* L. (synonym: *H. peruvianum* L.) is widely cultivated as an ornamental in tropical (e.g. Java), subtropical and temperate countries.

Properties Pyrrolizidine alkaloids are common constituents of various genera belonging to the *Boraginaceae* and *Compositae* and to the papilionoid genus *Crotalaria*. Biosynthetically, these alkaloids are derived from two molecules of the amino acid ornithine, which are utilized in the formation of the bicyclic pyrrolizidine skeleton (necine moiety). This basic skeleton seldom occurs in its free form, but is generally found as an ester

with rare monobasic or dibasic acids: the necic acids.
The interest in these compounds is mainly focused on their toxic effects in animals, livestock and sporadically in humans. Many pyrrolizidine alkaloids exhibit a pronounced hepatic toxicity. Toxic structures must have an 1,2-unsaturation in the pyrrolizidine ring, and an ester function on the side chain. Mammalian liver oxidases transform typical alkaloids into reactive pyrrole structures, which are potent alkylating agents and react with suitable cell nucleophiles, e.g. nucleic acids and proteins. Although the toxic effects of these metabolites are usually primarily seen in the liver, lung and/or other tissues may also be affected. In addition to the cytotoxic effects mentioned, mutagenic and carcinogenic activities of pyrrolizidine alkaloids have been reported in literature.
In general, animals will avoid eating plants containing pyrrolizidine alkaloids. However, in times of scarcity, and when fodder is contaminated, accidental consumption can lead to acute or chronic intoxication. In humans, generally only symptoms of chronic intoxication are observed, as a result of a prolonged use of herbal medicines consisting of plants containing pyrrolizidine alkaloids (e.g. *Senecio* and *Symphytum* species).
Indicine, indicine-N-oxide, acetyl-indicine, indicinine, heleurine, heliotrine, supinine, supinidine and lindelofidine are pyrrolizidine alkaloids isolated from *H. indicum*, that are all hepatotoxic. Furthermore, the literature contains reports of the presence of trachelanthamidine and retronecine in *H. indicum*. *H. curassavicum* contains trachelanthamidine, supinidine and retronecine. In all organs at all developmental stages, supinidine was the minor necine; trachelanthamidine was the dominant base in *H. curassavicum*, whereas retronecine was dominant in *H. indicum*. A larger proportion (17–65%) of retronecine has been found in the roots and generative parts of *H. curassavicum* than in the leaves and stems.
Indicine-N-oxide has shown significant activity against W-256 carcinoma in rats, and leukaemia L-121 in mice. The compound has also been administered as a brief infusion over 15 minutes to patients with solid tumours who had received prior chemotherapy. Dose-limiting effects were leukopenia and thrombocytopaenia, and the toxicity was cumulative with repeated doses. In general, the undesirable hepatotoxicity prevented any further development. In addition, anti-inflammatory and wound healing properties are reported.
Furthermore, phytochemical investigations have revealed the presence of the biogenic amines putrescine, spermidine and spermine in leaves and inflorescence of *H. indicum*, and the sterols diosgenin, tigogenin, lanosterol and β-sitosterol in *H. scabrum*.

Description Annual or perennial herbs or subshrubs. Leaves alternate, simple, petiolate or sessile, stipules absent. Inflorescence usually a unilateral, scorpioid cyme, sometimes 2 cymes close together on dichotomous branches, or even numerous short cymes crowded together in a head-like manner, with or without bracts. Flowers actinomorphic, bisexual, 5-merous; calyx lobes almost free, unequal; corolla tubular, funnel-shaped or hypocrateriform, white, yellow or purple; stamens included in corolla tube, with very short filaments; ovary superior, 4-locular. Fruit undivided with 4 locules or by reduction 1 fertile locule, or separating in 2 bilocular pyrenes, most often these pyrenes again separating into 2 unilocular nutlets; nutlets smooth or sculptured. Seedling with epigeal germination; cotyledons leafy, glabrous, with rounded apex; hypocotyl elongated, densely hairy, epicotyl very short.

Growth and development *H. indicum* may flower throughout the year. The flowering season is very long, and new flowers develop apically within a cyme while mature nutlets are already present at the base of the inflorescence.

Other botanical information *Heliotropium* belongs to the subfamily *Heliotropioideae*, which also includes *Tournefortia*. Infrageneric classification suffers from the absence of a recent taxonomic revision covering Old World and New World species. The Malesian *Heliotropium* species belong to several sections.

Ecology *Heliotropium* occurs in very diverse habitats, though drier places are preferred in general. Some species are weeds, often introduced from the New World at an early date and now widespread in the palaeotropics.

Harvesting Plants of *Heliotropium* are harvested when fully grown, and can be used fresh or dried.

Yield *H. curassavicum* and *H. indicum* grown under greenhouse conditions showed the greatest accumulation of alkaloids after the beginning of flowering. Young leaves, young inflorescences and seedlings showed very high alkaloid levels. With ageing, the content of alkaloids in leaves decreased 20-fold. In both species the highest alkaloid content was found in the roots and inflorescence. These parts also exhibited the highest relative amounts of N-oxides ranging from 60–90% of the total alkaloid content. No significant age-dependent differences in N-oxides were found.

Genetic resources and breeding Most *Heliotropium* species are widespread and common weeds. Therefore the risk of genetic erosion seems slight. No breeding programmes are known to exist.

Prospects The possible applications in cancer therapy are limited by the toxic effects, in particular the hepatotoxic effects, of the pyrrolizidine alkaloids.

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Selection of species

Heliotropium curassavicum L.

Sp. pl. 1: 130 (1753).

Distribution A native of the Americas from Patagonia to the United States and the West Indies; in Malesia occasionally occurring as a weed in Java and the Philippines.

Uses In the Americas the dried roots are ground to powder and applied to sores and wounds. In Curaçao a decoction of the plant is taken as a remedy for leucorrhoea. It is also taken as a substitute for *H. indicum*.

Observations An annual, prostrate to ascending, subsucculent herb; leaves oblong, spatulate to linear, 1–5 cm × 0.3–1 cm, glabrous, with short petiole; inflorescence a spike-like cyme, 3–10 cm long, dense, usually forked once, ebracteate; calyx glabrous, corolla 1–2.5(–3) cm long with 5 rounded lobes, white or bluish with a yellow centre, stigma an umbrella-shaped disk on a short style; fruit breaking up into 4 nutlets about 2 mm long, glabrous. In its native countries *H. curassavicum* is found in wet places, along the sea-shore and in similar habitats.

Selected sources 97, 221, 287, 921, 1229.

Heliotropium indicum L.

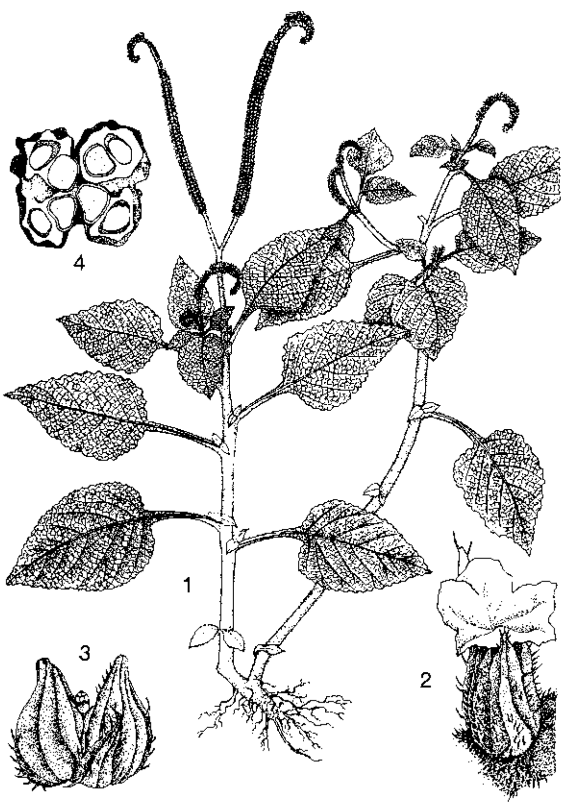
Sp. pl. 1: 130 (1753).

Vernacular names Indian heliotrope (En). Tournesol indien (Fr). Indonesia: buntut tikus (Malay), bandotan, gajahan (Javanese). Malaysia: rumput ekur kuching, rumput kala jenkeng, rumput oleh (Peninsular). Philippines: trompa ng elephante, buntot-leon (Tagalog, Bikol), kambra-kambra (Bisaya). Cambodia: promoi damrey, kantui damrey. Laos: nha nguong xang. Thailand: kuno kaa-mo (peninsular), yaa nguang chaang (general), yaa nguang chaang noi (northern). Vietnam: c[aa]y v[oi]i voi.

Distribution Probably a native of tropical America, now widespread in all tropical regions of the world. *H. indicum* is a common weed throughout Malesia.

Uses *H. indicum* has been used on warts and in poultices since antiquity, to treat inflammatory tumours. In Indonesia a decoction of the leaves is used against thrush. In folk medicine in Indo-China the whole plant, either in decoction or as a poultice, is applied to treat inflammation, swelling, sprain, contusion, pharyngitis, abscesses and rheumatism. A poultice of the leaves is used in the treatment of herpes and rheumatism. In the Philippines, the roots are considered a good emmenagogue. An infusion of the leaves is used to wash wounds and sores. In Thailand, a decoction of aerial parts is applied as an antipyretic and anti-inflammatory, and the roots are used for eye diseases. In West Africa, a poultice is applied in the treatment of eczema and impetigo. In South and Central America, the plant is used for similar purposes. In addition a decoction of the leaves is taken orally to cure dysentery and to treat haemorrhoids. The leaf juice is drunk to stop internal bleeding. An infusion is taken as a gargle to relieve sore throat.

Observations An annual herb, 15–60(–100) cm tall, stem simple or with a few branches, hairy; leaves ovate, (1.5–)2–10(–12) cm × 1–8(–9) cm, base truncate but narrowly long-decurrent, apex acute, with tubercules of mineralized cells and bristly hairs, petiole 1–9 cm long; inflorescence consisting of 1 to several spike-like cyme(s), elongated, 5–20 cm long, ebracteate; calyx with patent, bristly, white hairs, corolla salver-shaped, tube 3–4.5 mm long, lobes rounded, about 1 mm long, pale-violet, blue or white, apex of carpels strongly bidentate, strongly divergent at anthesis; fruit 2–3 mm long, fruit halves 2-celled, cells 2-locular, outer partition with one seed, inner one larger, empty. *H. indicum* is found in sunny places, on waste land, in periodically desiccating pools and ditches and other anthropogenic habitats, in general up to 800 m altitude.



Heliotropium indicum L. – 1, plant habit; 2, flower; 3, bilobed fruit; 4, fruit in cross-section.

Selected sources 97, 190, 201, 202, 221, 287, 531, 580, 614, 787, 921, 979, 1035, 1072, 1126, 1128, 1178, 1229, 1299, 1386.

Heliotropium ovalifolium Forssk.

Fl. Aegypt.-Arab.: 38 (1775).

Distribution Tropical Africa, Arabian Peninsula, India, Vietnam, Sumba, Timor and the Solomon Islands.

Uses In West and Central Africa, *H. ovalifolium* is used in the treatment of syphilis, both as a strong purgative and as a topical application to syphilitic ulcers. It is reported to have analgesic action and is applied in hot poultices to treat severe pain.

Observations A perennial herb, sometimes with woody base, up to 40 cm tall, much branched, covered by appressed short hairs; leaves oblong to obovate, 1–1.5 cm × 0.3–0.4 cm, tapering towards the base, apex obtuse, with silky hairs, petiole 0.1–0.5 cm long; inflorescence a spike-like cyme, up to 4 cm long, ebracteate, flowers variably densely arranged in two ranks; calyx densely covered by antrorse hairs, corolla funnel-shaped, 3 mm long, with dense antrorse hairs outside, lobes ovate-triangular to ovate, 0.8 mm long, white; fruit consisting of 4 nutlets, densely antrorse hairy. *H. ovalifolium* is found in valleys, on roadsides, in dried ponds and similar habitats.

Selected sources 201, 287, 921, 1229.

Heliotropium scabrum Retz.

Observ. bot. 2: 8 (1781).

Synonyms *Heliotropium marifolium* Retz. (1781), *Heliotropium cyrtostachyum* Miq. (1856).

Distribution Pakistan, India, Sri Lanka, Cambodia, southern China and Malesia (Java and Flores).

Uses The alkaloids found in *H. scabrum* indicate that it can be used for the same purposes as some of the other *Heliotropium* species.

Observations A perennial, prostrate, sometimes erect herb, stems 5–30 cm long, branched from the base, covered in antrorsely appressed, white, bristly hairs; leaves linear to lanceolate-oblong, 0.5–2 cm × 0.1–0.5 cm, base cuneate or rounded, apex acute, margin revolute, with antrorsely appressed bristly hairs, petiole 0–3 mm long; inflorescence a subcapitate cyme at the end of stems and branches with leaf-like bracts or flowers single in axils of leaves; calyx covered in bristly hairs, accrescent, corolla funnel-shaped, 3–3.5 mm long, with wavy margins, white; fruit separating into 4 nutlets. *H. scabrum* occurs in dunes, but also in dry roadsides and lawns, and shady places, in general near the sea. However, in Sri Lanka it is reported to occur in foothills up to 1500 m altitude.

Selected sources 97, 921, 1229, 1369.

Wongsatit Chuakul, Noppamas Soonthornchareonnon & Promjit Saralamp

Holarrhena R. Br.

Asclepiadeae: 51 (1810).

APOCYNACEAE

x = unknown; *H. pubescens*: $2n = 22$

Major species *Holarrhena pubescens* Wallich ex G. Don.

Origin and geographic distribution *Holarrhena* comprises 4 species and is found in tropical Africa, India, Sri Lanka, Burma (Myanmar), Indo-China, southernmost China, Thailand and northern Peninsular Malaysia.

Uses The stem bark of *Holarrhena* is a well-known medicine against amoebic dysentery, and has been used as such in India since antiquity. It has astringent, antidysenteric, anthelmintic, stomachic and febrifugal properties, and is also taken as a general tonic. The drug is usually administered as an extract or a decoction. The seeds are sometimes applied similarly; their oil is anthelmintic. Decoctions of the bark or leaves used to be applied in baths to cure scabies. The leaves are used in chronic bronchitis, and against boils, ulcers and haemorrhoids, sometimes as an anthelmintic. In Cambodia, the latex is used locally to treat conjunctivitis and in southern Vietnam as a vulnerary.

The pale yellow or pale pink wood is of low quality but is appreciated locally for small objects like picture frames, household utensils, carving and turnery articles, because of its fine grain. The wood ash has been used for dyeing and as a caustic to open abscesses. *H. pubescens* may prove useful for the reforestation of deforested land in comparatively dry regions, also because it is not readily browsed even by goats. It is also cultivated in India as an ornamental for its attractive flowers.

Properties The bark and seed of *H. pubescens* contain conessine, which is mainly responsible for the amoebicidal properties. This compound is the most important representative of a series of steroidal alkaloids that belong to the conanine type and that also occur in other *Holarrhena* species, both Asian and African. In contrast, the steroidal alkaloids in the leaves are mostly 5α-pregnane or pregn-5-ene derivatives with amino groups at the 3 or 20-positions. The fact that many of these substances have an oxygen or nitrogen function at position 18 has led to a detailed study of their chemistry aimed at using them as starting material for the partial synthesis of pharmaceutical steroids, such as adrenocortical hormones (corticosteroids) and sex hormones (e.g. oestrogens, progestogens and androgens). In all, about 40–45 steroidal alkaloids have been isolated from various parts of *H. pubescens*. The bark should be used with caution as an anti-amoebic, as one of the possible side effects is hypotension. Various aminoglyco-steroids are present in the leaves of *H. curtisii*, *H. mitis* (Vahl) R.Br. and *H. pubescens*. These substances contain an amino sugar, and in some of them e.g. holarosine and holacurtine, the steroidal part of the molecule is a cardenolide. In others, e.g. the holantosines, the oxygenated side-chain is of rather different structure. The 8 steroidal alkaloids isolated from the ethanolic extract of the leaves of *H. curtisii* all showed significant cytotoxic and leishmanicidal activity.

Apart from its anti-amoebic properties, conessine also possesses antitubercular activity in situ. It increases coronary outflow in isolated rabbit heart and induces narcosis in frogs. It also produces local anaesthesia in guinea-pigs, being about twice as active as cocaine, but causes tissue necrosis if injected subcutaneously. Furthermore, conessine is highly toxic to *Trichomonas intestinalis* and *T. vaginalis*.

The alcoholic extract of the fruit was found to show anti-cancer activity against human epidermoid carcinoma of the nasopharynx in tissue culture. The aqueous extract of the fruits exhibited hypoglycaemic effects in rats.

Chloroform and methanolic extracts of *H. pubescens* seed showed antibacterial activity against *Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Conessine from *H. pubescens* showed potential as a larval growth inhibitor, sterilant and antifeedant in laboratory tests on 4 insect species. The wood of *H. pubescens* contains 14% protein, 16% polyphenol, 5.4% oil and 4.8% hydrocarbons and due to its relatively high oil and hydrocarbon content it has been recommended as a renewable source of energy.

Adulterations and substitutes Seeds of *H. pubescens* are sometimes mixed with those of

Wrightia tinctoria R.Br., which do not have the same medicinal properties. However, they can be distinguished because *H. pubescens* seed is very bitter. Similarly, the bark of *W. tinctoria* is sold as a substitute for *H. pubescens*. The bark can be distinguished by a different thin layer chromatography pattern of the petroleum extract.

Description Evergreen or deciduous shrubs to medium-sized trees up to 25 m tall; bole short, up to 60 cm in diameter; bark flaking off irregularly, pale brownish or greyish, inner bark with abundant white latex; branchlets often pubescent. Leaves opposite or subopposite, simple, entire, pinnately veined, short petiolate; stipules intrapetiolar and often obscure or absent. Inflorescence terminal or seemingly axillary, cymose, many-flowered. Flowers bisexual, 5-merous, actinomorphic, fragrant; calyx persistent, sepals free or connate at the very base, valvate; corolla salver-shaped, white, tube cylindrical, pubescent at the throat, lobes in bud contorted and overlapping to the right; stamens included, inserted at the base of the corolla tube, filaments short, anthers mucronate; disk absent; ovary superior, with 2 carpels which are fused at base, ovules many, style 1, split at base, with an ovoid apex (stigma head). Fruit composed of two paired, slender follicles which split along a single line; wall thinly coriaceous. Seeds many, in 2 or more rows, linear to narrowly oblong, glabrous but with a dense and long tuft of hairs at the apex. Seedling with epigeal germination; cotyledons emergent, leafy; hypocotyl elongated; all leaves opposite.

Growth and development In India, early height increment of *H. pubescens* is low, only 10–15 cm/year under natural conditions. Its maximum annual diameter increment as observed in India is 0.7 cm, but is greatly reduced to 0.1 cm when it grows in shaded locations. In India, trees are leafless in December-January and new leaves appear after 2–3 months. Trees flower in (April-) May-June(-August), sometimes a second flush is produced in September-November. Fruits are full-grown in August-October but do not dehisce until February-April. The seeds are wind-dispersed.

Other botanical information *H. mitis*, an endemic from Sri Lanka, is also used medicinally for similar purposes. Information on the uses of *H. antidysenterica* from Sri Lanka probably refers to *H. mitis*.

Ecology *Holarrhena* is found in dry evergreen to dry deciduous forest, bamboo forest, scrub woodland and savannas, at 0–1500 m altitude. *H. pubescens* shows pioneer characteristics. In its natural habitats in India, *H. pubescens* grows in areas with an absolute maximum temperature of 40–48°C and an absolute minimum temperature of 0–12°C, and an annual rainfall between 750 mm and 3800 mm.

Propagation and planting *Holarrhena* can be propagated by seed, either by direct sowing or by raising seedlings in the nursery. Fresh seed has a high germination rate, but seed loses its viability after having been stored for 1 year. *H. pubescens* has 32 000–35 000 seeds/kg. Seed usually germinates in 2–3 weeks. In a germination experiment in Malaysia seed of *H. curtisii* took 12–28 days to germinate. Tissue culture of *H. pubescens* in India proved possible and rooted plantlets were obtained from nodal explants of a 20-year-old tree cultured on Murashige and Skoog medium with added indole acetic acid at 1 mg/l.

In vitro production of active compounds In India a callus culture of *H. pubescens* yielded a maximum of 300 mg alkaloids per 100 g dry cells in 40 days; a suspension culture reached 130 mg per 100 g dry cells in 8 days. A modified Murashige and Skoog medium may result in an increased production up to 660 mg per 100 g dry cells, depending on nutrient concentration and source. The alkaloid production can be boosted to 110 mg per 100 g dry cell weight per day by adding cholesterol as a precursor. About 90% of the total alkaloids produced in cell culture was conessine.

Husbandry *H. pubescens* easily recovers from damage, coppices well and produces root suckers in abundance.

Diseases and pests The moth *Glyphodes laticostalis* is one of the major pests on *H. pubescens* in Maharashtra State, India.

Harvesting In India, bark for medicinal use is collected from 8–12-year-old *H. pubescens* trees. The alkaloid content varies with the age of the tree and the season. The content in the bark is highest when new shoots are formed.

Yield Values for total alkaloid content may be as high as 4.3% for the stem bark of *H. pubescens*, but only 0.4% has also been reported for flowering plants. Leaves contain 1–1.6% and seeds 0.6–1.8% total alkaloids.

Handling after harvest The bark of *H. pubescens* is dried and sold in 1–7 mm thick pieces.

Genetic resources and breeding The Malesian *Holarrhena* species are common in their areas of distribution and are also found in open anthropogenic habitats. Therefore the risk of genetic erosion seems limited. The considerable variation in nature and content of alkaloids as found in market samples is probably also linked to non-seasonal differences. As both influence the therapeutical effect, breeding and selection may well improve the prospects of the crude drug.

Prospects The steroidal alkaloids of *Holarrhena* might be usable as starting material for the partial synthesis of steroids of pharmaceutical interest, so deserve further attention. Furthermore, the amoebicidal, bactericidal and insecticidal properties of the crude drug, and/or the main steroidal alkaloid conessine might be valuable alternatives e.g. in the treatment of amoebic dysentery.

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Selection of species

Holarrhena curtisii King & Gamble

Journ. Straits Branch Roy. Asiat. Soc. 74: 446 (1908).

Synonyms *Holarrhena densiflora* Ridley (1911), *Holarrhena latifolia* Ridley (1911), *Holarrhena pulcherrima* Ridley (1911).

Vernacular names Cambodia: doeum tuk das. Laos: mak mouk kuay, mouk noy[2]. Thailand: hatsakhun thet (Phangnga), mok noi (northern), phut nam (Surat Thani). Vietnam: h[oof] li[ee]n l[as] nh[or], m[uws]c hoa tr[aws]ng.

Distribution Indo-China, Thailand and northern Peninsular Malaysia.

Uses The bark and roots have been used to treat dysentery.

Observations A small shrub up to 2.5 m tall, branches pale grey to dark grey, often lenticellate or white-dotted; leaves narrowly elliptical or elliptical to obovate, 2.3–10 cm × 1.2–4.5 cm, apex rounded to emarginate, with 9–15 pairs of lateral veins, chartaceous when dry, petiole up to 6 mm long; corolla tube 12–22 mm long, the lobes 10–23 mm long; fruit carpels erect, at least when young, 11–33 cm × 3–8 mm. *H. curtisii* occurs in secondary rain forest, mixed deciduous forest, bamboo forest, scrub woodland, savanna and mangrove swamps, at 0–400 m altitude.

Selected sources 161, 330, 698, 1020, 1022, 1128, 1227, 1380.

Holarrhena pubescens Wallich ex G. Don

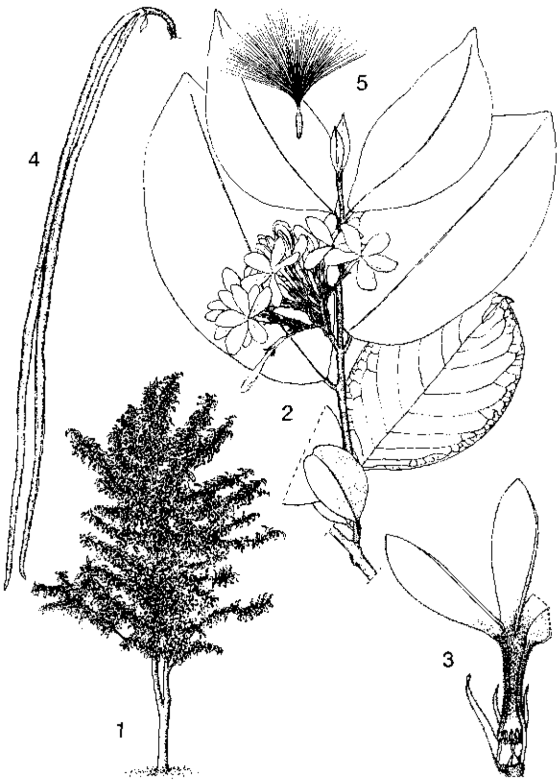
Gen. hist. 4: 78 (1837).

Synonyms *Holarrhena antidysenterica* (L.) Wallich ex A.DC. (1844), *Holarrhena malaccensis* Wight (1848), *Holarrhena macrocarpa* (Hassk.) Villar (1880).

Vernacular names Holarrhena (En). Ecorce de conessie (Fr). Cambodia: khleng kong, tuk das khla. Laos: mouk nhai[2]. Thailand: mok thung (northern), mok yai (central), so-thue (Karen-Mae Hong Son). Vietnam: m[ooj]c hoa tr[aws]ng, h[oof] li[ee]n l[as] to.

Distribution Tropical Africa, India, Burma (Myanmar), Indo-China, southern China (Yunnan) and Thailand.

Uses The most important medicinal application of this species is for amoebic dysentery, for which especially the bark and occasionally also the seeds are used. The wood is used for small implements and as fuel wood, and the tree is also planted for its ornamental value.



Holarrhena pubescens Wallich ex G. Don – 1, tree habit; 2, flowering twig; 3, opened flower; 4, fruit; 5, seed.

Observations A shrub to medium-sized tree up to 18 m tall, bole up to 25 cm in diameter, bark surface rough and corky, longitudinally fissured, pale to dark grey; leaves ovate to elliptical or narrowly so, 1.7–19.5 cm × 1.3–11 cm, apex acute to acuminate, with 5–25 pairs of lateral veins, papery when dry, petiole up to 12 mm long; corolla tube 9–19 mm long, the lobes 10–24(–30) mm long; fruit carpels pendulous, 20–37.5 cm × 2–9 mm. *H. pubescens* is found in open places in evergreen rain forest, mixed deciduous forest, bamboo forest, scrub woodland and savanna, at 0–1500 m altitude. It is often found gregarious, on clay, laterite or sand, but also on rocky outcrops.

Selected sources 138, 149, 150, 158, 161, 202, 239, 287, 318, 330, 364, 402, 480, 675, 689, 725, 741, 904, 1035, 1109, 1110, 1111, 1113, 1128, 1227, 1277, 1287, 1348, 1349, 1352, 1380, 1478, 1538.

Wongsatit Chuakul, Noppamas Soonthornchareonnon & Promjit Saralamp

Hydnocarpus Gaertner

Fruct. sem. pl. 1: 288, t. 60, f. 3 (1788).

FLACOURTIACEAE

$x = 12$; *H. alcalae*, *H. anthelmintica*, *H. kurzii*: $2n = 24$

Major species *Hydnocarpus alcalae* C.DC., *H. anthelmintica* Pierre ex Lanessan, *H. kurzii* (King) Warb.

Vernacular names Malaysia: setumpol (Peninsular), karpus (Sabah). Burma (Myanmar): kalaw. Thailand: krabao. Vietnam: phong t[uw]r.

Origin and geographic distribution *Hydnocarpus* comprises about 40 species occurring in south-western India, Sri Lanka, Burma (Myanmar), Indo-China, southern China, Thailand (7 species), Peninsular Malaysia (12), Sumatra (12), Java (2), Borneo (17), the Philippines (5) and Sulawesi (2). *H. kurzii* (from Burma (Myanmar)), *H. alcalae* (from the Philippines) and *H. anthelmintica* (from Indo-China) used to be cultivated but with the advent of synthetic leprosy drugs in the 1960s, this cultivation has lost its importance.

Uses Seeds of many *Hydnocarpus* species (notably *H. anthelmintica* and *H. kurzii*) yield an oil that has been well known as a cure for leprosy and skin diseases since antiquity. The oil has also been recommended as a topical application to treat rheumatism, sprains and bruises, sciatica and chest complaints, and for dressing wounds. Major sources are *H. kurzii* from Burma (Myanmar), known as 'chaulmoogra' oil, and *H. laurifolia* (Dennst.) Sleumer (synomyms: *H. pentandrus* (Ham.) Oken, *H. wightiana* Blume) from south-western India, known as 'moratti' or 'marotti' oil. The major source of *Hydnocarpus* oil in China, where it is known as 'lukrabo' or 'krabao' oil, is *H. anthelmintica* seed from Indo-China. In Cambodia, this oil has also been used for illumination and it has been used to make soap. *H. venenata* Gaertner from Sri Lanka known as 'makulu' is used medicinally to treat leprosy but also as a fish poison. The seed of many *Hydnocarpus* species can be used as a fish poison, similar to *Pangium edule* Reinw. The oil from *H. kurzii* seed has been used to treat saddle-sores, and for liniment in veterinary practice.

The fibrous bark of *H. anthelmintica* is made into cordage, whereas the pulp of the fruits is edible. The wood of *Hydnocarpus* is used for local house building (poles), temporary heavy construction, posts, fences, interior finishing, panelling and door and window frames.

Production and international trade In former times seeds or seed oil of *Hydnocarpus* were traded from India and Indo-China to the Malesian region, China, Hawaii and Europe. However, at present no information on trade is available.

Properties Cyclopentenylglycine and cyclopentenyl fatty acids are found in *Hydnocarpus* seed. The Malesian species *H. alcalae*, *H. cauliflora* Merr., *H. subfalcata* Merr. and *H. woodii* Merr. contain high concentrations of the cyclopentenyl fatty acid chaulmoogric acid and of hydnocarpic acid, whereas the seeds of many other species contain glycosides which, upon hydrolysis, discharge the highly toxic hydrocyanic acid. The percentages of individual fatty acids for the seed oils of *H. kurzii* and *H. laurifolia* respectively have been found to be (in %): hydnocarpic acid 23.0 and 33.9, chaulmoogric acid 29.6 and 35.0, gorlic acid 25.1 and 12.8, lower cyclic homologues 0.3 and 4.6, myristic acid 0.6 and 0.8, palmitic acid 8.4 and 5.6, stearic acid zero and 0.6, palmitoleic acid 6.0 and 1.3, oleic acid 5.4 and 3.6 and linoleic acid 1.6 and 1.8. Very pure hydnocarpic acid, chaulmoogric acid and gorlic acid have been prepared from the seed oil of *H. laurifolia*. The isolated acids were used as starting materials to synthesize the corresponding cyclopentenyl alkylmethane sulphonates (mesylates), cyclopentenyl alkanes, cyclopentenyl nitriles, cyclopentenyl alcohols, 1-0-cyclopentenyl and 1,2-0-cyclopentenyl alkylglyceryl ethers. Pure homohydnocarpic acid and homochaulmoogric acid could be obtained, as well as pure hormelic acid. The purity of the fatty products obtained was assessed using chromatographic and spectroscopic techniques and their physicochemical constants were determined. These products may find uses as potential pheromones or as chemotherapeutics against certain mycobacteria.

The oil from *H. kurzii* is active against *Mycobacterium leprae*; best results have been obtained by administering ethyl esters of the fatty acids (ethyl chaulmoograte) in combination with sulphone drugs.

Hydnocarpus oil alone and mixed with dapsone fed to mice infected with *M. leprae* inhibited the growth of the leprosy bacilli. Dapsone and oil combined had an additive inhibitory effect on the growth of the bacilli.

Flavonolignans isolated from *H. laurifolia* seed, namely hydnowightin, hydnocarpin, and neohydnocarpin, have demonstrated potent hypolipidemic activity in mice, lowering both serum cholesterol and triglyceride levels. Hydnowightin demonstrated the best lipid-lowering effect of the three compounds. Good anti-inflammatory and antineoplastic activity has been demonstrated for hydnocarpin in mice in vivo. The other two derivatives were not as active in these screens. All three compounds were moderately active against murine L-1210 leukaemia growth and demonstrated good activity against the growth of human KB nasopharynx, colon adenocarcinoma, osteosarcoma, and HeLa-S3 uterine growth. Hydnocarpin was the only compound of the three which was active against glioma growth. Hydnocarpin and neohydnocarpin demonstrated significant activity against Tmolt3 leukaemia cell growth.

In India, a pomace of *H. laurifolia* was found to be nematicidal. Aqueous extract showed greater nematicidal activity than the steam distillate. The nematicidal property is not adversely affected either by boiling or by change in pH (4–10).

A petroleum ether extract of seed of *H. laurifolia* at up to 1000 ppm was moderately active as an antifeedant against 4th-instar larvae of the noctuid *Spodoptera litura*. Positive activity was correlated with the percentage of linoleic acid and oleic acid in the seed oil.

Description Evergreen, dioecious or occasionally monoecious shrubs or small to medium-sized or rarely large trees up to 25(–50) m tall; bark surface usually smooth, sometimes cracking and scaly. Leaves alternate, simple, entire or serrate, variously asymmetrical at base; petiole thickened at apex; stipules early caducous. Flowers unisexual, 4–5-merous; sepals (3–)4–5, rarely 7–11, free or rarely slightly connate at base, imbricate; petals 4–5, rarely up to 14, with an in general densely pilose scale at base inside; male flowers in an axillary cyme or rarely in a raceme-like cauliflorous or ramiflorous panicle, with 5–many stamens; female flowers 1–3 together, with superior ovary, unilocular with many ovules, stigma sessile and with 3–5 spreading branches, often shortly bifid. Fruit an indehiscent, globose to obovoid drupe. Seeds closely packed, with membranous aril, endosperm albuminous-oily. Seedling with epigeal germination; cotyledons emergent or not, leafy; hypocotyl elongated; all leaves arranged spirally, conduplicate.

Growth and development Flowering in *Hydnocarpus* is usually once a year, but the period differs per region. Fruit takes rather long to develop, for instance about 7–8 months for *H. anthelmintica* and *H. woodii*. The fruits are probably dispersed by animals, but there are no reports of this.

Other botanical information There is widespread confusion on another *Flacourtiaceae* species *Gynocardia odorata* R.Br. that is reputed to yield seed oil comparable to *Hydnocarpus*. Unlike real *Hydnocarpus* oil, this oil is neither optically active, nor does it have any therapeutic activity.

Ecology Most *Hydnocarpus* species are found scattered in primary rain forest, in well-drained, flat locations or on hillsides, on sandy or clayey soils, up to 1000(–1800) m altitude, occasionally in beach forest or on rocky outcrops. The medicinally important species prefer well-drained, sandy, alluvial flats and floodplains along rivers, or at least moist but well-drained surroundings.

Propagation and planting *Hydnocarpus* is usually propagated by seed. Seeds are separated from the fruit pulp by washing. Seed of *H. kunstleri* (King) Warb. germinated for 50% in 4–8 months and that of *H. woodii* for about 50% in 5 months to over 2 years. Under natural conditions, seed germinates during the rains shortly after falling to the ground. Seedlings and saplings should be grown under shade.

Harvesting Traditionally, fallen fruits of *Hydnocarpus* were simply collected in the forest, giving often rise to a mixture of species being collected, as several *Hydnocarpus* contain chaulmoogric acid and hydnocarpic acid. The result was a very variable raw product. Accessibility of the floodplains at the time of harvesting was often difficult.

Handling after harvest Seeds tend to go rancid rather quickly. Therefore ripe fruits should be opened and the fruit pulp and aril removed from the seeds. Seeds are then washed and dried in the sun. Sun-dried seeds, either whole or broken, are cold-pressed or pressed under concurrent heating to extract the oil. The chemical composition of the end-product of these methods varies.

Genetic resources and breeding With the exception of *H. heterophylla* Blume, *H. kunstleri* and *H. woodii*, most *Hydnocarpus* have a limited geographical distribution. Together with the often low density at which species are present, this means there is a serious risk of genetic erosion. Because of their importance as leprosy drugs, many *Hydnocarpus* species were planted in botanical gardens in the Malesian region, South America and Central Africa, and some of them may still be present.

Prospects The use of seed oil of *Hydnocarpus* to treat leprosy has been replaced by synthetic drugs. However, with the renewed interest in medicines of plant origin, investigations of the oils and extracts of *Hydnocarpus* seem worthwhile, especially for the treatment of various skin diseases. The cyclopentenyl fatty acids and their synthesized derivatives are of interest as antibacterial compounds, whereas the flavonolignans may have potential as anti-inflammatory and anti-cancer agents.

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Selection of species

Hydnocarpus alcalae C.DC.

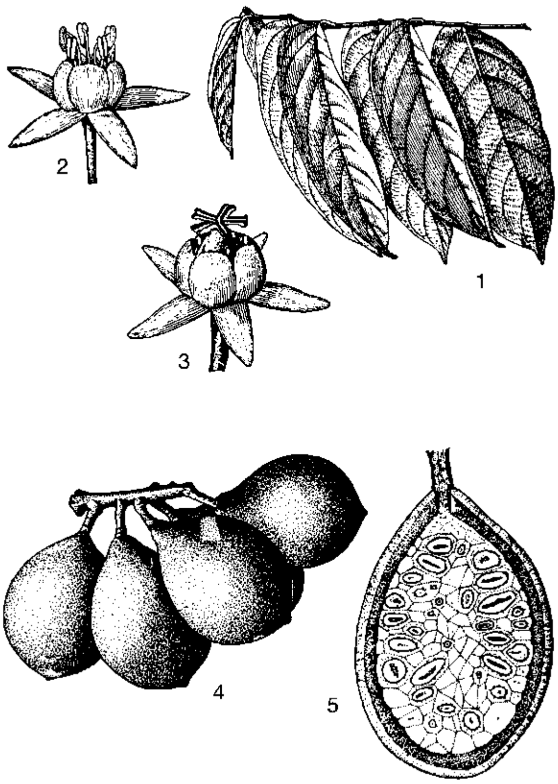
Philipp. Journ. Sci., Bot. 11: 37 (1916).

Vernacular names Philippines: dudoa (Bikol).

Distribution Philippines (southern Luzon), but planted and naturalized elsewhere in Malesia.

Uses The seed oil has been extensively used in the treatment of leprosy.

Observations A small tree or shrub, 4–7 m tall, branches glabrous; leaves ovate-oblong, 15–25 cm × 7–11 cm, subcoriaceous, base very asymmetrical,



Hydnocarpus alcalae C. DC. - 1, leafy twig; 2, male flower; 3, female flower; 4, fruits; 5, fruit in longitudinal section.

apex acuminate; inflorescence a pseudo-racemose panicle, 15–30(–60) cm long, male inflorescences in fascicles of 3–4, female inflorescences solitary, cauliflorous or ramiflorous; flowers 5-merous, greenish white or cream; fruit obovoid, pendent, 15–31 cm × 8–15(–20) cm, dark brown with purple and greenish spots, exocarp 0.3–0.7 mm thick, mesocarp stony, 6 mm thick, endocarp soft, 7 mm thick, with 80–110 seeds; seeds subglobular or ellipsoidal, 3–5 cm × 2.5–3 cm, with a pale yellow aril, embedded in a fragrant, astringent pulp. *H. alcalae* occurs naturally in moist ravines.

Selected sources 190, 332, 1126, 1178, 1376, 1377.

Hydnocarpus anthelmintica Pierre ex Lanessan

Pl. util. colon. franç.: 303 (1896).

Synonyms *Hydnocarpus alpina* Wight var. *elongata* Boerl. (1899), *Hydnocarpus alpina* Wight var. *macrocarpa* Boerl. (1899).

Vernacular names Sausage tree (En). Chaulmoogra (Fr). Burma (Myanmar): kalaw-wa. Cambodia: krabao (Kompong Thom), krabaou thom (Pursat), krabaou phlae thom (general). Laos: ka bao. Thailand: krabao (general), krabao yai (central), bao (peninsular). Vietnam: ch[uf]m bao l[ows]n, d[aj]i phong t[uwr], l[oj] n[oof]i.

Distribution Burma (Myanmar), Indo-China and Thailand; also cultivated within this region for its medicinal seeds.

Uses The seeds are used as a vermifuge in Thailand and Vietnam. However, the use of the seed oil in the treatment of leprosy and other skin complaints is more important. This species is reported to be the source of almost all *Hydnocarpus* seed used in China.

Observations A dioecious, small to medium-sized tree, 10–20(–30) m tall, outer bark lenticellate, greyish-black, inner bark brown; leaves ovate-lanceolate to ovate-oblong, 10–33 cm × 3–7 cm, coriaceous, glabrous, base cuneate to rounded-obtuse, usually asymmetrical, apex gradually long attenuate; inflorescence a 2–3-branched cyme, few-flowered; flowers 5-merous, white or greenish, scented, female flowers with 5 fusiform staminodes; fruit globose, 8–12 cm in diameter, brownish tomentulose, exocarp 0.2 mm thick, mesocarp yellowish, very hard; seeds 30–50(–100) per fruit, ovoid, compressed, 1.5–1.8 cm × 1–1.5 cm. *H. anthelmintica* occurs in evergreen forest and is locally common along river banks, at elevations up to 1300 m. It may well be grown in the Malesian region.

Selected sources 202, 260, 293, 294, 364, 843, 900, 1035, 1126, 1128, 1287, 1376, 1378, 1392.

Hydnocarpus kurzii (King) Warb.

Engl. & Prantl, Nat. Pflanzenfam. 3, 6a: 21 (1893).

Synonyms *Taraktogenos kurzii* auct. non King s.s.

Vernacular names Malaysia: kulau (Peninsular). Burma (Myanmar): kalaw. Thailand: ngaa yoi, ma duuk.

Distribution India, Burma (Myanmar), Thailand and Peninsular Malaysia.

Uses The oil extracted from the seeds is used in the treatment of leprosy. It is the major source of chaulmoogric acid. It is advised not to eat pigs nor fish that have been feeding on the seeds, as their flesh induces nausea and vomiting. A decoction of the bark is drunk for internal disorders and skin diseases in Burma (Myanmar). The roots as well as the seeds are used by Thai traditional doctors for the treatment of skin diseases.

Observations A dioecious tree, 8–20(–30) m tall, bark smooth, grey, young branchlets fulvous pubescent, rather soon glabrescent; leaves lanceolate-oblong, entire, 15–22(–32) cm × 4–6.5 cm, subcoriaceous, glabrous, base cuneate, symmetrical, apex subacuminate; inflorescence a short pedunculate cyme 5–7(–9)-flowered; flowers whitish with unpleasant odour, male flowers with 4 sepals and 8 petals, stamens (15–)18–25(–30), female flowers with 10–16 staminodes; fruit globose, (5–)8–10 cm in diameter, rugose, exocarp fibrose-cancellate, 3–4(–6) mm thick; seeds angular-ovoid, 3 cm × 1.5 cm. Two subspecies have been distinguished: subsp. *australis* Sleum. occurring in southern Burma (Myanmar), Thailand and Peninsular Malaysia, and subsp. *kurzii* from India and northern Burma (Myanmar). Subsp. *australis* differs from subsp. *kurzii* in the thicker exocarp and the venation of the leaves. *H. kurzii* occurs scattered in evergreen forest at 600–1800 m altitude.

Selected sources 202, 260, 580, 843, 900, 1126, 1308, 1376, 1377, 1378, 1564.

Khozirah Shaari & L.S.L. Chua

Hypericum L.

Sp. pl. 2: 783 (1753); Gen. pl. ed. 5: 341 (1754).

GUTTIFERAE

x = (6), 7, 8, 9, 10, 11, 12

Major species *Hypericum japonicum* Thunb. ex Murray, *H. monogynum* L.

Vernacular names St John's wort (En). Millepertuis (Fr).

Origin and geographic distribution *Hypericum* comprises about 400 species and can be considered cosmopolitan, occurring in all continents except for arctic and desert areas and most of the lowland tropics. There are 15 species of *Hypericum* in Malesia, but the genus is absent from the Moluccas. The genus is also present in Indo-China and Thailand and rare in Australia, with only 2 species.

Uses All *Hypericum* species are said to yield essential oils and to be medicinally interesting to some extent. Their medicinal use has been basically the same throughout the world, as they have been used internally against rheumatism, jaundice, oedema and gastric catarrh, and externally to treat wounds and bruises. These effects of *Hypericum* species are regarded as based on their astringent, diuretic, and haemostatic activities. Though there are 15 Malesian species, specific reports of medicinal use are only found for *H. gramineum*, *H. japonicum*, *H. monogynum*, *H. papuanum* and *H. uralum*.

Reports of medicinal use also exist for the non-Malesian *H. ascyron* L., *H. patulum* Thunb. ex Murray and *H. sampsonii* Hance. In Indo-China, the seeds of *H. patulum* are applied to treat dog bites and bee stings. *H. sampsonii* is reported to be used as a vulnerary in northern Vietnam. The fruits and seeds of *H. ascyron* are applied to treat skin problems, gonorrhoea and dysmenorrhoea in Indo-China and China. In Chinese medicine, *H. ascyron*, *H. japonicum* and *H. sampsonii* are mentioned as antihaemorrhagic, and the latter two as vulneraries in the treatment of scrofula and contusions.

A well-known medicinal species in Europe is *H. perforatum* L., which does not occur in South-East Asia. *H. perforatum* was already recognized as a medicinal plant by the ancient Greek writers Dioscorides and Hippocrates. Nowadays, drugs based on the plant are used to treat skin and mouth problems and as an antidepressant.

Hypericum species are often grown as ornamentals.

Properties The most characteristic compounds of *Hypericum* are xanthonoid pigments and anthraquinonoids (naphthodianthrones, hydroxyanthraquinones), such as hypericin and pseudohypericin. Also present is an essential oil containing considerable amounts of aliphatic compounds such as 2-methyloctane, nonane, undecane, octanal and decanal. Other constituents include some common phenolic components (catechins, leucoanthocyanins, chlorogenic acids, condensed tannins) and flavonoids (quercetin glycosides: rutin, quercitrin, hyperin).

Hypericin and pseudohypericin are present in *H. perforatum* and many other species, but are not found in the South-East Asian *H. ascyron*, *H. japonicum* and *H. monogynum*, while results are not clear for *H. patulum*. The pharmacology of hypericin and pseudohypericin has been well investigated. Strong antiviral properties against retroviruses, such as the HIV-1, influenza and cytomegalo viruses has been shown, with no toxic side-effects at therapeutic doses. In this respect, hypericin seems to be more potent than pseudohypericin and clinical trials have been initiated on this compound. At molecular level, hypericin and pseudohypericin specifically inhibit protein kinase C (PKC), having IC_{50} levels of respectively 1.7 μg/ml and 15 μg/ml. Thus, the anti-retroviral activity could be attributable to phosphorylation re-

actions being inhibited by the PKC occurring during viral infection of cells. In addition to the antiviral activity, antiproliferative activity against mammalian cells (possibly due to PKC inhibition) has been reported in the literature.
The ingestion of hypericin or pseudohypericin (or their biosynthetic precursors proto-hypericin/proto-pseudohypericin) and subsequent exposure to UV light (λ 320 nm) may cause photodermatitis. Therefore, exposure to the sun must be avoided after using *Hypericum*-based drugs. In animals, this syndrome is called 'hypericism'. Symptoms are swelling of the face, itches, loss of hair, appearance of sores and eventually apoplexy and death.
In Europe, extracts of *H. perforatum* are well known as an antidepressant. In several clinical trials of mild and moderate depressions they have been reported to be as effective as standard medications (e.g. using tricyclic antidepressants), but with far fewer side-effects. An antidepressant activity of *H. patulum* has also been reported in the literature. It remains unclear whether the antidepressant activity is related to the content of hypericin/pseudohypericin. Experiments with purified substances have not given unambiguous results, and tentative investigations of the extracts indicate that other compounds (e.g. flavones) might also play a role.
Several antimicrobial phloroglucinol derivatives (saroaspidin A, B and C, sarothralen A, B, C and D, sarothralin, and sarothralin G) have been isolated from *H. japonicum*. Of these compounds, sarothralin and sarothralin G have the strongest activity against gram-positive bacteria e.g. *Staphylococcus aureus*, *Bacillus cereus*, and *Nocardia gardneri*. In addition to the phloroglucinols, lactones and flavonoids have also been isolated. Furthermore, the phloroglucinol derivative japonicine A (from *H. japonicum*) is reported to show antimalarial activity in mice. Acetone extracts of the leaves of *H. papuanum* showed antibacterial activity against *Staphylococcus aureus*.
Aqueous plant extracts of *H. japonicum* (10 mg/ml) have been found to have strong in vitro antiviral activity against the herpes simplex virus HSV-II, whether administered simultaneously (simultaneous addition of extract and virus to the cell bottle) or therapeutically (virus inoculated into the cell bottle, later followed by addition of the extract). Methanolic plant extracts of *H. uralum* have shown antiviral activity against 3 mammalian viruses: herpes simplex, Sindbis and polio. The activity was not enhanced by UV light, which suggests that antiviral compounds other than the naphthodianthrones (hypericin, pseudohypericin) are present.

Description Herbs or shrubs, sometimes small trees, usually glabrous; branchlets terete or 2–4-lined or -angled. Leaves opposite or rarely whorled, simple and entire, with translucent glands and/or black or red glands, sessile or shortly petiolate. Inflorescence a terminal dichasium or monochasium. Flowers bisexual, (4–)5-merous; sepals quincuncial or rarely decussate, coriaceous to chartaceous, glandular; petals yellow to orange, sometimes tinged or veined red, glandular, glabrous, persistent or deciduous; stamens in epipetalous fascicles, free or variously united, glabrous, persistent or deciduous, each fascicle with up to 70 stamens, filaments yellow, slender, anthers short, oblong, yellow or reddish, dorsifixed or apparently basifixed; ovary superior, 3–5-celled or 1-celled with (2–)3–5 parietal or axile placentas, ovules 2–many on each placenta, styles (2–)3–5, free to united, slender, stigmas small. Fruit a (2–)3–5-valved capsule. Seeds 1–many on each placenta, curved cylindrical to ellipsoid, sometimes carinate or winged; embryo cylindrical, straight or curved, with cotyledons usually shorter than hypocotyl. Seedling with epigeal germination; cotyledons leafy, sessile, glabrous; hypocotyl short, epicotyl very short.

Growth and development *Hypericum* includes species with very different habits, from herbs to small trees. The arrangement of stamens in the flowers, with the innermost shorter and not attaining the level of the stigmas favours cross-pollination. The flowers are typically visited by less-specialized insects such as *Diptera*. Usually seeds are shed by septical dehiscence of the capsule. Seed from *Hypericum* growing in damp or marshy locations may possibly adhere to the feet and feathers of wading birds and waterfowl and be dispersed thus.

Other botanical information *Hypericum* is closely related to *Cratoxylum* (from a different tribe). The tribes *Vismieae*, *Cratoxyleae* and *Hypericeae* together constitute the subfamily *Hypericoideae*. As this subfamily forms a natural group, in the past it was often given family ranking (*Hypericaceae*), but nowadays it is usually classified within the large family *Guttiferae* (*Clusiaceae*). *Hypericum* has been further divided into no fewer than 30 sections.

Ecology In the tropics, *Hypericum* is generally a high-altitude genus, though some species are sometimes found at low elevations. In temperate regions, it is found in widely varying conditions, but never in very arid habitats. In South-East Asia, *Hypericum* is found in forest margins, grassland, marshes or among rocks. It occurs from sea-level in Sumatra up to 3400 m in New Guinea, but is rarely found in the lowlands.

Propagation and planting *Hypericum* can be propagated by seed, cuttings, division or suckers. *H. monogynum* is propagated by division. Light is essential for germination of seed.

Handling after harvest Whole plants can be used fresh or dried.

Genetic resources and breeding Wild *Hypericum* hybrids have been found, but only between closely related species. Artificial hybrids are always sterile and usually weak, though some crosses have thrived.

Prospects *Hypericum* extracts have shown strong antiviral, antidepressant and antimicrobial activity, with limited toxic side-effects. Because of these promising medicinal properties, *Hypericum* may become important in the future. However, chemical and medicinal properties vary between species and there is very little information on the presence of active compounds in South-East Asian *Hypericum* species.

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Selection of species

Hypericum gramineum G. Forster

Fl. ins. austr. prodr.: 53 (1786).

Synonyms *Hypericum involutum* (Labill.) Choisy (1821).

Distribution From India, Vietnam, Taiwan, and China (Yunnan), to Australia, New Zealand and New Caledonia. In Malesia only in New Guinea.

Uses In Papua New Guinea, Simbu province, the leaves are chewed with traditional ash salt daily to treat malarial fever.

Observations Perennial or annual herb, (3–)5–72 cm tall, with erect or decumbent stems, branching strictly from the base or unbranched, not rooting; leaves usually lanceolate to linear or oblong, 4–25 mm × 1–8 mm, with 1–3 basal veins, without reticulate venation, laminar glands pale, sessile; inflorescence lax, 1–30-flowered; flowers (5–)6–12(–15) mm in diameter, sepals 2.8–7.5(–9) mm × 0.8–2 mm, free, 3–5 veined, often with prominent midrib, laminar glands pale, petals 5–10 mm × 2–5 mm, persistent, pale yellow to orange, without glands, stamens 30–50, ovary 1-celled, placentas 3, parietal, styles divergent; fruit narrowly ovoid to cylindrical; seeds minute, cylindrical, longitudinally ribbed with striae, not carinate. *H. gramineum* is found in humid to dry localities, but always in open and well-drained habitats, from sea-level to 2600 m altitude.

Selected sources 600, 1238, 1243.

Hypericum japonicum Thunb. ex Murray

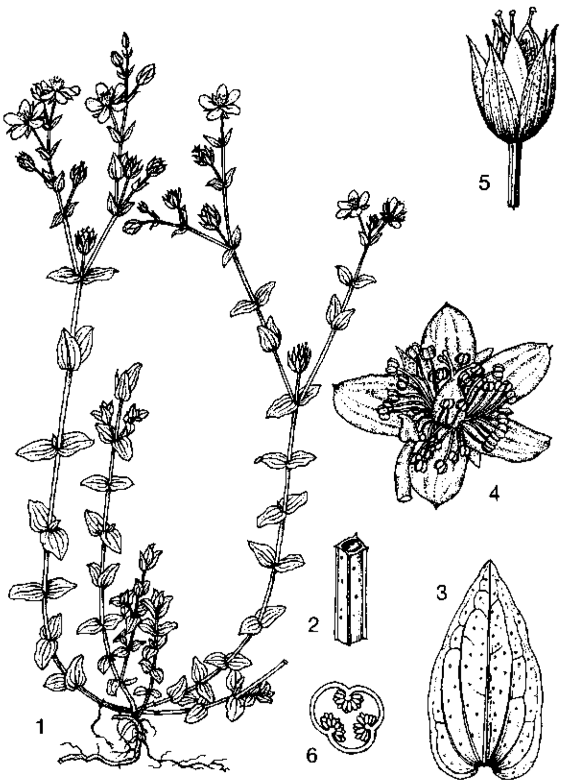
Syst. veg. ed. 14: 702 (1784).

Synonyms *Hypericum pusillum* Choisy (1821), *Hypericum mutilum* Maxim. (1881) non L., *Sarothra japonica* (Thunb. ex Murray) Y. Kimura (1951).

Vernacular names Papua New Guinea: ngotokong (Mt Hagen, Western Highlands). Vietnam: n[ojc] s[owrl]i c[or] ban, di[eef]n c[ow] ho[af]ng.

Distribution From Japan, South Korea and south-eastern China, Nepal, India and Sri Lanka to Australia, New-Zealand and Hawaii. *H. japonicum* occurs throughout Malesia, Indo-China and Thailand.

Uses Generally, *H. japonicum* is thought to have astringent and alterative action, and it is used externally to treat swellings, abscesses, scrofula and fungal skin diseases. In Malaysia, it is applied externally to treat wounds. In Papua New Guinea, crushed plants are reported to be used internally against malaria, together with ginger and ash salt. In Vietnam, *H. japonicum* is used internally as stomachic and externally as vulnerary on wounds, leech and snake bites, and to treat caries and bad breath. In Chinese medicine, it is applied as vulnerary on wounds and leech bites, and to treat bacterial diseases, hepatitis and tumours.



Hypericum japonicum Thunb. ex Murray – 1, plant habit; 2, detail of stem; 3, leaf; 4, flower; 5, dehisced capsule; 6, ovary in cross-section.

Observations An extremely variable annual herb, 2–50 cm tall, with erect to decumbent or prostrate stems rooting at the base; leaves usually ovate or ovate-triangular to oblong or elliptical, 2–18 mm × 1–10 mm, chartaceous, lower side sometimes glaucous, with 1–7 basal veins, usually without reticulate venation, laminar glands pale, sessile; inflorescence lax, 1–30-flowered; flowers 4–8 mm in diameter, sepals 2–5.5 mm × 0.5–2 mm, free, 3–5-veined, often with prominent midrib, laminar glands pale, petals 1.7–5 mm × 0.8–1.8 mm, persistent, pale yellow to orange, without glands, stamens 5–30, in 5 irregular groups, ovary 1-celled, placentas 2–3, parietal, styles divergent, broadening to capitate stigmas; fruit cylindrical to globose, 2–6 mm long; seeds minute, cylindrical, longitudinally ribbed with striae, not carinate. *H. japonicum* is found in wet or marshy to dry localities, but always in exposed places, from sea-level up to 3400 m altitude.

Selected sources 97, 202, 456, 597, 655, 656, 657, 658, 1035, 1126, 1128, 1238, 1239, 1240, 1241, 1242, 1243, 1476, 1513, 1655.

Hypericum monogynum L.

Sp. pl. ed. 2: 1107 (1763).

Synonyms *Hypericum chinense* L. (1759) non Osbeck.

Vernacular names Vietnam: ban.

Distribution Native to south-eastern China and Taiwan, now cultivated in many parts of the world, including Java and Sulawesi.

Uses In Indo-China, the green twigs and leaves are made into a paste, which is used to treat dog bites and bee stings. In India, *H. monogynum* is considered astringent and alterative and it is used to treat diarrhoea and vomiting.

Observations A bushy shrub, 50–130 cm tall, with spreading branches; leaves elliptical or oblong to oblanceolate, 2–4.5 cm × 1–1.8 cm, lower side paler, with 4–6 main lateral veins and dense reticulate venation, glands pale, sessile or petiolate; inflorescence corymbose, 1–15-flowered; flowers 3–5 cm in diameter, sepals 4.5–10 mm × 1.5–3 mm, free, glands all pale, petals 20–30 mm × 12.5–15 mm, caducous, golden yellow to lemon yellow, glands pale, stamens in 5 fascicles, each with 25–35 stamens, caducous, ovary 5-celled, placentas 5, axile, styles 5, united almost to the apex, stigmas small; fruit broadly ovoid or ovoid-conical to subglobose, 6–10 mm long; seeds minute, cylindrical, curved, narrowly carinate, shallowly linear-reticulate to linear-foveolate. In Malesia, *H. monogynum* is only found as a cultivated ornamental, up to 1800 m altitude.

Selected sources 287, 1128, 1238, 1239, 1240, 1241.

Hypericum papuanum Ridley

Trans. Linn. Soc. II, Bot. 9: 19 (1916).

Synonyms *Hypericum helwigii* Laut. (1922), *Hypericum habbemense* A.C. Smith (1941).

Vernacular names Papua New Guinea: enaime (Tauade, Central Province).

Distribution New Guinea, where it is widespread in the mountainous regions.

Uses The leaves are reported to be used in New Guinea to treat sores.

Observations A very variable woody herb or shrub, 10–130 cm tall, branches often creeping and rooting at the base; leaves narrowly ovate to elliptical or subcircular, 0.6–2.5 cm × 0.3–1.7 cm, concolorous, with 4–6 main lateral veins and reticulate venation, laminar glands pale, intramarginal glands pale or (partly) black, sessile; inflorescence 1-flowered; flowers 1.8–2 cm in diameter, sepals 3–8 mm × 1–3.5 mm, free, foliaceous, laminar glands pale, submarginal glands black or absent, petals 9–15 mm × 4–9 mm, persistent, bright yellow, laminar glands pale, marginal glands black or absent, stamens (15–)25–40(–50), not clearly in fascicles, persistent, ovary ovoid, placentas 3(–5), parietal, styles 3(–5), divergent, stigmas capitate; fruit ovoid to ellipsoid, 5–10 mm long, longitudinally striped; seeds minute, cylindrical or subcylindrical, scarcely carinate, densely linear foveolate to scalariform. *H. papuanum* is found in wet to dry alpine grasslands, bogs, and screes at 1800–3800 m altitude.

Selected sources 597, 827, 1238, 1239, 1240, 1241.

Hypericum uralum Buch.-Ham. ex D. Don

Bot. Mag.: t. 2375 (1823).

Synonyms *Norysca urala* (Buch.-Ham. ex D. Don) K. Koch (1853), *Hypericum patulum* Thunb. var. *uralum* (Buch.-Ham. ex D. Don) Koehne (1893).

Distribution Nepal, northern India, Burma (Myanmar), China, Thailand and northern Sumatra.

Uses No reports have been found of medicinal use in South-East Asia, but in Nepal the root juice is used against fever.

Observations A shrub, 120–180 cm tall, branches arching, sometimes frondose; leaves lanceolate to ovate, 1–4.5 cm × 0.5–2.5 cm, lower side very glaucous, with 3 main lateral veins and pale glands, subsessile or petiolate; inflorescence corymbose, racemiform, 1–3(–10)-flowered; flowers 1.5–3 cm in diameter, sepals 3.5–9 mm × (1–)2–6.5 mm, free, glands pale, petals 9–18 mm × 5–12 mm, caducous, bright yellow to golden yellow, glands pale, stamens in 5 fascicles, each with 40–60 stamens, caducous, ovary 5-celled, placentas 5, axile, styles 5, free, stigmas narrowly capitate; fruit subglobose to globose, 7–11 mm long; seeds minute, cylindrical-ellipsoid, not curved, slightly carinate, shallowly linear-reticulate. The Sumatran form tends to be more luxuriant and to have larger flowers than plants from elsewhere. *H. uralum* is found in grassy or rocky slopes, in pastures, thickets, open woodland and montane forest at 1700–3300 m altitude.

Selected sources 1238, 1239, 1240, 1241, 1442.

M. Brink

Imperata Cirillo

Pl. rar. neap. 2: 26, t. 11 (1792).

GRAMINEAE

$x = 5$; *I. cylindrica*: $2n = 20$

Major species *Imperata conferta* (J.S. Presl) Ohwi, *I. cylindrica* (L.) Raeuschel.

Vernacular names Cogon grass (En). Indonesia: alang-alang. Philippines: kogon.

Origin and geographic distribution *Imperata* comprises about 8 species, occurring in tropical and subtropical regions. *I. conferta* and *I. cylindrica* are found throughout the Malesian region.

Uses The uses (including medicinal) of *I. cylindrica* and *I. conferta* are very similar and both are in general used indiscriminately. *I. cylindrica* is reported to be used in various countries in South-East Asia for a wide range of medical problems such as fever, nausea, dropsy, jaundice, asthma, haematura, influenza, internal haemorrhages, nose bleeding, cough and kidney diseases. A decoction of the rhizome is commonly applied to purify the blood, as a diuretic and in the treatment of diarrhoea and dysentery.

Both *Imperata* species are an important source of roofing material, readily available and durable. When young, they may be used as fodder for ruminants. Both species have been used for making paper. The aggressive rhizomatous growth makes them suitable for erosion control and stabilizing slopes, despite their weedy characteristics.

Production and international trade *Imperata* is used only locally and has no importance in international markets.

Properties The rhizomes of *I. cylindrica* contain the biphenyl ethers cylindol A and B, the phenolic compound imperanene, the sesquiterpenoid cylindrene, and the lignans graminone A and B. Cylindol A has shown 5-lipooxygenase activity, which may be partly involved in the reputed anti-inflammatory activity of *I. cylindrica*. Imperanene has shown inhibitory activity against rabbit platelet aggregation. Cylindrene and graminone B have shown inhibitory effects on rabbit aorta contraction. *I. cylindrica* has also been found to contain 5-hydroxytryptamine (serotonin) and the triterpenoids arundoin, cylindrin, fernenol, isoarborinol and aimiarenol. The rhizome has been found to contain 19% sugars (saccharose, dextrose, fructose, xylose) and various acids (including malic, citric, tartaric, chlorogenic, coumaric and oxalic acid). An aqueous extract of stem and leaves is reported to have shown some antitumour activity against sarcoma 180 and adenocarcinoma 75 in mice. Although *I. cylindrica* is widely considered to have diuretic properties, this could not be confirmed in a recent double blind study. Besides the above pharmacological activities, antiviral, antihepatotoxic, antihistamine and larvicidal activities are also reported.

Description Rhizomatous, herbaceous, unbranched perennials up to 150(–300) cm tall, with deep, branched, fleshy rhizomes; culms with solid internodes. Leaves mostly basal, leaf sheath non-auriculate, with a fringed membranous ligule; leaves sometimes pseudopetiolate, without cross venation, persistent. Inflorescence a spiciform panicle, cylindrical; spikelets paired, homologous, bisexual, 3–6 mm long, 2-flowered, at the base with a dense whorl of silky white hairs, unequally pedicellate in each pair; glumes 2, more or less equal; lower floret reduced to a hyaline lemma; upper floret fertile, stamens 1–2, ovary glabrous. Fruit an ellipsoidal caryopsis, about 1 mm long, brown.

Growth and development *I. cylindrica* is a prolific seed producer and the light seeds are readily dispersed by wind. There is no dormancy and seeds may give 95% germination within one week after fruit maturation. The optimum temperature for growth is about 30°C with negligible growth at 20°C and 40°C. Some individual plants flower frequently, some never flower, and others are intermediate. The rhizomes are highly competitive and penetrate the roots of other plants, causing rot or death. In a controlled greenhouse experiment young plants initiated new rhizomes between the third and fourth leaf-stages. Rhizome growth is determinate, with the apical bud forming a shoot and sub-apical buds forming rhizome branches. Under favourable conditions apical and sub-apical buds develop simultaneously, but under stress the growth of the apical bud is favoured. Roots and buds develop at the distal nodes of the young rhizome long after the rhizome has been formed. Flowering is in general promoted by burning, and follows a few weeks after the fire.

Other botanical information *Imperata* is divided into two sections, based on the number of stamens: section *Imperata* (2 stamens) with only 1 species (*I. cylindrica*), and section *Eriopogon* Endl. (1 stamen). A number of varieties have been described for *I. cylindrica*, often pertaining to geographical regions. However, as these varieties more or less intergrade, the distinction is at present generally ignored.

Ecology *I. cylindrica* is often found in areas receiving more than 1000 mm rainfall/year, but has been recorded in sites receiving 500–5000 mm annual rainfall. It can withstand waterlogging but not continuous flooding. It grows at altitudes from sea-level up to 2000 m in several countries and has been recorded at 2700 m in Indonesia. Whereas *I. cylindrica* may have originally been restricted to infertile and acid soils in the tropics, it has become widespread through man's intervention, particularly following slashing and burning of forest lands. Its resistance to burning is associated with its vigorous underground rhizomes, but seedlings also establish after burning. It is found in a wide range of habitats, including the dry sand dunes of seashores and deserts, as well as swamps and river valleys. It grows in grassland, cultivated areas, and plantations. It quickly invades abandoned farmland and occurs on railway and highway embankments and in deforested areas. It is regarded as a light-loving plant and will not persist under heavy shade in plantations. Although it grows in a wide range of soil types of widely differing fertility, it grows most vigorously in wet soil of reasonable fertility. It has been reported to grow on soils with pH 4.0–7.5. It can even tolerate very hot, steamy and sulphurous conditions near an active volcanic fumarole or vent. *I. cylindrica* is reported to have allelopathic properties that adversely affect the growth of other plants.

Propagation and planting *Imperata* is seldom propagated deliberately, but spreads by rhizomes and seed. Rhizomes accidentally cut by cultivation can reestablish from pieces with as few as 2 nodes.

Husbandry *Imperata* is favoured by burning, which can lead to virtually monospecific swards. If it is to be used for thatching, swards are left ungrazed until after the mature growth has been removed. It can be eliminated by heavy continuous grazing; vigour will be reduced by close, frequent cutting and rhizomes can be destroyed by frequent intensive cultivation. It has been suggested that *I. cylindrica* that is used regularly for grazing should be grazed rotationally when 15–25 cm high. Because of its aggressiveness and low quality as forage, *I. cylindrica* is widely regarded as a weed. It is considered to be one of the most pernicious weeds in South-East Asia. In Indonesia, it is considered to be one of the three most important weeds (the others being *Echinochloa crus-galli* (L.) P. Beauv. and *Monochoria vaginalis* (N.L. Burmann) Kunth), and to be the single most important weed in perennial crops.

Harvesting *Imperata* is either grazed when young or cut for thatch when mature. To collect the medicinally important rhizomes, plants are simply uprooted.

Yield Reported above-ground dry matter yields of *I. cylindrica* are 2–11 t/ha per year. In Indonesia per ha production was found to be 11 t of leaves and 7 t of rhizomes, with on average 4.5 million shoots.

Genetic resources and breeding *Imperata* is widespread and common throughout Malesia, in general favoured by human activities, and therefore certainly not endangered. There are no known breeding programmes on *Imperata*.

Prospects Although *Imperata* is widely considered a serious weed, it can be useful for various purposes, especially to provide fodder when young and thatching material when mature. A broad range of medicinal uses has been reported, but most claims still need to be validated, though compounds that have shown vasodilative activity, anti-inflammatory properties or inhibition of platelet aggregation have been isolated.

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Selection of species

Imperata conferta (J.S. Presl) Ohwi

Bot. Mag., Tokyo 55: 549 (1941).

Synonyms *Saccharum confertum* J.S. Presl (1830), *Imperata exaltata* (Roxb.) Brongn. (1831).

Vernacular names Malaysia: lalang jawa. Philippines: kogon-lake (Tagalog), gogon (Bikol), kogon (Tagalog, Bisaya, Sulu). Vietnam: c[or] lau.

Distribution *I. conferta* is found throughout South-East Asia in habitats similar to *I. cylindrica*, but it is less common.

Uses In the Philippines a decoction of the rhizomes is drunk against diarrhoea caused by indigestion and against gonorrhoea. The leaves are often used for thatching and the young shoots are grazed. The plants are sometimes used to make hats and mats. Experiments have shown that they can be used to make good paper.

Observations A rhizomatous, herbaceous perennial up to 200 cm tall, culms glabrous or with a few hairs below the nodes; leaf sheaths of basal leaves glabrous, leaf blade 30–80 cm × 0.7–2 cm, scabrid, glabrous; inflorescence a spiciform panicle 25–50 cm long, floret with upper glume 3–4-veined, stamen 1. *I. conferta* is found in a wide range of open, disturbed anthropogenic habitats from sea-level up to 1000 m altitude, but in the Philippines in general preferring forest clearings at higher elevations.

Selected sources 97, 172, 190, 202, 577, 580, 630, 1178, 1386.

Imperata cylindrica (L.) Raeuschel

Nomencl. bot., ed. 3: 10 (1797).

Synonyms *Lagurus cylindricus* L. (1759), *Imperata arundinacea* Cirillo (1792).

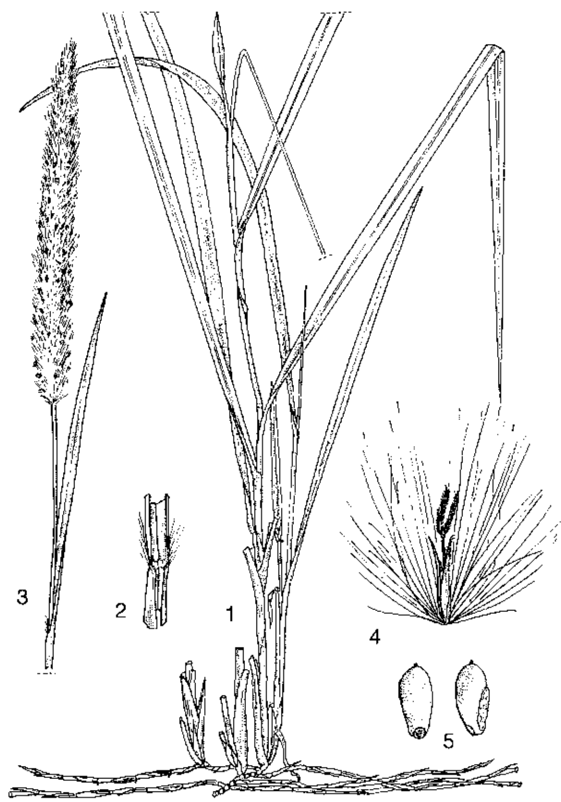
Vernacular names Cogon grass, satintail (En). Paillotte (Fr). Indonesia: alang-alang, ilalang, lalang (general). Malaysia: lalang, alang-alang. Papua New Guinea: kunai (Pidgin), kurukuru (Barakau, Central Province). Philippines: kogon (Tagalog), gogon (Bikol), bulum (Ifugao). Burma (Myanmar): kyet-mei. Cambodia: sbö':w. Laos: hnha:z kh'a:. Thailand: ya-kha, laa laeng, koe hee (Karen, Mae Hong Son). Vietnam: c[or] tranh.

Distribution Widely distributed throughout the tropics and subtropics of Africa, the Indian subcontinent, South-East Asia and Australia; occurring to a lesser extent in North, Central and South America, and also occurring in warm temperate areas, being recorded at latitudes of 45° in New Zealand and Japan.

Uses Rhizome decoctions of *I. cylindrica* are used as a diuretic in Indonesia, Malaysia, Thailand, Indo-China and China. A rhizome decoction is used to treat dysentery in the Philippines and to treat diarrhoea and gonorrhoea in Malaysia. In Malaysia and Papua New Guinea, rhizome decoctions are used to purify the blood. Furthermore, *I. cylindrica* is administered in the treatment of nose, kidney and bladder complaints in Papua New Guinea, and the shoots are chewed to treat diarrhoea. In Brunei, a root decoction is used as febrifuge. In Indo-China and by Chinese throughout the South-East Asian region the rhizomes are considered haemostatic and cooling and are prescribed as a general tonic as well as in cases of acute nephritis, hypertension, epistaxis and haemoptysis. The flowers or sprouts are reported to be thirst-relieving and digestive, and are used in the treatment of haemorrhages and wounds. In the Philippines the fruiting spikes are considered a vulnerary and sedative. The rhizomes contain a fair amount of starch and a kind of beer can be made from them. The leaves are often used for thatching and the young shoots are grazed. The plants are sometimes used to make hats and mats. Experiments have shown that they can be used to make good paper.

Observations A rhizomatous herbaceous perennial up to 120(–300) cm tall, culms below the nodes usually with a crown of long slender hairs; leaf sheaths of basal leaves coriaceous, glabrous or finely hairy, leaf blade 12–80 cm × 0.5–2 cm; inflorescence a spiciform panicle 10–30 cm long, floret with upper glume 4–5-veined, stamens 2. *I. cylindrica* is found in a wide range of open anthropogenic habitats, prefering well-aerated soils, from sea-level up to 2700 m altitude.

Selected sources 89, 97, 172, 190, 202, 287, 332, 362, 401, 404, 474, 572, 577, 580, 597, 614,



Imperata cylindrica (L.) Raeuschel – 1, plant habit; 2, ligule; 3, inflorescence; 4, spikelet; 5, caryopsis in front and side view.

630, 1035, 1043, 1126, 1178, 1375, 1385, 1386, 1571.

Juliana Jonathan & Bambang P.J. Hariadi

Ixora L.

Sp. pl. 1: 110 (1753); Gen. pl. ed. 5: 48 (1754).

RUBIACEAE

x = 11; *I. chinensis*, *I. coccinea*, *I. javanica*, *I. nigricans*: $2n$ = 22

Major species *Ixora chinensis* Lamk, *I. coccinea* L., *I. javanica* (Blume) DC., *I. longifolia* J.E. Smith, *I. nigricans* R.Br. ex Wight & Arn.

Vernacular names Indonesia: soka (general), ki soka (Sundanese), areng-arengan (Javanese). Malaysia: pechah priok, jarum-jarum, todong periok (Peninsular). Philippines: santan (Tagalog). Burma (Myanmar): ponna, pan. Cambodia: chann tanea, tè prey. Thailand: kheme (general). Vietnam: d[ow]n, b[oo]ng trang.

Origin and geographic distribution *Ixora* consists of about 400 species, and is distributed throughout the tropics. The Indo-Malesian region is richest in species. In Malesia about 160 species occur; the highest number of species (about 65) is found in Borneo, most of them endemic.

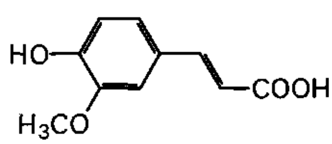
Uses Several *Ixora* species are used in traditional medicine, e.g. as an astringent and to treat dysentery and tuberculosis. The use in China and India is widespread. An infusion of the leaves or flowers of several species is administered to treat fever, headache and colic. A decoction of the roots is used as a sedative; the roots are believed to be more potent. The internal application is based on stomachic and antiseptic properties, while external applications are based on astringent and antiseptic properties.

Ixora species are well known as ornamentals (e.g. *I. chinensis*, *I. coccinea*, *I. javanica*), and are commonly planted in gardens, parks and along roadsides. The fruits of *I. philippinensis* Merr. are edible. The wood of *Ixora* is occasionally used, often for implements and comparatively small objects; only a few species reach timber size.

Properties In a modified tumour promotion test, complete inhibition of all kinds of tumours was exhibited by decoctions of flowers of *I. coccinea* and *I. chinensis*. The antitumour factor from *I. javanica* flowers showed broad activity against transplantable solid tumours in mice by inhibiting the growth of tumours and arresting the growth of already formed tumours; it showed lesser activity against ascites tumours. In vitro studies showed 50% cytotoxicity to Dalton's lymphoma and Ehrlich ascites tumour cells at concentrations of 12 μg and 65 μg, respectively, with no activity against normal lymphocytes but preferential activity against lymphocytes derived from leukaemia patients and K 562 suspension cell culture. Topical application of 100 mg/kg body weight of *I. javanica* flower extract inhibited the growth and delayed the onset of papilloma formation in mice initiated with 7,12-dimethylbenz-α-anthracene (DMBA) and promoted by using croton oil. When administered orally at the same dose the extract significantly inhibited the growth of soft tissue fibrosarcomas induced by subcutaneously injected 20-methylcholanthrene. Oral administration of 200 mg/kg of the extract inhibited the growth of intraperitoneally transplanted sarcoma-180 and Ehrlich ascites carcinoma tumours and also showed an increase in the life span of the treated mice. Toxicity studies showed that the blood urea nitrogen levels were elevated after treatment. Furthermore, tritiated thymidine incorporation studies indicated that the mechanism of action of the factor is at the site of DNA synthesis. The purified fractions contained ferulic acid, pyrocatechuic acid and caffeic acid. The compounds responsible for the inhibitory effects on tumour growth were identified as ferulic acid (4-hydroxy-3-methoxycinnamic acid) and its structural isomer, 3-hydroxy-4-methoxycinnamic acid.

Antimutagenity tests with *I. coccinea* by the Rec-Assay and the Micronucleus Test revealed that the crude alcoholic extract and the ethyl acetate fraction showed antimutagenic activity. Fractions obtained from the ethyl acetate extract were found to be antimutagenic against a known carcinogen, 4-nitroquinoline, in two *Bacillus subtilis* strains. After purification the antimutagenic fraction was identified by spectroscopic methods as ursolic acid. The activity of the isolated compound was confirmed by the Rec-Assay.

The saponifiable fraction of the petroleum ether extract of *I. coccinea* root was found to have anti-inflammatory activity in carrageen-induced paw oedema in albino rats. The ethanol (50%) extract of the aerial parts potentiates barbiturate activity and causes semen coagulation. The same type of



ferulic acid

extract of aerial parts of *I. nigricans* showed antiviral and hypothermic activities.

The roots of *I. coccinea* contain an acrid aromatic oil, tannin, fatty acids, and a white crystalline substance. The root bark contains δ-9,11-octadecadienoic acid, mannitol and myristic acid. The flowers have a yellow colouring matter related to quercitrin, an astringent principle, wax, and a neutral crystalline substance. The roots of *I. chinensis* also contain an iridoid derivative called ixoside (1,8-dehydroxyforsythide).

Description Shrubs to small or sometimes medium-sized trees up to 25 m tall; bark surface smooth, lenticellate, fissured or scaly, greyish-brown; twigs terete, often with series of rather close, leafless nodes especially at branching points. Leaves opposite or sometimes in whorls of 3, simple, entire, broadly elliptical to linear, herbaceous to coriaceous, base usually acute or cuneate, apex obtuse to acute, acuminate or caudate, almost always glabrous; petiole usually present, concave or canaliculate; stipules interpetiolate, connate at base, distinctly cuspidate or with a long, stiff, needle-like extension at the tips. Inflorescence a terminal corymb or corymbose panicle, peduncle short with an erect inflorescence or longer with a nodding or pendulous inflorescence, often puberulous or pubescent, usually 45–300-flowered. Flowers often 3 together, bisexual, 4-merous, fragrant or not, protandrous; calyx often divided to the base; corolla with a cylindrical tube, lobes contorted in bud, spreading and flat or reflexed in the open flower, often white but sometimes pink, yellow or red; stamens inserted at corolla throat, with short filaments, anthers dorsifixed, sagittate and reflexed, usually yellow; disk annular; ovary inferior, 2(–3)-locular with 1 ovule per cell, style filiform, slightly exserted from the corolla tube, the exserted part not longer than the corolla lobes, stigma 2-lobed, the lobes linear and recurved. Fruit a globose to 2-lobed drupe, 5–15 mm in diameter, ripening red to black, with 1–2 pyrenes; pyrenes 1-seeded, thin-walled, plano-convex, with a round excavation inside. Seed with thin testa, endosperm entire. Seedling with epigeal germination; cotyledons leafy, green.

Growth and development Malesian *Ixora* species are generally evergreen. Flowering is seasonal but cultivars may bloom throughout the year. The flowers are mainly pollinated by moths and butterflies probing for the nectar at the corolla base, but honey-suckers may also visit the flowers, particularly the reddish ones. The seeds are probably dispersed by fruit-eating birds.

Other botanical information As a rule the Malesian *Ixora* species have a rather local distribution. *I. nigricans* is an exception, ranging from India to Bali. Many of the species in Java are endemic, as are most of the Bornean species. The New Guinean species are all endemic.

Pavetta closely resembles *Ixora*, but can be distinguished by its long-exserted style with coherent stigmas, whereas the anthers are conspicuously twisted. The differences between the widely cultivated *I. chinensis* and *I. coccinea* are sometimes obscure as a result of selection for rare or extreme forms. Accidental or deliberate hybridization appears to occur.

Ecology *Ixora* species are usually confined to lowland and lower montane forest up to 1700 m altitude. Some species are also found in swampy locations in the vicinity of rivers or occasionally in rice fields (e.g. *I. grandifolia*).

Propagation and planting *Ixora* may be propagated by seed, although ornamental species are usually propagated by cuttings. Both seeds and sown fruits of *I. lobbii* have been found to have about 25% germination in 1–3 months. Treating *I. coccinea* cuttings of 15 cm long by dipping them in indole butyric acid at 2000 ppm for 10 seconds, gave a rooting success of 87%, the development of a high number of primary roots and a survival of 96%. This was considerably better than the performance of untreated cuttings: only 40% rooting success and 67% survival.

Genetic resources and breeding The high incidence of endemism in *Ixora* may increase the risk of genetic erosion. However, the species with a reported medicinal use have a relatively large area of natural distribution or are widely cultivated.

Prospects The reported antitumour and antimutagenic activities of *Ixora* may justify more research, which might result in future applications in modern medicine. Moreover, several species are attractive ornamentals.

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Selection of species

Ixora chinensis Lamk

Encycl. 3: 344 (1789).

Synonyms *Ixora stricta* Roxb. (1820).

Vernacular names Chinese ixora (En). Indonesia: kembang soka, siantan. Malaysia: jarum-jarum merah, pechah priok, siantan hutan (Peninsular). Philippines: santan (Tagalog, Bikol), santan-pula, santan-tsina (Tagalog). Cambodia: kam rontea. Vietnam: d[ow]n d[or], b[ooj]ng trang d[or].

Distribution Southern Burma (Myanmar), Vietnam, Peninsular Malaysia, Borneo; cultivated in Java, the Philippines and elsewhere.

Uses In Malaysia a decoction of the root is used after childbirth. In the Philippines an infusion of the fresh flowers is said to be a remedy against incipient tuberculosis and haemorrhage. An infusion of leaves or flowers is used against headache. In Indonesia, a decoction of the roots is used against bronchial disorders; a decoction of the flowers is prescribed in amenorrhoea and hypertension. *I. chinensis* is widely cultivated as an ornamental.

Observations A shrub with many stems, up to 2 m tall; leaves obovate-oblong, 6–10 cm × 2.5–5 cm, coriaceous, base rounded, cordate or sometimes obtuse, apex obtuse, petiole short, stipules long-awned; branchlets of inflorescence opposite, red; flowers with corolla tube 3–3.5 cm long, lobes circular-obovate, broadly rounded at apex, 6 mm × 6 mm, orange-red or white (cultivated plants only), not fragrant; fruit globose, black. *I. chinensis* is reportedly common on river banks in Peninsular Malaysia.

Selected sources 97, 182, 202, 427, 625, 768, 1126, 1178, 1227, 1572, 1591.

Ixora coccinea L.

Sp. pl. 1: 110 (1753).

Synonyms *Ixora montana* Lour. (1790), *Ixora grandiflora* Loddiges (1819).

Vernacular names Red ixora (En). Indonesia: soka merah (general), kembang santen merah (Malay), soka beureum (Sundanese). Philippines: santan-pula, santan (Tagalog), tangpupo (Bisaya). Cambodia: kam ron tea. Thailand: khem baan, khem nuu (Bangkok), khem farang (central). Vietnam: b[oo]ng trang d[or], d[ow]n d[or].

Distribution Native in India, widely cultivated in Indonesia, Malaysia, the Philippines, Vietnam, Cambodia, Laos and Thailand.

Uses In the Philippines a decoction of the roots is used as a sedative in the treatment of nausea, hiccups and loss of appetite. The flowers are used in the treatment of dysentery, leucorrhoea and dysmenorrhoea, and a decoction of the flowers is prescribed to treat haemoptysis and catarrhal bronchitis. In Indo-China a decoction or infusion of the roots is administered to clear the urine. A decoction of the root is used in folk medicine as an analgesic, sedative, diuretic and antidysenteric; the flowers have the same but weaker properties. In Thailand, the roots or flowers are used as anti-inflammatory and antidiarrhoeal drugs, astringent, tranquilizer and appetite stimulant. The flowers are also used as cholagogue and stimulant of digestive enzyme secretion. In India the roots are reported to possess sedative and stomachic properties and are used against hiccups, fever, gonorrhoea, loss of appetite, diarrhoea and dysentery. They are reported to stimulate gastric secretions and bile and to provide relief in abdominal pains. The roots possess astringent and antiseptic properties and are applied to sores and chronic ulcers, and also to treat headache. A decoction of the

Ixora coccinea L. – 1, flowering twig; 2, flower; 3, flower as seen from above.

flowers or the bark is employed as a lotion against eye troubles, sores and ulcers. The leaves are used to treat diarrhoea. *I. coccinea* is widely cultivated as an ornamental.

Observations A shrub with many stems, up to 3 m tall, glabrous; leaves ovate to oblong or obovate, 3.5–10 cm × 2–5 cm, coriaceous, base subcordate or rounded, apex obtuse or slightly acuminate, mucronate, with 8–15 secondary veins, petiole absent or short, stipules long-awned; inflorescence sessile, densely corymb-shaped; flowers with triangular calyx lobes, about 3 mm long, acute, red, corolla tube 3–4.5 cm long, lobes lanceolate or ovate-lanceolate, 1–1.5 cm long, acute, orange to scarlet or white, yellow or pink (mostly in cultivated plants), not fragrant, style 3–4 mm exserted, red; fruit globose, about the size of a pea, reddish, fleshy. *I. coccinea* is cultivated in lowland areas but also at higher elevations.

Selected sources 97, 182, 202, 288, 332, 427, 531, 580, 768, 1035, 1126, 1128, 1178, 1227, 1310, 1591.

Ixora grandifolia Zoll. & Moritzi

Syst. Verz.: 65 (1846).

Synonyms *Ixora crassifolia* Ridley (1918), *Ixora ridleyi* Bremek. (1937).

Vernacular names Pink river ixora (En). Indonesia: sikatan (Javanese), ki soka (Sundanese). Malaysia: jarum hutan, segading jantan, kelat tandok (Peninsular). Thailand: khem yai (Bangkok, peninsular).

Distribution Sri Lanka, Burma (Myanmar), Indo-China, Thailand, Peninsular Malaysia, Singapore, Sumatra, Bangka, Java, Madura and Borneo.

Uses In Malaysia a decoction of the root is used to treat ague and colic. The leaves are eaten before childbirth, at the commencement of labour and are considered to make delivery easier. An infusion of leaves is drunk against stomach-ache.

Observations A shrub or small to medium-sized tree up to 18 m tall, bark smooth to lenticellate, fissured or scaly, grey-brown; leaves elliptical, ovate or obovate, 10–32 cm × 4–18 cm, thickly coriaceous, glabrous, base acute, rounded or cordate, apex acute or blunt, with 6–16 secondary veins, petiole 0.5–3.5 cm long, stipules broadly triangular, apiculate; inflorescence subsessile, with 3 main branches, erect, spreading, up to 5 cm long, branches not jointed; flowers long-pedicellate, calyx tube 0.5–1 mm long, lobes triangular and less than 0.5 mm long, corolla tube 0.5–3 cm long, lobes 2.5–6 mm × 1.5–2 mm, white sometimes pink-tipped, fragrant, anthers grey; fruit globose or strongly 2-lobed, up to 12 mm wide, red turning black. *I. grandifolia* occurs in both lowland and hill forest, also on swampy ground.

Selected sources 97, 182, 202, 288, 768, 1126, 1227, 1591.

Ixora javanica (Blume) DC.

Prodr. 4: 487 (1830).

Synonyms *Ixora amoena* Wallich ex G. Don (1834).

Vernacular names Javanese ixora (En). Thailand: khem thong (Chumphon).

Distribution Southern Burma (Myanmar), Thailand, Peninsular Malaysia, Sumatra, Java and Borneo.

Uses There are no medicinal uses reported for *I. javanica*, but extracts showed promising antitumour activity. It is cultivated as an ornamental.

Observations A shrub, 3–5 m tall; leaves elliptical, oblong or oblong-ovate, 7.5–17 cm × 2.5–7 cm, herbaceous, base acute, apex acuminate, with 9–10 secondary veins, petiole 3–6 mm long, stipules long-awned; inflorescence loose, short-haired, peduncle 1–4 cm long; flowers with calyx tube 0.2 mm long, lobes ovate, 0.4 mm long, corolla tube 2.5–3.5 cm long, lobes ovate, obtuse or rounded, 6–8 mm long, orange-red sometimes pink or yellow, not fragrant, anthers pale orange, style 5 mm long slightly exserted; fruit about the size of a pea. *I. javanica* is common in evergreen forest on fertile soils in Java.

Selected sources 97, 182, 768, 1001, 1002, 1591.

Ixora lobbii Loudon

Encycl. pl. new edition: 1543 (1855).

Vernacular names Brunei: petagar mangas. Malaysia: bunga selang, pechah priok, kramat hujan (Peninsular). Thailand: khem daeng (Yala).

Distribution Thailand and Peninsular Malaysia.

Uses In Malaysia a decoction of the root is given during and after childbirth, and a poultice is made from it against headache. In Brunei, a decoction of the root of a plant identified as *I. lobii* is taken as a tonic, or used as a herbal bath.

Observations A shrub up to 2 m tall; leaves entire, oblong to lanceolate, 10–20 cm × 2–4.8 cm, subcoriaceous, base cuneate, apex caudate or mucronate, with 15–25 secondary veins, petiole short, 2–4 mm long, stipules triangular, acuminate; inflorescence a subsessile loose corymb with about 50 flowers; flowers with red pedicel, calyx cylindrical campanulate, corolla tube 3–4 cm long, lobes 9 mm × 3–4 mm, acute, bright orange-red, not fragrant; fruit black. *I. lobbii* is a common shrub in forest throughout Peninsular Malaysia and Thailand.

Selected sources 182, 202, 288, 964, 1126, 1227.

Ixora longifolia J.E. Smith

Rees, Cycl. XIX: n. 3 (1811).

Synomyms *Ixora amboinica* (Blume) DC. (1830), *Ixora fulgens* auct. non Roxb.

Vernacular names Indonesia: jarong-jarong (Moluccas).

Distribution The Moluccas.

Uses The roots have been reported long ago to be used against pain in the side in the Moluccas, both internally and externally; chewing the roots has been reported to ease toothache.

Observations A shrub 1.5–3 m tall; leaves lanceolate or oblong-lanceolate, 15–30 cm × 9–11 cm, herbaceous or subcoriaceous, base rounded or subacute, apex acuminate, with about 13 secondary veins, petiole 1–1.5 cm long, stipules broadly triangular, shortly awned; inflorescence loose, shortly pubescent, peduncle 3 mm long, with up to 100 flowers; flowers with calyx tube 0.5 mm long, lobes broadly ovate and 0.5 mm long, corolla tube 4 cm long, lobes about 1 cm long, acute, red; fruit red turning black at maturity. *I. longifolia* is found in abandoned fields and dense scrub up to the beach, but it is less common at higher elevations.

Selected sources 97, 182, 580, 1126, 1227, 1265.

Ixora nigricans R.Br. ex Wight & Arn.

Prodr. fl. Ind. orient. 1: 428 (1834).

Vernacular names Thailand: khem tuut maa (Sukhothai), khem nam, khem phuut maa (Surat Thani, Yala). Vietnam: b[oo]ng trang tr[aws]ng, d[ow]n tr[aws]ng.

Distribution India, Burma (Myanmar), Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Bali.

Uses In Vietnam *I. nigricans* is used similar to *I. coccinea*. The leaves are reported to be used in India for antidysenteric purposes.

Observations A shrub or small tree up to 5 m tall; leaves elliptical, obovate or oblong, 7–12.5 (–18) cm × 4–6.5 cm, herbaceous, base acute, apex acutely acuminate, with 7–9 secondary veins, dark green above, pale green below, turning black when dried, petiole about 5 mm long, stipules subtruncate with a very long awn; inflorescence loose, subpaniculiform, peduncle 2–4.5 cm long, often nodding, with 100–200 flowers; flowers with pedicel 0.5–2 mm long, calyx lobes oblong-triangular, about 1.2 mm long, corolla tube 8–12 mm long, glabrous, lobes 6–7 mm long, acute, white, fragrant, style about 6 mm long exserted, glabrous, anthers 4–6 mm long, violet; fruit globose, black. *I. nigricans* is found in evergreen forest on fertile soils from sea-level up to 800 m altitude.

Selected sources 97, 182, 288, 768, 1035, 1126, 1128, 1591.

M.C. Ysrael & J.L.C.H. van Valkenburg

Jasminum L.

Sp. pl. 1: 7 (1753); Gen. pl. ed. 5: 7 (1754).

OLEACEAE

$x = 13$; *J. multiflorum*, *J. sambac*: $2n = 26, 39$

Major species *Jasminum elongatum* (Bergius) Willd., *J. multiflorum* (Burm.f.) Andr., *J. sambac* (L.) Aiton.

Vernacular names Jasmine (En). Jasmin (Fr).

Origin and geographic distribution *Jasminum* consists of about 200 species, with approximately 90 species occurring in the Old World tropics. It comprises 52 indigenous species in the Malesian region. *J. multiflorum* and *J. sambac* have been cultivated since antiquity.

Uses The flowers and leaves of several *Jasminum* species are used as a lactifuge in the Malesian region. Either the bruised flowers or a poultice of the leaves are applied to the breast. The flowers are also considered cooling and are soaked in water overnight; the fluid is used as a face wash. Poultices of the leaves of several species are used in the treatment of ulcers or skin complaints in general. The leaves are also employed as a mouthwash for inflamed gums and ulceration of the mucous membranes. Extracts of the roots of several species are used as febrifuges. A tincture made from the root of *J. sambac* is said to have very strong sedative, anaesthetic and vulnerary properties. Roots are used as poultices to treat sprains and fractures. A decoction of the roots or an infusion of the flowers is employed in pulmonary catarrh, bronchitis, and also asthma.
The flowers of *J. grandiflorum* L. and *J. sambac* are the traditional flavouring agents for jasmine tea. *J. grandiflorum* is widely cultivated in the tropics and subtropics, particularly for its essential oil, but also for its ornamental and medicinal properties.

Production and international trade In South-East Asia, the flowers of *J. grandiflorum* and *J. sambac* are produced for the local market only and no export data are available. In India, *J. sambac* is commercially cultivated for its essential oil. *J. grandiflorum* is commercially cultivated in Algeria, Morocco, Italy, Spain, Egypt, India and China for essential oil.

Properties The fresh leaves and flowers of *J. multiflorum* have been reported to contain 4 secoiridoid lactones: jasmolactones A, B, C, and D. They all contain a bicyclic 2-oxo-oxepano (4,5-C) pyran ring system. The jasmolactones B and D have been found to possess coronary vasodilating and cardiotropic activities. Furthermore, five 10-hydroxyoleoside-type secoiridoid glycosides (probably derived from secologanin) have been isolated: 10-hydroxyoleuropein, 10-hydroxyligustroside, multifloroside, multiroside and 10-hydroxyoleoside-11-methylester. Two of them showed cardiotropic and coronary-dilating activities on preparations from isolated guinea-pig organs: multifloroside ($\geq$ 1.5 μM and $\geq$ 3.7 μM, respectively) and 10-hydroxyoleuropein (both $\geq$ 9 μM).
Direct contact with bruised flowers of *J. multiflorum* in mice suppressed milk production and caused involution of the mammary gland. Exposure to the smell of the flowers alone produced similar, but less marked changes. In humans, the fresh flowers placed on the breasts of women who had just delivered, showed antigalactogogue and prolactin-inhibition activities.
An extract of the young shoots of *J. subtriplinerve* inhibited the growth of *Staphylococcus aureus* and *S. haemolyticus*. The whole plant, excluding the root, of *J. sambac* showed hypotensive activity and depressant activity on the central nervous system of mice.
Several terpenes (e.g. caryophyllene, menthene, jasminin and jasmone) and flavonoids (quercetin, rutin and isoquercetin) have been isolated from *J. sambac* flowers. The characteristics of the concrete of *J. sambac* flowers are: specific gravity (30°C) 0.8794, refractive index 1.4665 and melting point 46°C.

Adulterations and substitutes Jasmine absolute is frequently adulterated with synthetics, inferior quality absolutes and non-jasmine material. No substitute is able to duplicate the original accurately.

Description Scandent shrubs or climbers. Leaves opposite (rarely alternate), seemingly simple (1-foliolate) or 3–9-foliolate, leaflets entire, stipules absent. Inflorescence a terminal or axillary 2–3-chotomous cyme or flowers solitary. Flowers bisexual, regular, usually heterodistylous, fragrant; calyx short, funnel- or bell-shaped with 4–10 linear lobes; corolla with a long narrow cylindrical tube and 4–14 imbricate lobes, white or yellow, outside often tinged with violet or almost entirely violet; stamens 2, inserted on the corolla tube, included or almost so, with short filaments, anthers large, ovoid or oblong, connective apiculate; ovary superior, 2-locular with 2 ovules per cell, style filiform, stigma oblong, 2-lobed. Fruit a 2-lobed berry with 2 seeds, or by abortion entire and 1-seeded. Seeds exalbuminous. Seedling with epigeal germination, paracotyledons thin, green, leaf-like and relatively long persistent.

Growth and development In India *J. sambac* grown from layers will start flowering in the second year, but commercial harvest only commences in the third year, and best yields are obtained from the fifth year onwards. Profitable yields are obtained for up to 20–25 years. In India the flowering season lasts from March until September, with flowering peaking in April–July. In Java and

Thailand flowering is more or less throughout the year with the highest production in November-December, whereas in Malaysia, *J. sambac* flowers throughout the year but fewer flowers are produced in the rainy season. Dispersal of seed is most likely by birds that eat the fruits.

Other botanical information Within the *Oleaceae*, *Jasminum* is placed in the subfamily *Jasminoideae* and the tribe *Jasmineae* together with *Menodora* from tropical and subtropical America and southern Africa. The common jasmine (*J. officinale* L.) is a native of the Sino-Himalayan region, but cultivated worldwide in many temperate regions; single-flowered and double-flowered forms exist. In Europe, common jasmine is cultivated commercially for perfume. In subtropical and tropical regions *J. grandiflorum* L. is widely cultivated for its essential oil and for its fresh flowers; in China and Java the flowers are used to flavour tea. In South-East Asia *J. sambac* is more important for its fresh flowers and essential oil.

Ecology *Jasminum* species occur from seashore habitats to high mountain tops and limestone locations, but most species prefer lowland and lower montane conditions. They are frequently found on forest edges as they do not tolerate deep shade. In general the Malesian species prefer well-drained light loams rich in organic matter with a plentiful supply of moisture. Though species may be cultivated in a wide range of soils, preference is given to slightly sandy loams which are easy to work.

Propagation and planting Fruits and seeds are rarely produced by the ornamental *Jasminum*, and propagation is therefore almost exclusively by stem cuttings. The best time for vegetative propagation is during the rainy season when production of flowers tends to be lower and vegetative growth more prolific. Propagation of *J. sambac* is most successful when using hardwood cuttings with 5–6 buds, with sand as growing medium. In India layering of *J. sambac* is commonly practised; a small strip of bark is removed from the branch, which is bent down and partly buried to promote rooting. Propagation from leaf cuttings, consisting of a mature leaf, petiole and an axillary bud, is also possible. The cutting is soaked for about 24 hours in 20 ppm naphthalene acetic acid and then half immersed in the planting medium. After 1 month the roots have developed well; shoot formation follows 2–4 weeks later. In India plants are spaced at 2 m × 2 m giving 2500 plants/ha. Production of flowers increases by 170% if the density is increased to 10 000/ plants/ha.

Husbandry In commercial cultivation *J. sambac* is trained into bushes. In home gardens it is often trained on arbours. Pruning of *J. sambac* consists of heading back the bushes to about one third of the length of shoots, and thinning unwanted shoots or runners. Pruning should be done during the resting period of the crop and before new flushes emerge. When production of foliage is too prolific, some of the foliage should be selectively removed to promote flowering.

To obtain optimal flower production, *J. sambac* should be grown in full sun, with a regular supply of water and with farm manure applied twice a year during active vegetative growth. Application of nitrogen significantly increases flower production in *J. sambac*. Flowering can be regulated by applying cycocel (chlormequat) after moderate pruning; this shortens time to flowering, prolongs flowering and increases flower yields.

Diseases and pests The bud worm *Hendecasis duplifacialis* is a pest of some consequence in *J. sambac* plantings.

Harvesting Flowers open and are most scented at dusk. The content of essential oils increases considerably at the time of opening of the flowers. Flowers should preferably be harvested in the early morning. However, flower buds for garlands are usually picked in the late afternoon in India. In general, picked flower buds open 7–9 hours after harvesting. In Malaysia, flower buds are gathered in the morning for sale the same day as garlands or to be put in the hair. Strings of threaded flowers are sold per 'hasta' (measurement from elbow to finger tips). For home use, buds are picked in the evening when they are about to burst.

Yield In India the annual production of *J. sambac* flowers amounts to 10 t/ha, yielding 1.2–12 kg concrete. In Indonesia (Java) the monthly flower production per ha is 600 kg for November–December, 90–150 kg for January–June and 90 kg for July–October. Production figures per ha per day for *J. grandiflorum* in Java range from 50 kg in the rainy season to 15 kg in the dry season.

Handling after harvest In Malesia the flowers of *J. sambac* are picked as fully developed buds. These are brought to the market as quickly as possible to maintain good quality, i.e. a fresh white colour without blemishes. The quality of the flowers can be improved by ice cooling at the time of harvesting and hydro cooling before packing. Flowerbuds can be stored in polyethylene bags at 10°C for up to 4 days without affecting quality or shelf life.

Perfume can be extracted by enfleurage using sesame oil as fragrance receptor, but at present jasmine flowers are usually extracted by solvents (e.g. petroleum ether, hexane or liquid carbondioxide) to obtain concrete which is subsequently distilled to produce jasmine absolute.

Genetic resources and breeding Few *Jasminum* species are widespread and common e.g. *J. elongatum*. Most species are endemic, sometimes with a very local distribution. The latter are more at risk in view of the continuing forest conversion. Although a considerable number of species are adapted to forest fringes, they do not adapt well in secondary forest settings.

Prospects The medicinal potential of the cardiotonic and coronary-dilating activities of the secoiridoids in leaves and flowers deserves further attention. The production of flowers for local consumption will remain an interesting market for small-scale growers. The prospects of plantations of *J. sambac* for production of the essential oil are limited, in view of the technology required and the world market prices.

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Selection of species

Jasminum elongatum (Bergius) Willd.

Sp. pl. 1: 37 (1797).

Synonyms *Jasminum aemulum* R.Br (1810), *Jasminum bifarium* Wallich ex G. Don (1837), *Jasminum pubescens* sensu Backer (1931) non (Retz.) Willd., *Jasminum multiflorum* sensu Bakhuizen f. (1950) non (Burm. f.) Andr.

Vernacular names Indonesia: pancasuda (Javanese), malati leuweung (Sundanese), gambir hutan (general). Malaysia: melor hutan, pekan hutan, pekan jantan (Peninsular). Philippines: manol (Central Bisaya), sampagitang-gubat (Tagalog). Thailand: mali som, malulee (Bangkok), mali luei (central).

Distribution South-East Asia, occurring from India to Australia, and to southern China. Common throughout the Malesian region, and present on almost all islands.

Uses In Malaysia a decoction of the root is administered after childbirth and as a febrifuge, and an infusion against yaws. A poultice of leaves is applied to relieve headache and vertigo, and ague in children. In the Philippines, a decoction of the root is used externally for scurvy, and as a gargle for inflamed gums. In Indonesia the leaves are used in a mixture to reduce fever. A decoction of the leaves can be used to cure intestinal complaints and kidney stones. An infusion of the leaves can be used to treat catarrh of the bladder.

Observations A slender, erect or climbing shrub up to 2 m tall, glabrous or subpubescent, with distinctly annular nodes and short opposite branches; leaves 1-foliolate, ovate to ovate-oblong, 3–10 cm × 1.5–5 cm, chartaceous, base rounded or truncate, apex acuminate, round or truncate, with pinnate venation, veins glabrous or midrib pubescent, petiole 3–7(–10) mm long; inflorescence a sub-capitate cyme with (1–)6–9(–15) flowers, subsessile, supported by foliaceous bracts; flowers with a campanulate calyx tube 1.5–2 mm long, with 5–7 subulate teeth 1–4(–7) mm long, usually pubescent, corolla tube 10–25 mm long with 6–9 narrow ovate-oblong lobes 6–15 mm × 2–4 mm, apiculate, white; fruit a 2-lobed berry, black. *J. elongatum* is very common in open or disturbed primary and secondary forest and forest fringes from sea-level up to about 1500 m altitude and occasionally up to 3000 m, e.g. on Mount Kinabalu.

Selected sources 92, 97, 202, 271, 506, 732, 750, 1126, 1178, 1227.

Jasminum multiflorum (Burm.f.) Andr.

Bot. repos. 8: t. 496 (1807).

Synonym *Jasminum pubescens* (Retz.) Willd. (1797).

Vernacular names Star jasmine (En). Philippines: sampagitang-sunsong (Tagalog). Vietnam: nh[af]i nhi[eef]u hoa.

Distribution A native of India and cultivated in western Malesia.

Uses In India the root is reportedly used as an emmenagogue or emetic. The flowers are applied as a lactifuge. A poultice of the leaves is used to treat indolent ulcers. In Malaysia *J. multiflorum* is grown in gardens to supply flowers for home Hindu altars.

Observations A robust bushy climber up to 5 m long, young shoots densely pubescent-tomentose; leaves broadly ovate, 4–7 cm × 1.5–4 cm, base rounded or often cordate, apex acute or often mucronate, pubescent beneath especially at the veins, with 4–6 pairs of secondary veins, slightly bullate, petiole 6–10 mm long; inflorescence a compact, cymose panicle, terminal or at the extremities of short axillary branches, with up to 40 flowers, supported by large, ovate, acute foliaceous bracts; flowers with a 13–16 mm long calyx tube, lobes 7–10(–13) mm long, densely tomentose, corolla tube (15–)20–22 mm long, glabrous, with yellowish-green eye, with 6–9 lobes opening horizontally, recurved at the tip, up to 17 mm × 7–8 mm, overlapping at the base, slightly fragrant; fruit a globose berry, black, surrounded by the suberect calyx lobes.

Selected sources 460, 580, 731, 732, 741, 900, 921, 1021, 1178.

Jasminum sambac (L.) Aiton

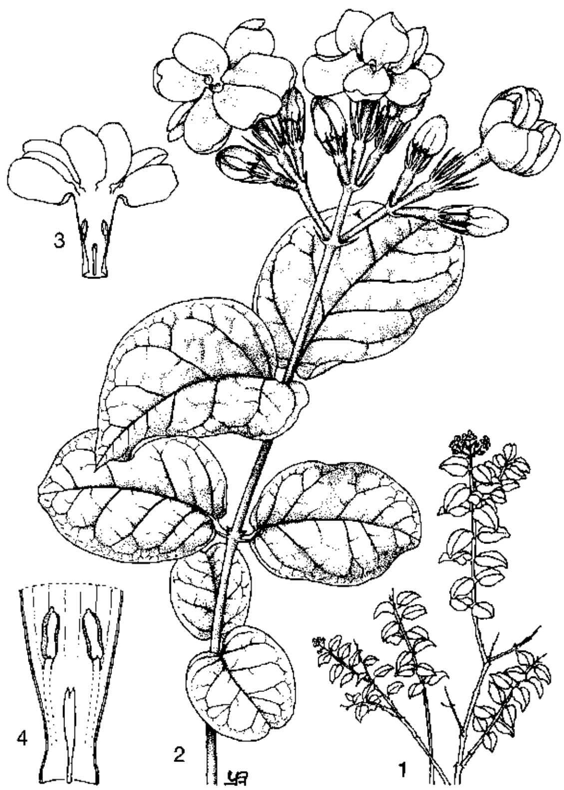
Hort. Kew. 1: 8 (1789).

Synonyms *Nyctanthes sambac* L. (1753).

Vernacular names Arabian jasmine (En). Jasmin d'arabie (Fr). Indonesia: melati (general), menur (Javanese). Malaysia: melor (Peninsular). Philippines: manul (Bisaya), sampaguita (Tagalog), kampupot (Tagalog, Pampanga). Cambodia: molih (Chinese). Thailand: khao taek (Mae Hong Son), tiamuun (Chiang Mai), mali son. Vietnam: l[af]i, hoa nh[af]i.

Distribution *J. sambac* probably originated in India and was brought to Malaysia and Java around the 3rd Century; since then widely cultivated throughout the Malesian region for its heavily scented flowers.

Uses The leaves are more medicinal than the flowers. A decoction is used internally against fever. A poultice of the leaves is applied to treat skin complaints and wounds in Malaysia. In India, Indonesia, Malaysia and the Philippines the bruised leaves or flowers are applied as a poultice to the breast of women as a lactifuge. An infusion of the flowers is applied to the eyelids as a decongestant. Besides the above mentioned uses, in Thailand the leaves are used as an astringent and antiamoebic. The root is given fresh to treat venereal diseases in Malaysia and to treat fever in Indonesia. A tincture made from the root is said to have very strong sedative, anaesthetic and vulnerary properties. Roots are used as poultices for sprains and fractures. A decoction of the roots or an infusion of the flowers is employed in pulmonary catarrh, bronchitis, and also asthma. The



Jasminum sambac (L.) Aiton – 1, plant habit; 2, flowering twig; 3, opened corolla; 4, detail of stamens and style.

stems are employed as an antipyretic and in the treatment of abscesses. The flowers are widely used for their scent and their cooling effect, either directly or in perfumes. In China and Java flowers are used to flavour jasmine tea. In India, *J. sambac* is commercially cultivated for its essential oil.

Observations A shrub, untidy (straggling) climbing or lax when young and rooting at the nodes or ascending, up to 3 m tall; leaves all 1-foliolate, ovate, 2.5–9 cm × 2–6.5 cm, thin, base subcordate to obtuse or cuneate, apex obtuse or acuminate, margins subundulate, glabrous or finely pubescent on the main veins, with several sunken and bearded vein-axils beneath; inflorescence a 3-flowered cyme or a many-flowered compact cluster; flowers single or double (in cultivated varieties), with 7–10 calyx segments, 2.5–7 mm long, finely pubescent, corolla tube 7–15 mm long, with 5–many lobes, oval or oblong, 8–15 mm long, mostly white, heavily fragrant; fruit a black berry, surrounded by the calyx. *J. sambac* is widely planted and occurring from sea-level up to 800 m altitude. Several double-flowered varieties are recognized, none of which produce fruit.

Selected sources 97, 202, 219, 220, 271, 332, 460, 505, 580, 741, 900, 1021, 1035, 1126, 1128, 1178, 1287, 1571.

Jasminum subtriplinerve Blume

Mus. bot. 1 : 272 (1851).

Vernacular names Vietnam: d[aaj]y v[awf]ng, ch[ef] v[awf]ng, d[aaj]y c[aar]m v[aa]n.

Distribution Northern India, Vietnam, Laos and Cambodia.

Uses In Vietnam an infusion of the leaves is administered to women after childbirth. The dried young shoots are used in the treatment of lymphadenopathy, metritis, galactophoritis, leucorrhoea, rheumatism, ostalgia, impetigo, dysmenorrhoea and haematometra. A decoction of the fresh leaves is used to wash wounds and against skin problems; a poultice is used to treat ulcers and mastitis. In Laos, an extract of the pounded root is used to treat quotidian fever. The stem is used for wickerwork and binding.

Observations A straggling shrub, lax or ascendant, with slender branches up to 20 m long, glabrous; leaves 1-foliolate, elliptical-lanceolate, 4–8 cm × 2–5 cm, with a round to obtuse base, apex acuminate, 3-veined, petiole 3–12 mm long, glabrous, articulate; inflorescence an axillary or terminal cyme with up to 9 flowers; flowers with a calyx tube 3 mm long, glabrous, calyx lobes 9, linear, up to 9 mm long, corolla tube 16–18 mm long, with 9 oblong and subobtuse lobes, 15 mm × 3–4 mm, with 3 veins, white, fragrant, anthers 5 mm long, not exserted, style short; fruit a subglobose 1-seeded berry, 7–8 mm in diameter. *J. subtriplinerve* occurs in rather humid forested areas. It may well be grown in similar habitats in the Malesiana region.

Selected sources 271, 363, 460, 1035, 1126, 1128.

Joeni Setijo Rahajoe, R. Kiew
& J.L.C.H. van Valkenburg

Jatropha L.

Sp. pl. 2: 1006 (1753); Gen. pl. ed. 5: 437 (1754).
EUPHORBIACEAE
$x = 11$; *J. curcas*: $2n = 22, 44$, *J. gossypiifolia*, *J. multifida*: $2n = 22$

Major species *Jatropha curcas* L., *J. gossypiifolia* L., *J. multifida* L.

Vernacular names Jatropha, physic nut (En). Indonesia: jarak (general), balacai (Moluccas). Malaysia: jarak (Peninsular). Philippines: tagumbau (Iloko), tuba (Bikol, Tagalog). Laos: nhao.

Origin and geographic distribution *Jatropha* comprises about 175 species and is found from warm temperate North America to Central America, the West Indies and drier regions of South America, and furthermore in drier regions of tropical Africa, in South Africa and in India. Several *Jatropha* species are widely cultivated in the tropics and these can be encountered throughout the Malesian region, sometimes as escapes. The centre of origin of *J. curcas* probably lies in Mexico and Central America. It was brought to the Cape Verde Islands and elsewhere in the Old World long ago by the Portuguese. It was present in the Philippines before 1750.

Uses The seed oil of *Jatropha* is known as cathartic, although its applications often lead to strong irritation of the gastro-intestinal tract or even poisoning. Further applications include the use, both internally and externally, as an abortifacient. Whole seeds are reported as being cathartic, as well as anthelmintic, and they are used in the treatment of e.g. gout and skin diseases. However, because they contain toxic diterpenes, it is considered unsafe and inadvisable to use seeds and seed oil for these indications. The latex of several *Jatropha* species have a long-standing reputation for healing wounds, as a haemostatic, and in the treatment of various skin problems like eczema and dermatomycosis. It is applied externally in

the treatment of infected wounds, ulcers, cuts, abrasions, ringworm and scabies. Upon drying, the initially viscous juice dries, forming an airtight film, resembling that produced by collodium. Leaves of *J. curcas*, *J. gossypiifolia* and *J. multifida* are used as a purgative, as a cure for eczema and itches, as an antiparasitic to scabies, and as a rubefacient to treat rheumatism. Decoctions of the roots are a cure for indigestion (*J. multifida*) and diarrhoea (*J. curcas*). Fresh stems of *J. curcas* are used as toothbrushes, to strengthen the gums, and to cure bleeding, spongy gums or gum boils.
J. curcas is widely cultivated in the tropics as a living fence. The seed oil is used for the manufacture of candles and soap, for lamp and motor oil and as fuel for cooking, whereas the seed-cake is applied as fertilizer. *J. multifida* is widely grown for its ornamental foliage and flowers. The seed oil is an ingredient of hair conditioners. *J. curcas* and *J. multifida* might also be used as fish poison.

Properties The fatty acid composition of the seed oil of *J. curcas* has been analysed: palmitic acid, stearic acid, oleic acid and linoleic acid occur in large quantities. The toxic principles of the oil have been identified as esters of the diterpene 12-deoxy-16-hydroxyphorbol. Their irritant properties have been evaluated in the mouse irritation test, and their co-carcinogenic properties by their enhancing effects on Epstein-Barr virus-induced transformation of human lymphocytes and induction of skin tumours after initiation with 7,12-dimethylbenz[a]anthracene. The toxic properties of entire *J. curcas* seeds in animals and man might not only be attributable to the seed oil and its phorbol esters, but also in part to a toxic protein fraction, sometimes referred to as 'curcin'. More purified proteins from this fraction have been shown in vitro to inhibit protein synthesis in rabbit reticulocytes and to agglutinate human erythrocytes.
Investigations to test the hypothesis that proteolytic activity might be responsible for some of the therapeutic effects (e.g. healing wounds, haemostatic) of *J. curcas* latex resulted in the protease curcain being isolated. Curcain is a protein with an average molecular weight of 22 000. Since successful treatment of wounds by the application of various proteolytic enzymes is reported, the wound-healing properties of this protein were investigated in a mouse model. It was shown that healing of wounds by curcain in a hydrophilic ointment (0.5–1%) was better than observed for nitrofurazone.
Focused phytochemical investigation has revealed the presence of two cyclic peptides, curcacycline A and B, in the latex of *J. curcas*. So far, it seems that they may be restricted to *Jatropha*. The primary structure of curcacycline A appeared to be cyclo-gly-leu-leu-gly-thr-val-leu-leu. Curcacycline B was shown to be a cyclic heptapeptide, containing 1 val, 1 ser, 2 asn, 1 phe and 2 trp residues. All residues in both peptides were found to have the L-configuration. Curcacycline A showed a moderate dose-dependent inhibition of human T cell proliferation. No direct cytotoxic effects as measured by trypan blue dye exclusion were observed.
The leaves of *J. curcas* have a potent cardiovascular action, and are a possible source of an anti-arrhythmic (β blocker) agent. Experiments on guinea-pigs showed decreased heart force (negative inotropic), decreased heart rate (negative chronotropic) and blocking of the isoprenaline stimulation response on the auricle, which is somewhat similar to that of a β blocker. The methanol extract of the leaves also showed antispasmodic activity agains KCl and acetylcholine.
Steroids (stigmasterol, β-sitosterol, β-sitosterol-β-D-glucoside) and flavonoids have been found to be present in *J. curcas* too.
In Costa Rica and on Aruba and Curaçao, a decoction of the whole plant or the stems of *J. gossypiifolia* has a reputation in the treatment of cancer. On the other hand there is a high incidence of oesophageal cancer on Curaçao, which is possibly due to co-carcinogenic esters of 12-deoxy-16-hydroxyphorbol occurring in the seed oil. In a search for tumour inhibitors of plant origin, it was observed that an alcoholic root extract of *J. gossypiifolia* showed significant inhibitory activity in standard animal systems. This finding led to the isolation of jatrophone and the related 2α-hydroxyjatrophone, 2β-hydroxyjatrophone and 2β-hydroxy-5,6-isojatrophone. Evaluation of the antineoplastic activity in the P-388 lymphocytic leukaemia test in vitro and in vivo and Eagle's carcinoma of the nasopharynx in vitro revealed all components to be very active, except for 2β-hydroxy-5,6-isojatrophone showing in vitro, but lacking in vivo activity. In addition, it was found that jatrophone had direct inhibitory effects on contractions of cardiac and smooth muscle preparations, which were typically non-competitive in nature. The action of jatrophone may involve more than one mechanism; this might be related to alterations in Ca^{2+} handling by cells.
Much effort has been invested in evaluating the molluscicidal properties of *J. gossypiifolia* preparations, because snails are important as interme-

diate hosts in the spread of several infectious diseases (schistosomiasis, trematodiasis). Both the latex and a methanolic seed extract of *J. gossypiifolia* have been investigated. The extract was found active against the snail *Bulinus globosus*, but was considered of little value, because of the large quantity required for lethal concentrations and the rapid inactivation in the environment under field conditions. The latex, however, was shown to be strongly active against the snail *Lymnaea acuminata* in its aquatic environment. Toxicity of the latex is partly due to inhibitory effects of its constituents on acetylcholinesterase, and on acid and alkaline phosphatases in the snail. The latex of *J. gossypiifolia* furthermore contains cyclic peptides. Cyclogossine A and B were isolated from latex collected from plants growing in Indonesia, and their primary structures were determined as cyclo-leu-ala-thr-trp-leu-gly-val, and cyclo-ala-ile-leu-gly-gly-trp-leu-ala, respectively. Latex from plants growing in Aruba also yielded two cyclic peptides: on the basis of preliminary analysis one was tentatively identified as cyclogossine B, the other was shown to be different from cyclogossine A and B and represents another novel compound named cyclogossine C. All residues were determined to have the L-configuration.

In addition to yielding the compounds mentioned above, phytochemical investigations of *J. gossypiifolia* have revealed the presence of lignans in the light petroleum extract of stem, root and seeds, e.g. gadain and prasanthaline, alkaloids in the latex, and flavonoids, i.e. apigenin, vitexin and isovitexin and triterpenes in the ethanolic leaf extract.

The seed oil of *J. multifida*, sometimes used as a purgative, may cause strong irritation and poisoning. The toxic principles have been shown to be esters of the diterpene 16-hydroxyphorbol, known for their irritant and co-carcinogenic properties. Researchers seeking a molecular explanation for some therapeutical effects of *J. multifida* claimed (e.g. treatment of infected wounds, ulcers) subjected the latex to activity-guided isolation procedures. These led to the isolation of, amongst others, 2 cyclic peptides: labaditin and biobollein, with primary structures cyclo-ala-gly-val-trp-thr-val-trp-gly-thr-ile and cyclo-trp-ala-ala-ser-ile-leu-gly-leu-gly, respectively. All residues in both peptides were determined to have the L-configuration. Labaditin and biobollein were found to selectively inhibit classical pathway complement activity; no significant effects on the alternative pathway or terminal route were observed. More detailed mechanistic studies revealed that their effects were caused by the activation (consumption) of complement rather than a direct inactivation of participating components. Complement component C1 was shown to be the primary target, not C2 or C4. Biobollein was furthermore studied for antigenicity in an in vivo model using mice for delayed-type hypersensitivity. The results indicated that the cyclic peptide is not immunogenic in this model.

Besides yielding the cyclic peptides, the procedure led to the isolation of multifidol and multifidol glucoside, 2 acylphloroglucinols which inhibit the luminol-dependent chemiluminescence mediated by reactive oxygen species produced by activated human polymorpho-nuclear leukocytes, and a proanthocyanidin which inhibits activation of the classical complement pathway through Ca^{2+} chelation. The presence of minor amounts of (+)-catechin and (–)-epicatechin was also established; both catechins were found to have an inhibitory effect in the chemiluminescence assay. Furthermore, phytochemical investigations revealed the presence of multifidin (a cyanoglucoside) in the latex, and in the tannins (6–14%).

Finally, *J. curcas* preparations (seeds, seed oil, and seed extracts) are reported to have insecticidal properties.

The energy value of the seed oil is 39–41 MJ/kg for *J. curcas*, 42 MJ/kg for *J. gossypiifolia* and 57 MJ/kg for *J. multifida*. Seed oil from *J. curcas* can be used in diesel engines, but it appears to be advisable to make the oil less viscous by trans-esterification.

Description Monoecious or rarely dioecious trees, shrubs or herbs with the stem arising from a thick, perennial rootstock, sometimes succulent, with yellow to red latex; indumentum simple, sometimes glandular. Leaves alternate, simple to palmately lobed, less often pinnately lobed, margin entire to serrate, veins looping (brochidodromous); stipules simple or branched, sometimes spiny. Inflorescence terminal or axillary, often corymb-shaped, dichotomously cymose, with a solitary female flower terminating each major axis, lateral cymules male. Flowers unisexual or rarely bisexual, actinomorphic, with (4–)5(–6) sepals often connate at base, and 5 petals which are free or coherent and white, green, yellow-green, yellow-brown or red, or rarely without petals. Male flowers with disk entire or composed of 5 free glands; stamens (6–)8–10, rarely more, commonly arranged in 2 distinct whorls, filaments free to fused into a column, anthers longitudinally dehiscing; pistillode absent. Female flowers with disk annular, 5-lobed or composed of 5 free glands; ovary superior, (1–)3(–5)-locular with 1 ovule per locule, styles free or connate at base; staminodes sometimes present. Fruit a somewhat fleshy to dry capsule, explosively to tardily dehiscent into 2-valved cocci. Seeds spherical to ovoid or oblong, carunculate, plain or variously mottled; testa crustaceous. Seedling with epigeal germination; hypocotyl elongated; cotyledons emergent or occasionally not emergent (e.g. *J. multifida*), petiolate to subsessile; first 2 leaves alternate or less often opposite to subopposite (e.g. *J. multifida*), subsequent ones alternate.

Growth and development Growth of *J. curcas* is intermittent, and is regulated by fluctuations in rainfall, temperature and light. Flowers of *Jatropha* are generally insect-pollinated. They produce nectar and may be scented. In subgenus *Jatropha* the nectaries are usually exposed and accessible to flies, wasps and other insects, whereas those in subgenus *Curcas* are hidden in a tube and only accessible to insects with a long proboscis or tongue, such as butterflies. In inflorescences of *J. curcas* the female flowers open one or two days before the male ones or at the same time as the earliest males. Male flowers last only one day. The sweet, heavy perfume at night and greenish-yellow flowers of *J. curcas* suggest that this species is pollinated by moths. Its occasionally bisexual flowers are self-compatible; seed never sets in indoor cultivation unless the flowers are pollinated by hand. In Thailand, *J. curcas* flowers in November and May. The explosively dehiscing capsules of some *Jatropha* species disperse seed over some distance. Ants are presumably another dispersal vector as they may be attracted by the fleshy caruncle. Mycorrhizae have been observed on *J. curcas*. They promote growth, especially where phosphate is limiting.

Other botanical information *Jatropha* belongs to the tribe *Jatropheae* of the subfamily *Crotonoideae*. It has been subdivided into 2 subgenera, subgenus *Jatropha* and subgenus *Curcas*, and these again into several sections and subsections. *J. gossypiifolia*, and *J. multifida* belong to subgenus *Jatropha*, *J. curcas* belongs to subgenus *Curcas*.

Ecology Most *Jatropha* species are well-adapted to arid and semi-arid conditions and generally occur in seasonally dry areas. They grow in grass savanna, scrub vegetation, and other open vegetation. *J. curcas* is most successful in drier tropical regions with an average annual rainfall of 300–1000 mm, but it has been reported from an area with 2380 mm of rain annually. In its centre of origin it is found in regions with average annual temperatures of 20°C to 28°C, but it does withstand slight frost.

Propagation and planting *J. curcas* can be easily propagated by stem cuttings 45–100 cm long and development is more rapid than from seed. Stem cuttings root readily in well-aerated rooting media without rooting hormones. Cuttings 30 cm long developed more roots and their survival rate was higher than cuttings 15 cm long. In one kg there are 1700–2400 seeds of *J. curcas*. Soaking seed overnight improves the germination of *J. curcas*. The seed takes about 10 days to germinate. Both direct seeding and sowing in pots are feasible. Explants from hypocotyls, petioles and leaves effectively produced plants by tissue culture techniques. In heavy soils, root formation of *J. curcas* is reduced. In Thailand, a spacing of 2 m × 2 m showed best vegetative development and the highest first seed yield of nearly 800 kg/ha from plants 13–14-months old. Spacings applied for *J. curcas* are 0.5–1.5 m × 1–2 m (rainfed) to 2 m × 2 m (irrigated) when seeding directly, 1–3 m when seedlings are planted, and 2–3 m × 1.5–3 m when cuttings are planted.

Husbandry *J. curcas* cuttings start producing seed 4–5 months after planting. Plants from cuttings are more short-lived and less drought- and disease-resistant than those raised from seed. In north-eastern Thailand, seedling plants 4–5 months after sowing are 1 m tall and start flowering. Plants from cuttings attain 2 m height in 8 months. The mean plant height and mean stem diameter of 11 provenances of *J. curcas* tested in Senegal were 150 cm and 7.5 cm, respectively, 15 months after planting. As plants are not browsed and grow into dense bushes they are favoured for living fences and can also be coppiced. *J. gossypiifolia* is a serious weed in pastures in Papua New Guinea.

Diseases and pests Although a number of diseases and pests have been observed in different regions in *J. curcas*, none of them causes serious problems.

Harvesting Fruits of *J. curcas* which turn yellow on maturity can be easily plucked. Harvesting is often during the dry season and thus it does not interfere with other agricultural activities.

Yield Annual seed yield of *J. curcas* in Cape Verde is 400–1200 kg/ha; in Thailand average annual yields of 2150 kg/ha have been obtained. In the Philippines, 5-year-old plants produce 4–6 kg of dry seed.

Handling after harvest Fruits are harvested and allowed to dry and dehisce spontaneously. Seeds are then dried, roasted and ground. The ground seed is boiled in water and the oil can be collected from the surface. When oil is extracted by pressing about 50% of the seed weight remains as seed-cake. This residue contains toxic compounds and cannot be used as animal feed. Biogas has been produced on an experimental scale, using an anaerobic filter; the daily yield was 3.5 m^3 gas from 13 kg seed-cake.

Genetic resources and breeding There are only four records of systematic provenance trials on *J. curcas*. *J. curcas* germplasm is maintained in three institutions: Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Costa Rica, the Centre National de Semences Forestières (CNSF) in Burkina Faso and Instituto Nacional de Investigacao e Desenvolvimento Agrario (INIDA), Cape Verde.

Prospects The seed or the seed oil of *Jatropha* should not be used as cathartic, because they contain toxic diterpenes, with irritant and co-carcinogenic properties. The latex of several *Jatropha* species has a long-standing reputation for healing wounds, as a haemostatic, and in the treatment of various skin problems like eczema and dermatomycosis. Several constituents that display interesting pharmacological activities have been isolated. The latex seems to be an interesting topical application for use in rural communities. *J. curcas* is well adapted to marginal areas with poor soils and low rainfall, where it grows without competing with annual food crops. Of its many uses, the combination of erosion control and oil production seems particularly promising.

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Selection of species

Jatropha curcas L.

Sp. pl. 2: 1006 (1753).

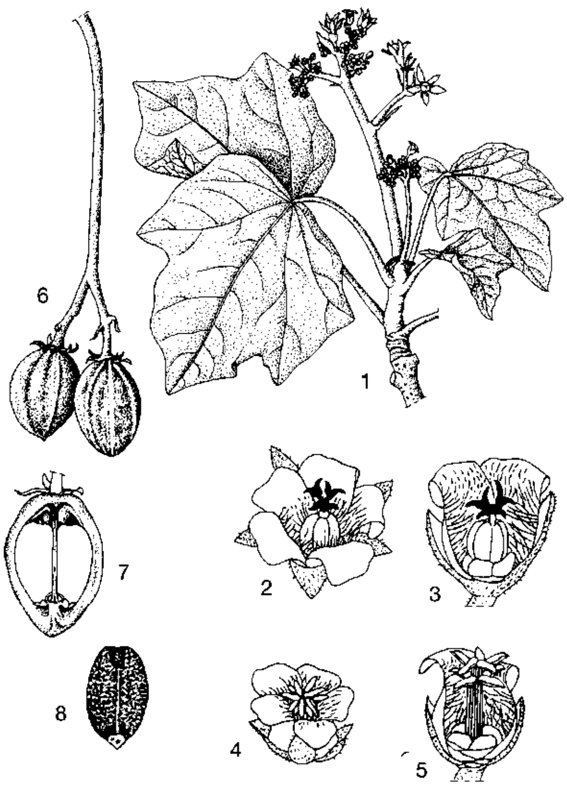
Synonyms *Curcas purgans* Medik. (1771), *Curcas indica* A. Rich. (1853), *Jatropha afrocurcas* Pax (1909).

Vernacular names Physic nut, purging nut (En). Poughère, pignon d'Inde (Fr). Indonesia: jarak kosta jarak pagar (general), balacai (Moluccas). Malaysia: jarak belanda, jarak keling, jarak pagar (Peninsular). Papua New Guinea: kadel, lam (Gunantuna, New Britain). Philippines: tagumbau-na-purau (Iloko), tuba (Igorot, Bikol, Tagalog), tubang-bakod (Tagalog). Cambodia: kuang, lohong. Laos: nhao. Thailand: ma yao (northern), sabuu dam, salot paa (central). Vietnam: d[aaf]u m[ef], ba d[aaj]u nam.

Distribution *J. curcas* probably originated from Mexico and Central America, but it was introduced long ago in all tropical regions and some subtropical regions like Florida and South Africa. It is cultivated throughout the Malesian region, though especially in the drier areas.

Uses The seed oil is possibly the best known product of *J. curcas* applied as a cathartic, although application often leads to poisoning. Seeds themselves are also used as a cathartic, as well as an anthelmintic, and in the treatment of gout and skin diseases. They are often a source of poisoning, both in animals and humans. The latex is used as a vulnerary by the Malays. It is used to treat ear disease, toothache, eczema and scabies in Indonesia, as a styptic in India, and in Cambodia it is applied to sores and ulcers. The fresh, viscous juice flowing from the leaf stalks or stems is employed to arrest bleeding, and to treat ulcers, cuts and abrasions. It is said to promote healing by coagulating the blood and forming an airtight film when dry, resembling that produced by collodium. Furthermore, it is a successful local remedy for ringworm. Decoctions of leaves or roots are a good cure for diarrhoea and to treat polyuria, whereas a decoction of the leaves is also employed as a cough remedy. Leaves are applied to wounds and itches (Cambodia), as an antiparasitic to scabies, and as a rubefacient to treat paralysis and rheumatism (Indonesia). In India, crushed leaves are applied as a cataplasm to swollen breasts, and as a lactagogue. The bark is bruised and placed in the mouth as a cure for the bites of snakes or other animals. The bark is also used as a poultice for sprains and dislocations. In Goa, the root bark is applied externally for rheumatism. The fresh stems are used as toothbrushes, to strengthen the gums, and to cure bleeding, spongy gums or gum boils. The juice may kill fish, and can also be applied for stupefying them while hunting (the Philippines). In arid and semi-arid regions *J. curcas* is commonly planted as living fence and for erosion control. A dark blue dye from the bark has been used in the Philippines for colouring cloth, fishing nets and lines. The oil is used for the manufacture of candles and soap and as fuel for cooking, whereas the seed-cake is applied as fertilizer.

Observations A somewhat succulent shrub or small tree up to 5(–8) m tall with pink latex, bark smooth, shiny, greenish-brown or yellowish-grey, peeling off in papery scales; leaf blade broadly ovate in outline, usually shallowly (3–)5(–7)-lobed or occasionally not lobed, 7–14(–18) cm × 5.5–14 (–18) cm, shallowly to deeply cordate at base, sparsely puberulous along the veins below at first, otherwise glabrous, petiole (3–)10–15(–20) cm long, glabrous; inflorescence subcorymbose, peduncle up to 5(–7) cm long; male flowers with ovate calyx lobes about 2 mm long, petals fused in lower half, about 3 mm long, greenish-yellow, stamens 10, in two whorls of 5; female flowers with about 4 mm long calyx lobes, petals about 6 mm long, staminodes present, stigmas bifid; fruit broadly ellipsoid, 2.5–3 cm × 2 cm; seeds about 1.7 cm long, black, with minute caruncle. *J. curcas* frequently escapes from cultivation and may become naturalized. It grows on well-drained, well-aerated soils and is well-adapted to low fertility. It may be found on rocky slopes, dry river beds and similar habitats, from sea-level up to 1700 m altitude.



Jatropha curcas L. – 1, flowering stem; 2, female flower; 3, opened female flower; 4, male flower; 5, opened male flower; 6, fruits; 7, fruit in longitudinal section; 8, seed.

Selected sources 122, 190, 202, 284, 287, 332, 338, 418, 573, 580, 690, 899, 984, 1010, 1128, 1135, 1178, 1187, 1380, 1400, 1409, 1500, 1525, 1571.

Jatropha gossypiifolia L.

Sp. pl. 2: 1006 (1753).

Synonyms *Jatropha elegans* (Pohl) Klotzsch (1853).

Vernacular names Cotton-leaved physic nut

(En). Indonesia: jarak kosta merah (general), jarak ulung (Lampung, Sumatra), kaleke bacu (Kangean). Malaysia: jarak beremah, jarak hitam, jarak merah (Peninsular). Philippines: lansi-lansinaan (Tagalog), tagumbau-a-nalabaga (Iloko), tuba-tuba (Panay Bisaya, Cebu Bisaya). Laos: nhao luat. Thailand: sabuu daeng (central), sabu lueat, salot daeng (peninsular). Vietnam: d[aaf]u lai ti[as].

Distribution *J. gossypiifolia* is native to tropical America from Mexico to Paraguay and the West Indies. It has been introduced as an ornamental elsewhere in tropical America and many parts of the Old World tropics, especially West Africa and Malesia, and regularly escapes from cultivation.

Uses Seeds of *J. gossypiifolia* are used as a cathartic. The Madurese use them after roasting, as a purgative for adults. The seed oil may be useful in treating leprosy. The latex from the leaves is applied on the tongue of babies to cure sores. In general, the latex is used externally to cure ulcers. It also has molluscicidal properties. In the Philippines, a cataplasm of fresh leaves is applied to swollen breasts. Leaves are also employed as a febrifuge in intermittent fevers, or boiled and used in a bath to cure fever. A decoction of the leaves is given as a purgative, as a stomachic, in the treatment of ear and venereal diseases, and as a blood purifier. Externally, leaves are applied to boils and carbuncles, eczema and itches. The roots are employed against leprosy, and a decoction of the bark is used as an emmenagogue.

Observations A small, somewhat succulent shrub up to 3 m tall; leaf blade deeply 3–5-lobed, 6–20 cm × 7–22 cm, base cordate, lobes broadly ovate to obovate, margin denticulate, with coarsely stipitate glandular hairs, petiole (2.5–)4–8(–14) cm long, sparsely to densely set with coarse glandular hairs; inflorescence opposite a leaf, cymose, glandular hairy; male flowers with elliptical-lanceolate to ovate, about 2.5 mm long calyx lobes, petals free, about 3.5 mm long, purplish-red, stamens 8(–12), outer ones shorter than inner ones, filaments partly united; female flowers with calyx and petals as in male flower but twice as large, staminodes absent, stigmas capitate, bifid; fruit 3-lobed, roundish, about 1 cm in diameter; seeds about 7.5 mm long, pale greyish-brown, with a multifid caruncle. *J. gossypiifolia* may be locally common in drier regions along roads, on waste places, in lawns, scrub vegetation, generally at low altitudes. In Asia all plants are referred to as var. *elegans* (Pohl) Muell. Arg. which differs from var. *gossypiifolia* in having denticulate and glandular-ciliate leaf margins.

Selected sources 83, 97, 122, 202, 284, 287, 332, 338, 618, 1128, 1135, 1178, 1187, 1380.

Jatropha multifida L.

Sp. pl. 2: 1006 (1753).

Synonyms *Adenoropium multifidum* (L.) Pohl (1827), *Jatropha janipha* Blanco (1837).

Vernacular names Coral plant, French physic nut, Spanish physic nut (En). Arbre corail, médicinier d'Espagne, noisetier purgatif (Fr). Indonesia: jarak cina (Javanese), jarak gurita (Sundanese), balacai batai (Ternate). Philippines: mana (Filipino), tubang amerikano (Bikol). Cambodia: lohong khvang kraham. Thailand: fin ton, malako farang (Bangkok), ma hung daeng (northern). Vietnam: d[aaf]u m[ef] d[or], b[aj]ch ph[uj] t[uwr].

Distribution *J. multifida* is native to tropical America from Mexico to Paraguay; it was introduced as an ornamental into the Old World tropics long ago. Within Malesia it is cultivated at least in Peninsular Malaysia, Java, the Moluccas and the Philippines.

Uses The seed oil of *J. multifida* is sometimes used as a cathartic, although it may cause strong irritation and even poisoning. The oil is applied both internally and externally as an abortifacient. Seeds are used fresh as a purgative and emetic. The latex is used externally in the treatment of infected wounds, ulcers, skin infections and scabies. In Indonesia one of its local names is 'yodium' ('iodine'), which reflects the popular use as a wound-healing remedy. In Indo-China, dried roots are given as a decoction against indigestion and colic; they are also prescribed as a tonic to treat orchitis and oedemas. The leaves are used as a purgative, and in the treatment of dysentery and scabies. *J. multifida* is widely grown, often in hedges, for its ornamental foliage and flowers. The tuberous roots can be eaten after roasting. The plant may also be used as a fish poison.

Observations A glabrous, slightly succulent shrub or small tree up to 6 m tall with white latex, roots tuberous; leaf blade peltate, broadly ovate-orbicular, 15–35 cm in diameter, palmatipartite with (9–)11(–12) segments, segments simple to deeply pinnatipartite, petiole 10–25(–35) cm long; inflorescence tightly corymb-shaped, peduncle up to 23 cm long; male flowers with broadly ovate calyx lobes, about 1 mm long, petals free, about 5 mm long, scarlet, stamens 8, filaments free; female flowers with petals up to 9 mm long, stigmas capitate, bilobed; fruit tardily dehiscent to subdrupaceous, broadly obovoid, about 3 cm long, 3-lobed with keeled lobes, yellow when mature; seeds 1.7–2 cm long, buff, mottled brownish, with a small caruncle. *J. multifida* occasionally escapes from cultivation into grassland and thickets, generally at low altitudes.

Selected sources 97, 122, 202, 287, 332, 338, 771, 772, 1035, 1128, 1178, 1187, 1380, 1501.

S. Susiarti, E. Munawaroh & S.F.A.J. Horsten

Justicia L.

Sp. pl. 1: 15 (1753); Gen. pl. ed. 5: 10 (1754).

ACANTHACEAE

x = 7, 8, 9, 11, 13, 14, 15, 16, 17, 18; *J. adhatoda*: $2n$ = 30, 34, 40, 46, 50, 56, 58, *J. gendarussa*: $2n$ = 28, 30, 32, *J. procumbens*: $2n$ = 18, 28, 36

Major species *Justicia adhatoda* L., *J. gendarussa* Burm.f., *J. procumbens* L.

Origin and geographic distribution *Justicia* is a large genus with somewhere between 300 and 600 species. It is distributed in all tropical and subtropical regions, with some species extending into temperate regions (e.g. in China and Japan).

Uses Leaf and root extracts of *Justicia* are commonly used in traditional medicine throughout South-East Asia, India and China, particularly for treating bronchitis, asthma, cough, fever and jaundice. Fresh leaves are often applied as a topical, poultice or lotion to treat swellings, skin eruptions, rheumatism and as a sedative. In India, *J. adhatoda* has a considerable reputation for its anti-allergic and anti-asthmatic properties.

J. adhatoda and *J. gendarussa* are often planted in hedges or as ornamental; the wood of the former is used as firewood.

Properties Several lignans (e.g. justicidins A–H, diphyllin, diphyllin apioside, diphyllin apioside-5-acetate, justicidinosides A–C, neojusticin A–B, taiwanin E, taiwanin E methyl ether) have been identified from *J. procumbens*. Neojusticin A and B, taiwanin E methyl ether and taiwanin E significantly inhibit platelet aggregation. The methanolic extract of the herb has been found to have significant inhibitory activity in vivo against P-388 lymphocytic leukaemia in mice, as well as in vitro cytotoxicity in the 9-KB (human nasopharyngeal carcinoma) cell culture assay. Justicidin A and diphyllin were demonstrated to be the active compounds. Justicidin A and B, diphyllin, diphyllin apioside and diphyllin apioside-5-acetate showed strong antiviral activity against vesicular stomatitis virus and low cytotoxicity against cultured rabbit lung cells. Justicidin A and B caused respectively 100% and 90% mortality of fourth-instar larvae of *Bombyx mori* after 6 days of feeding at 20 ppm. Several justicidins have piscicidal activity. Methods for synthesis of justicidin B and E and diphyllin have been described. The lignan justisolin and the lignan glucoside simplexoside, exhibiting growth regulatory properties in plants, have also been isolated from *J. procumbens*. Simplexoside produced a weak depressant action on the central nervous system in mice and rats, whereas the free lignans produced a stimulant action on the central nervous system.

The alkaloids found in *J. adhatoda* include vasicine, vasicinone, vasicinine, vasicinolone, adhatodane, adhatodine, adhavascinone and anisotine. The yield of vasicine in the leaves ranges from 0.5–2% on dry weight basis. Comprehensive pharmacological investigations have been reported on drugs from *J. adhatoda*. A combination of the two alkaloids vasicine and vasicinone showed bronchodilator activity comparable to that of theophylline and greater than that achieved with each alkaloid separately. The mechanism of action is thought to be anticholinergic. A hitherto unidentified alkaloid showed pronounced protection against allergen-induced bronchial obstruction in guinea-pigs (10 mg/ml aerosol). Vasicine exhibits strong respiratory stimulant activity, moderate hypotensive activity and cardiac-depressant effect; vasicinone does not have these activities. Vasicine has been reported to lower blood pressure. The benzylamines bromhexine and ambroxol, semi-synthetic derivatives of vasicine and widely used as mucolytics, have a pH-dependent growth-inhibiting effect on *Mycobacterium tuberculosis*; they have a potentially useful adjunctive function in the therapy of tuberculosis. The leaf juice of *J. adhatoda* showed activity against some strains of e.g. *Bacillus subtilis*, *Staphylococcus epidermidis* and *Salmonella typhosa*. In rats fed for 10 days following insemination a leaf extract was 100% abortive at a dose equivalent to 175 mg/kg of starting dry material. The alcohol extract of dried leaves showed atropine-like activity due to the presence of a non-nitrogenous and non-toxic principle, vasakin. Vasakin exhibits hypoglycaemic activity, but is less potent than tolbutamide. The oil, which is present in small amounts e.g. in the root, showed slight insecticidal activity against the stored-grain pests *Bruchus chinensis*, *Sitophilus oryzae*, *Rhizopertha dominica*, *Stegobium paniceum* and *Sitotroga cerealella*, but it displayed superior activity against freshly moulted fifth-instar nymphs of the red cotton bug *Dysdercus koenigii*. The leaf powder did not afford protection against attack of *Callosobruchus chinensis* on stored pulses. Larvae of the noctuid *Spodoptera littoralis* fed with *J. adhatoda* leaves showed high mortality. Powdered preparations of the leaves combined with burning charcoal to produce smoke repelled the mosquitoes *Armigeres subalbatus* and *Culex quinquefasciatus*. A 10% alcoholic water extract was effective in decreasing the severity of powdery mildew (caused by *Phyllactinia corylea*), leaf spot (caused by *Pseudocercospora mori*) and leaf rust (caused by *Cerotelium fici*) in mulberry (*Morus* spp.). Chromatographic analysis revealed the presence of caffeic, ferulic, vanillic, p-coumaric, p-hydroxybenzoic and tannic phenolic acids in aqueous extracts of *J. adhatoda* for which allelopathic activities are known.

Four simple o-disubstituted aromatic amines have been isolated from the leaves of *J. gendarussa* and characterized as 2-amino benzyl alcohol, 2-(2'-amino-benzylamino) benzyl alcohol and their respective O-methyl ethers. β-Sitosterol (a phytosterol) has also been reported. A leaf infusion of *J. gendarussa* showed analgesic effect in tests with mice. Fungicidal activity was reported for a crude extract; the extract was quite effective against *Rhizoctonia*-like isolates. Aqueous extracts significantly inhibited aflatoxin production by *Aspergillus parasiticus* in rice, wheat, maize and groundnut.

Justicidin B has also been isolated from the Central and South American *J. pectoralis* Jacq., which is considered as wound-healing in Jamaica. It also contains coumarin and umbelliferone, which relax smooth muscles and is used as snuff. The Mexican *J. spicigera* Schltdl. showed high trophozoite mortality and had a clear in vitro antigiardiasic effect, better than tinidazol commonly used in the treatment of giardiasis. In animal tests, extracts from the South American *J. cydoniifolia* (Nees) Lindau showed anti-inflammatory activity equipotent to aspirin. The alkaloid 7-methoxyvasicine exhibited anti-inflammatory properties.

Adulterations and substitutes In India, leaves of *J. adhatoda* are sometimes adulterated with those of *Ailanthus excelsa* Roxb.

Description Erect shrubs or herbs, sometimes procumbent or ascending. Leaves opposite-decussate, simple, ovate to elliptical or linear-lanceolate, usually entire, often with cystoliths, petiolate, exstipulate. Inflorescence a terminal or axillary congested spike or panicle, sometimes a thyrsoid cyme or flowers solitary; bracts small and linear or subulate to large and foliaceous, bracteoles 2, linear-lanceolate, occasionally absent. Flowers sessile or pedicellate, bisexual, zygomorphic, white, pink or purple; calyx deeply 4–5-lobed, persistent; corolla with often narrow, funnel-shaped, straight or incurved tube, bilabiate, upper lip narrow, entire to bifid, lower lip broad, patent or recurved, 3-lobed; stamens 2, slightly exserted, with filiform filaments attached near the middle of the tube, anthers dorsifixed, with 2 usually unequal thecae, one or both thecae apiculate or calcarate; ovary superior, 2-locular, each locule with 2 ovules, style simple, filiform, with minute unequally 2-lobed stigma. Fruit an oblong, ovoid or obovoid-clavate capsule, distinctly stiped, bivalved and elastically and loculicidally dehiscent from apex downwards, usually 4-seeded. Seeds orbicular-lenticular, compressed, rough, tuberculate or smooth, on curved retinacula.

Growth and development The flowers of *Justicia* are insect-pollinated, mainly by bees, butterflies and flies. *J. adhatoda* and *J. gendarussa* rarely produce fruits in Java, but the latter apparently fruits regularly in the Philippines.

Other botanical information Taxonomical studies on *Justicia* have followed one of two divergent trends, resulting either in the recognition of a large number of small segregate genera, or in the adoption of a very broad definition of *Justicia*. Here, the concept of *Justicia* sensu lato is adopted. As a result, each species treated here is found in the literature under several names: *J. adhatoda* is often considered as belonging to the split genus *Adhatoda*, *J. gendarussa* to *Gendarussa*, and *J. procumbens* to *Rostellaria* or *Rostellularia*. *Justicia* is related to *Rungia*, but differs in the usually not rising placenta; when it does rise (e.g. in *J. gendarussa*), then both bracts at each node are fertile.

Ecology In South-East Asia, *J. procumbens* occurs in open locations, such as grasslands and roadsides, whereas *J. gendarussa* prefers more shady places such as forest, forest borders or along streams.

Propagation and planting Cuttings taken from terminal shoots of *J. gendarussa* root easily when planted in sand, particularly when treated with auxin (e.g. naphthalene acetic acid or indole butyric acid). Cuttings taken from lateral shoots by systematically decapitating apical meristems of growing shoots, rooted earlier and produced more roots than normal cuttings. Rooting of *J. adhatoda* stem cuttings in India is usually satisfactory, with a maximum success of 90%. *J. procumbens* is a short-living herb which reproduces freely by seed.

Husbandry *Justicia* is rarely planted for medicinal purposes. In India, *J. adhatoda* is reported to be suitable for intercropping with poplar (*Populus* sp.).

Diseases and pests *Fusarium* spp. may attack *J. gendarussa*. A rust disease caused by *Puccinia thwaitesii* is reported from Malaysia for *J. gendarussa*, resulting in premature drop of infected leaves. A graft-transmissible disease, possibly of mycoplasma origin, and resulting in witches' broom symptoms has been described from India. In India, *J. adhatoda* is host for root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) and for fungi such as *Phyllosticta ribiseda* and *Phomopsis pustulata*. The most common fungal disease is greasy rust caused by *Chnoopsora butleri*.

Genetic resources and breeding All *Justicia* species described here have a large area of distribution, either naturally or as a result of cultivation, and do not seem to be at risk of genetic erosion. However, as some *Justicia* species rarely fruit in at least part of Malesia (e.g. *J. adhatoda* and *J. gendarussa* in Java) and are consequently propagated vegetatively, the genetic base is probably comparatively small in this region. There is no known selection and breeding work for medicinal purposes.

Prospects The known active compounds of *Justicia* are quite different for each species, but all species described here deserve special attention. The alkaloids and their derivatives from *J. adhatoda* show promising activity as bronchodilator, and have a potentially adjunctive function in the treatment of tuberculosis. Vasicine is reported as a promising uterotonic abortifacient, and may prove useful for the control of postpartum haemorrhage. It acts as a cholagogue and may be employed in some types of jaundice. Moreover, the insecticidal activity suggests some promise against insect pests of crops and mosquitoes transferring malaria. Some lignans from *J. procumbens* showed antitumour and antiviral activity, but more research is needed to establish their value for modern medicine. The fungicidal activity of *J. gendarussa* extracts warrants more research.

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Selection of species

Justicia adhatoda L.

Sp. pl. 1: 15 (1753).

Synonyms *Adhatoda zeylanica* Medic. (1790), *Adhatoda vasica* Nees (1832).

Vernacular names Malabar nut tree (En). Thailand: kra niat (peninsular), kulaa khaao (northern), saniat moraa (central). Vietnam: xu[aa]n ti[ees]t.

Distribution Possibly a native of India, but now much cultivated, e.g. in Java and Thailand.

Uses The roots and leaves are widely used in the Ayurvedic and Unani systems of medicine in India and Thailand for treating bronchitis, asthma, fever and jaundice. *J. adhatoda* is often planted in hedges, and the wood is used as firewood. In India, it is also grown as a green manure in rice, tobacco and tea. Boiled tender shoots are eaten with salt locally in India.

Observations An erect, much branched shrub up to 4(–6) m tall, stems quadrangular to nearly terete; leaves lanceolate-elliptical, 8–25 cm × 2.5–8 cm, with (1–)1.5–3.5(–4.5) cm long petiole; flowers in spikes with leafy, broadly elliptical, 1.5–4 cm long bracts, 3–4.5 cm long, white; fruit broadly clavate, about 2.5 cm long, pubescent. *J. adhatoda* is planted in Java up to 1400 m altitude.

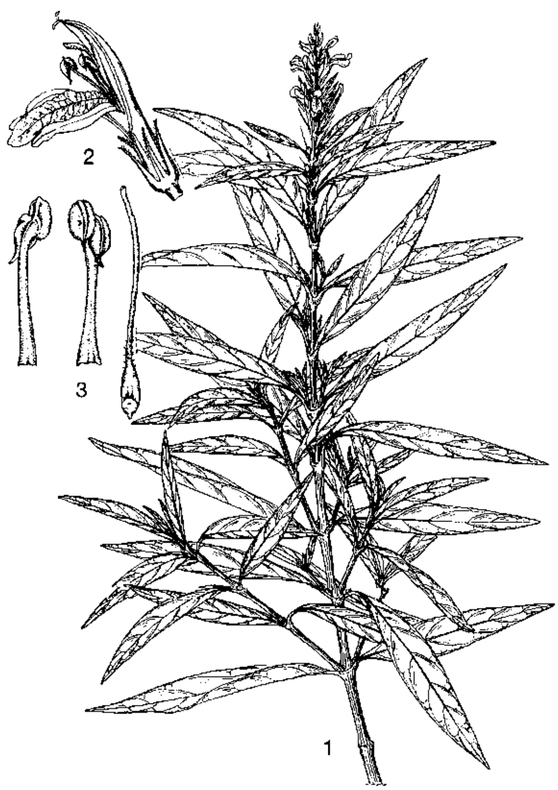
Selected sources 97, 226, 288, 369, 410, 502, 1012, 1013, 1126, 1535.

Justicia gendarussa Burm.f.

Fl. indica: 10 (1768).

Synonyms *Gendarussa vulgaris* Nees (1832).

Vernacular names Indonesia: gandarusa (general), besi-besi (Aceh), kawo (Seram). Malaysia: gandarusa, temenggong melela, urat sugi (Peninsular). Philippines: kapanitulot (Tagalog), bunlao (Bisaya), tagpayan (Iloko). Thailand: chiang phraa mon (central), pong dam (Trat), kraduuk kaidam (northern). Vietnam: t[aaf]n c[uwr]u, thu[oos]c tr[awj]c, t[aaf]n giao.



Justicia gendarussa Burm. f. – 1, flowering twig; 2, flower; 3, stamens and pistil.

Distribution Pakistan, India, Sri Lanka, Indo-China, China, Thailand, Peninsular Malaysia, Java, the Moluccas and the Philippines; possibly a native of China, but now much cultivated and naturalized.

Uses An extract of the leaves or young shoots is used as an emetic in coughs and asthma in the Philippines, whereas fresh leaves are applied as topical to cure oedema of beri-beri and rheumatism. A decoction of the leaves is used for bathing during childbirth. In Malaysia, the leaves are much applied for poulticing to treat headache and pains, as a lotion to treat swellings and rheumatism, and in a bath after confinement, the roots for treating thrush and cough. The leaves are also used in preparations to treat gonorrhoea, amenorrhoea and malaria. In Indonesia, the leaves are used to treat headache, rheumatism and pain. In Vietnam, the leaves are applied externally, as a poultice, decoction or tincture, to treat rheumatic arthritis and swellings. In Thailand, the roots are used against diuresis, diarrhoea and as antivenin; the bark is used as antipyretic, anticough, diuretic and anti-amoebic, in the treatment of wounds and allergy; the leaves are taken internally against cough, fever and as a cardiotonic, and used externally to treat inflammation, wounds and allergy. Numerous medicinal uses are recorded from India and China; the roots are used to treat rheumatism, dysuria, fever, carbuncles, jaundice and diarrhoea, the leaves as a diaphoretic and febrifuge and to treat lumbago, amenorrhoea, swellings, coughs, asthma, colics, eczema, cephalalgia, hemiplegia, facial paralysis, earache and hemicrania, and the bark as emetic. Magical uses are reported for Indonesia, Malaysia and the Philippines. *J. gendarussa* is cultivated as an ornamental, and is often used for living fences.

Observations An undershrub up to 150 cm tall, stems terete, young twigs usually dark purple; leaves linear-lanceolate, 5–20 cm × 1–3.5 cm, with up to 1 cm long petiole; inflorescence a spike, bracts lanceolate, about 4 mm long; flowers 1.5–2 cm long, white with purplish streaks and spots inside; fruit clavate to ellipsoid, about 1.3 cm long, glabrous. *J. gendarussa* is cultivated, and naturalized in forest, forest borders and on river banks in Java, up to 1500 m altitude. In the Philippines, it often grows along streams in primary and secondary forest.

Selected sources 97, 202, 332, 580, 909, 1012, 1035, 1126, 1178, 1366, 1572.

Justicia procumbens L.

Sp. pl. 1: 15 (1753).

Synonyms *Justicia japonica* Thunb. (1784), *Justicia simplex* D. Don (1825), *Rostellularia procumbens* (L.) Nees (1832).

Vernacular names Vietnam: t[uw][ows]c s[af]ng.

Distribution Pakistan, India, Sri Lanka, Burma (Myanmar), Indo-China, China, Taiwan, Japan, Peninsular Malaysia, the Philippines, Timor, possibly Australia; probably also Java.

Uses In the Philippines, the leaves are used externally as an astringent to cure certain eruptions of the skin. In India, the herb is considered as an alterative, expectorant, laxative and diuretic, and an infusion or decoction is used to treat asthma, coughs, rheumatism, backache and flatulence. The juice from the leaves is used to treat ophthalmia. In Chinese medicine, whole plants are used to treat fever, pain due to pharyngo-laryngeal swelling and cancer.

Observations A herb up to 50 cm tall, with erect or procumbent to ascending, quadrangular stems, often diffusely branched; leaves elliptical-ovate to lanceolate-elliptical, 1–5 cm × 0.5–2.5 cm, with up to 1(–1.5) cm long petiole; inflorescence a spike; bracts obovate to elliptical-ovate or linear-lanceolate, 4–5 mm long; flowers 8–10 mm long, pink or purplish-pink; fruit oblong, 3–5 mm long, hairy to glabrescent. *J. procumbens* and its related species are in need of a thorough taxonomical revision covering the complete area of distribution. Several closely related species are reported from Malesia and Australia. These might be conspecific. *J. procumbens* occurs in grasslands and roadsides, in Japan also in forest, up to 1600 m altitude.

Selected sources 77, 202, 241, 440, 623, 1012, 1079, 1126, 1178.

H. Sangat-Roemantyo

Kaempferia L.

Sp. pl. 1: 2 (1753); Gen. pl. ed. 5: 3 (1754).

ZINGIBERACEAE

x = 11, 12, 13, 14; *K. angustifolia*: $2n$ = 36, *K. galanga*: $2n$ = 54, *K. rotunda*: $2n$ = 44, 45, 54

Major species *Kaempferia galanga* L., *K. rotunda* L.

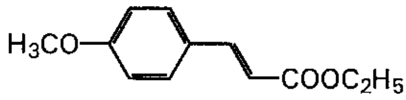
Vernacular names Galangal, kaempferia (En).

Origin and geographic distribution *Kaempferia* comprises about 40 species and occurs in India and Sri Lanka to Indo-China, Thailand and Malesia east to the Moluccas. Within Malesia some 7 species are present; Thailand has 15 species.

Uses Rhizomes of various *Kaempferia* species are credited with stimulant, stomachic, carminative and similar properties, and are also used throughout South-East Asia to relieve headache. They are commonly applied in the treatment of abdominal disorders, apparently for their astringent properties. In Peninsular Malaysia and Indonesia the leaves and rhizomes are chewed as an expectorant for coughs and sore throat, or pounded and used in poultices or lotions; they are often an ingredient of children's medicines and tonics. In Indonesia, rhizomes of *Kaempferia* are a common ingredient of a multitude of 'jamus'. Rhizomes are applied externally as a 'drawing' agent on boils and, mixed with oil, as a cicatrizant. Leaves and rhizomes of *K. galanga* are applied externally as a poultice to treat abdominal pains, and as an embrocation or sudorific to treat swellings, inflammations, and muscular rheumatism. Pounded rhizomes are also applied to traumatic injuries and nose bleeding. Mixed with rice flour, they are used in 'beras kencur', a refreshing drink used as a sudorific. In the Philippines, the whole plant is applied as a remedy for cold. A decoction of rhizomes is a tonic, carminative, gargle, a remedy for dyspepsia and malarial chills, and given after childbirth. Rhizomes of *K. rotunda* and *K. angustifolia* are considered cooling. Rhizomes of *K. galanga* are well-known in Chinese medicine as a remedy for toothache or a wash to treat dandruff or scabs on the head.

Rhizomes of *K. galanga* and *K. rotunda* are also widely known as a flavouring for various dishes and rice; in Indonesia, leaves of *K. galanga* are used in a similar way. Rhizomes are also used in perfumery and as a means to preserve cloth from insects. In Indonesia, leaves of *K. galanga* and *K. rotunda* are eaten raw in 'lalab' or cooked as a vegetable. Dried and ground rhizomes of *K. galanga* are also an ingredient of cosmetics, especially powders. Furthermore, rhizomes of *K. galanga* are used as an ingredient of a fermentation agent and in the production of 'kretek' cigarettes. *K. rotunda*, and several other *Kaempferia* species, are often cultivated as an ornamental; the flowers of *K. rotunda* are fragrant. In Vietnam, rhizomes of *K. angustifolia* are chewed as a masticatory together with betel nuts.

Production and international trade The estimated area planted with *K. galanga* in Boyolali (Central Java) and West Pasaman (West Suma-



ethyl-p-methoxy-trans-cinnamate

tra) in Indonesia is about 2000 ha, yielding at least 20 000 t of fresh rhizomes annually.

Properties The roots of *K. galanga* contain 2.4–3.9% of an essential oil whose main constituents are about 25% ethyl cinnamate (cinnamic acid ethyl ester) and up to 30% methyl-p-methoxycinnamate (p-methoxycinnamic acid methyl ester).

The chloroform extract of *K. galanga* rhizome has been found to inhibit tonic contractions in the rat aorta induced by high K^+ concentrations or phenylephrine, in a dose-dependent manner. It was suggested that the chloroform extract inhibits vascular smooth muscle contraction by inhibiting Ca^{2+} influx through both voltage and receptor-operated non-selective cation channels, and Ca^{2+} sensitivity of contractile elements. Ethyl-p-methoxy-trans-cinnamate isolated from *K. galanga* rhizomes, acted as a mono amine oxidase-inhibitor; such inhibitors are sometimes used as drugs to treat depression. In experiments on guineapigs, ethyl-p-methoxy-trans-cinnamate caused trachea and tracheal branches to dilate. This finding supports its traditional use in the treatment of asthma.

Furthermore, the ethanol extract of *K. galanga* showed cytotoxicity against human cervical carcinoma (HeLa) cells (CD_{50} 10–30 μg/ml). *K. galanga* extracts showed amoebicidal activity in vitro against 3 Acanthamoeba species, the causative agents of granulomatous amoebic encephalitis and amoebic keratitis.

The larvicidal principles obtained from the methanolic extract of rhizomes of *K. galanga* are ethyl cinnamate, ethyl-p-methoxycinnamate, and p-methoxycinnamic acid. Two active metabolites, benzyl benzoate and the cyclohexane derivative crotepoxide, have been isolated from the rhizome of *K. rotunda*. Crotepoxide was active in the chronic feeding bioassay of larvae of *Spodoptera littoralis* (LC_{50} 5.6 μg/cm). Finally, *K. galanga* also exhibits antifungal activity.

Description Perennial, rhizomatous, short-stemmed herbs; rhizome sympodial, tuberous or cylindrical, fleshy; roots often bearing small tubers. Leaves usually few, distichous, simple, lower ones sheathing; sheath auriculate at apex; ligule small or absent; petiole short; blade usually broad, with fan-like venation. Inflorescence terminal; peduncle usually enclosed by the imbricating leaf-sheaths. Flowers arranged spirally on a discoid receptacle (the reduced rachis), solitary in the axil of a bract, bisexual, zygomorphic; bracteoles 1 or 2, small, 2-topped to divided almost to the base; calyx tubular, split for a short distance, unequally toothed, usually much shorter than the corolla tube; corolla tubular at base, with 3 subequal, usually linear lobes; staminodes 3, petaloid, the anterior one, called labellum, nearly flat, deeply bilobed, usually white or lilac, sometimes with a different colour towards the base, the 2 lateral ones spreading, often similar to the halves of the labellum; fertile stamen 1, filament very short or absent, anther not or hardly exserted, thecae parallel, dehiscing with longitudinal slits, connective (also called anther-crest) usually large, entire or lobed, often reflexed and filling the throat of the flower but not enfolding the style; ovary inferior, 3-locular with axillary placentation and few to many ovules, style 1, filiform with funnel-shaped stigma, held between the thecae. Fruit a thin-walled, dehiscent capsule. Seeds few to many, ellipsoidal to nearly globular, with a lacerate aril.

Growth and development In Java, *K. angustifolia* flowers from October to January and in April, *K. galanga* in November and December, and *K. rotunda* in April and September to November. *K. galanga* can be induced to flower by a period of drought. Each flower opens for only one day. Pollination is by ants, flies and bees. Fruits are seldom formed.

Other botanical information *Kaempferia* belongs to the tribe *Hedychieae* and is closely related to *Boesenbergia*, *Scaphochlamys* and *Haplochorema*, from which it differs by its variably deeply 2-lobed bracteoles. All African species formerly included in *Kaempferia* have been attributed to a distinct genus called *Siphonochilus*. They differ amongst others in the position of their lateral inflorescences, absence of bracteoles and structure of the labellum.

In *Kaempferia* flowers the 'petal-like' organs, the labellum and 2 lateral staminodes, are modified stamens that function as petals, a situation called homeosis. There seem to be two forms within *K. galanga*, a broad-leaved one and a narrow-leaved one. Both have been reported from Cambodia, Thailand and Java.

About 10 cultivars of *K. galanga* are currently distinguished in Indonesia with 'Cileungsi Besar' the highest yielder.

Ecology Most *Kaempferia* species occur naturally in open forest, forest margins, and teak forest, at low altitudes. They easily escape from cultivation and can then be found in grassy waysides, lawns and waste places. They occur in both everwet and seasonal climates. *K. galanga* thrives best up to 1000 m altitude, in areas with an annual rainfall of 2000–4000 mm, but waterlogging causes damage. It can grow on various soils, from heavy vertisols to latosols and andosols, with clayey to silt-loamy texture, but it develops poorly on acid soils. *K. galanga* and *K. rotunda* grow best in fertile garden soil in shaded conditions.

Propagation and planting *Kaempferia* can be propagated by rhizome pieces 2.5–4 cm long, with at least 2–3 buds; both the younger and older parts of rhizomes may be used. Rhizome cuttings may be kept for 1–2 weeks under dry, shaded conditions prior to planting at the beginning of the rainy season. *K. galanga* and *K. rotunda* can also be propagated by tissue culture using rhizome explants with vegetative buds. In Central Java *K. galanga* is usually planted in furrows 7.5–10 cm deep at 10–15 cm spacing. In West Sumatra it is planted in separate planting holes 5–7.5 cm deep at a spacing of 25–60 cm. In Java *K. galanga* is usually intercropped with groundnut and rice.

Husbandry In *K. galanga* application of 15 t/ha manure proved to be most effective in increasing rhizome yield; higher doses, however, promoted the development of aerial parts only. It loses its leaves towards the east monsoon period and it is recommended to dig up the rhizome then to prevent fungal decay.

Diseases and pests *Pythium* sp. has been observed in Central Java to cause rhizome soft rot of *K. galanga*, particularly under poor drainage conditions.

Harvesting In Central Java *K. galanga* is harvested 6–18 months after planting, in West Sumatra after 18–24 months.

Yield Fresh rhizome yields of *K. galanga* in Central Java are 6–15 t/ha, compared with 12–20 t/ha in West Sumatra. Yields as low as 1.2 t/ha have also been reported.

Handling after harvest Rhizomes of *K. galanga* can be washed, sliced and dried for storage.

Genetic resources and breeding There are no germplasm collections and breeding programmes of *Kaempferia*.

Prospects In Indonesia most rhizomes of *K. galanga* are obtained from the wild. Since it is expected that *K. galanga* will be increasingly used in the rapidly developing Indonesian industries of traditional medicine and cosmetics, cultural practices need to be developed to meet this demand. In Thailand, *K. galanga* rhizomes are collected from the wild and from small-scale cultivation and exported to China. Further agronomic research may lead to market expansion.

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posium, May 22–25, 1989, Jakarta, Indonesia. Pudoc, Wageningen, the Netherlands. pp. 306–308.

Selection of species

Kaempferia angustifolia Roscoe

Trans. Linn. Soc. London 8: 351 (1807).

Synonyms *Kaempferia roxburghiana* Schult. (1822), *Kaempferia undulata* Teijsm. & Binnend. (1855) non Link, *Kaempferia gilbertii* W. Bull (1882).

Vernacular names Indonesia: kunci kunot (Sundanese), kunci menir (Malay, Jakarta), kunci pepet (Javanese). Laos: 'van^2 toup 'moup. Thailand: thao nhang hang, prab samut. Vietnam: thi[eef]n li[eef]n l[as] h[ej]p.

Distribution The eastern Himalayas, Laos, Vietnam, Thailand and Java; also cultivated in Java.

Uses The small roots and tubers of *K. angustifolia* have astringent properties and are used against dysentery and diarrhoea, but also to treat coughs; the watery main rhizome is considered cooling.

Observations A small herb; leaves 2–8, glabrous, sheaths 3–4 cm long, blade linear-lanceolate to oblong-elliptical, 7–20 cm × 1–10 cm; inflorescence emerging from between the leaves, sessile, with 10–12 flower buds, only a few of which develop; calyx 3–5 cm long, white, corolla white, tube up to 8.5 cm long, lobes up to 3.5 cm long, labellum obovate, 20–30 mm × 10–25 mm, incised to about one third, purple, other staminodes lanceolate to oblong-obovate, 18–37 mm long, white, fertile stamen about 10 mm long, connective shortly bilobed with acute lobes. *K. angustifolia* is found in teak forest, lowland rice, and on calcareous marl, up to 150 m altitude.

Selected sources 97, 455, 580, 1128, 1372, 1495, 1496.

Kaempferia galanga L.

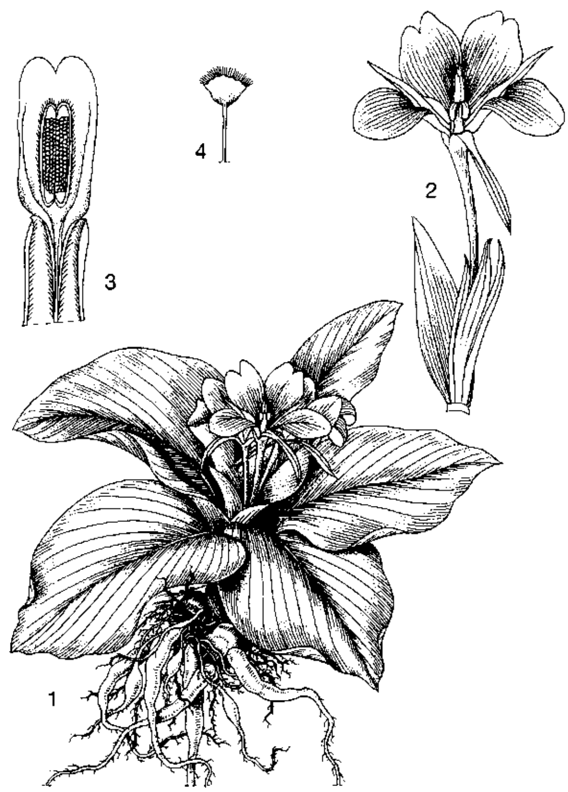
Sp. pl. 1: 2 (1753).

Vernacular names East-Indian galangal (En). Indonesia: kencur, cekur (general), bataka (North Sulawesi, Ternate, Tidore). Malaysia: cekur, cekur Jawa, cengkur (Peninsular). Philippines: gisol (general), disok (Iloko), dusol (Tagalog). Laos: 'van^2 'hom. Thailand: hom proh (central), waan hom, waan teen din (northern). Vietnam: dia li[eef]n, s[ow]n nai, tam n[aj]i.

Distribution Possibly native only to India, where it is widespread, cultivated throughout South-East Asia, including southern China, in Malesia east to the Moluccas, possibly also introduced in northern Australia.

Uses In Malaysia, rhizomes are used in traditional medicine for the treatment of high blood pressure, swellings, ulcers, sprains and asthma. Leaves and rhizomes are chewed to treat coughs and sore throat; they are also pounded and used in poultices and lotions applied to relieve many ailments. Rhizomes are an ingredient of post partum medicine and to treat common cold. Leaves and rhizomes are eaten fresh as a vegetable and used in cosmetic powder and as a food flavouring agent. In Indonesia, *K. galanga* is used in a similar way, to treat swellings, muscular rheumatism, wounds and as an antidote. It is a common ingredient of 'jamus'. In the Philippines, the whole plant is used as a remedy for common cold. Rhizomes are used to treat headache, dyspepsia and malarial chills. Rhizomes and leaves are used as a flavouring in food, rhizomes also in perfumery. The leaves are used as vegetable.

Observations A small herb; leaves usually



Kaempferia galanga L. – 1, plant habit; 2, flower; 3, apex of fertile stamen; 4, style apex.

2–3(–5), sheaths 1.5–5 cm long, blade often horizontal and appressed to the soil, broadly elliptical to suborbicular, 6–15 cm × (2–)5–10 cm, acuminate, glabrous above, arachnoid-hairy below; inflorescence emerging from between the leaves, sessile, 4–12(–15)-flowered; calyx 2–3 cm long, corolla white, tube 2.5–5 cm long, lobes 1.5–3 cm long, labellum broadly obovate, divided to about halfway or more, white or pale purple with violet to purple spots at base, each lateral lobe about 2–2.5 cm × 1.5–2 cm, other staminodes oblong-obovate to oblanceolate, 1.5–3 cm long, white, fertile stamen 10–13 mm long, connective deeply bilobed with reflexed lobes. *K. galanga* thrives best in slightly shaded places such as open forest, forest edges, and bamboo forest, on various soils, up to 1000 m altitude.

Selected sources 97, 190, 202, 261, 287, 350, 363, 455, 580, 615, 875, 1035, 1066, 1126, 1128, 1178, 1287, 1372, 1406, 1496.

Kaempferia rotunda L.

Sp. pl. 1: 3 (1753).

Synonyms *Kaempferia longa* Jacq. (1798).

Vernacular names Round-rooted galangal (En). Indonesia: kunci pepet, kunir putih (Javanese), temu rapet (eastern Sumatra). Malaysia: kencur, kunyit putih, temu putih (Peninsular). Philippines: gisol na bilog (general). Thailand: waan nonlap (Chiang Mai), waan haao non (Ratchaburi), ueang din (northern). Vietnam: c[aar]m dia la, ng[ar]i m[as]u.

Distribution Possibly native to Indo-China, but nowadays cultivated almost throughout tropical Asia, mainly as an ornamental but especially in South-East Asia also for medicinal purposes; regularly escaping from cultivation.

Uses In Indonesia, rhizomes are used to treat abdominal illness; the watery little corms are considered cooling. In the Philippines, rhizomes are used internally to treat gastric complaints, and externally, mixed with oil, as a cicatrizant. They are also used in perfumery and as a means to preserve cloth from insects. Leaves and rhizomes are eaten fresh or cooked as a vegetable and used in cosmetic powder and as a food flavouring agent.

Observations A small herb; leaves (2–)3–5, erect, petiolate, sheaths 7–24 cm long, blade oblong-lanceolate to elliptical, (7–)12–25(–36) cm × 4–7(–11) cm, gradually acuminate, glabrous above, puberulous below, often flamed or marked; inflorescence appearing before the leaves on stems with rudimentary leaves, on a well-developed peduncle, 4–16-flowered; calyx 3–7 cm long, white or greenish, corolla white, interruptedly striped-punctate, tube 3.5–7 cm long, lobes 3.5–7 cm long, labellum obcordate, divided halfway or further, 4–7 cm × 2–4 cm, purple with yellowish midrib, other staminodes elliptical to linear, 3–5 cm long, white or lilac, fertile stamen 0.8–2.5 cm long, connective 2–4-lobed. *K. rotunda* grows well in teak forest, open lower montane forest, old bamboo forest, but also in open grassland, up to 1300 m altitude.

Selected sources 97, 202, 455, 580, 615, 875, 1066, 1126, 1128, 1178, 1372, 1496.

Halijah Ibrahim

Kalanchoe Adans.

Fam. pl. 2: 248 (1763).

CRASSULACEAE

$x = 17, 18$; *K. laciniata*: $2n = 34, 68$

Major species *Kalanchoe ceratophylla* Haw., *K. crenata* (Andrews) Haw.

Vernacular names Malaysia: sedingin, seringin (Peninsular).

Origin and geographic distribution *Kalanchoe* includes about 60 species, mainly from the Old World tropics and South Africa. Only a few species occur in South-East Asia. *K. crenata* is probably native to Africa, but since long naturalized in the drier parts of South-East Asia. *K. ceratophylla* is native to continental Asia and commonly cultivated in Malesia. *K. laciniata* is indigenous in Africa, southern India and Thailand.

Uses The uses of the various *Kalanchoe* species generally involve their antiseptic and cooling properties. Crushed leaves of *K. crenata* are applied to ulcers in the Philippines and Indo-China. In Taiwan, a decoction of *K. crenata* is employed as an eyewash and a styptic for contusions. In East and West Africa the juice of the leaves is applied to septic wounds, or is used to relieve headache. The roots and leaves are said to be toxic and are used as an abortifacient in some parts of East Africa.

The leaves of *K. ceratophylla* have styptic, astringent, antiseptic and cooling properties. In the Philippines, the pulped leaves are used to treat chronic ulcers and headache. In Indo-China, the leaves are used as topicals for ulcers. In Malaysia, the leaves are applied as a poultice on the chest for coughs and cold. In India, poulticed leaves of *K. ceratophylla* or their juice are applied to bruises and contusions to allay inflammation and prevent discoloration. The leaves are also used as a

styptic to cuts, abrasions and other wounds, and applied to insect bites. The plant is used internally to treat diarrhoea, dysentery, lithiasis, cholera and phthisis. In Malaysia, twigs are placed in houses to attract good spirits and drive away evil ones, and to ward off diseases, such as cholera. *K. laciniata* probably has similar uses to *K. ceratophylla*.
K. ceratophylla, *K. crenata* and *K. laciniata* are all grown as ornamentals too. Many other *Kalanchoe* species are also used as ornamentals, e.g. *K. blossfeldiana* Poelln., a well-known pot plant in Europe and the United States. In South-East Asia, *K. blossfeldiana* plants are sold as 'flower of longevity' in spring festivals.

Properties The leaves and flowers of *K. crenata* are reported to contain several flavonoids (quercetin, kaempferol, patuletin) and their glycosides (quercetin-3-O-glucoside-7-O-rhamnoside, kaempferol-3-O-rhamnoside, patuletin-3,7-di-O-rhamnoside). Several sterols (sitosterol, stigmasterol, campesterol) and triterpenoids (friedelin, taraxerol, glutinol) have also been isolated from the flowers of *K. crenata*.
Little is known about the biological activities of the *Kalanchoe* species described or their constituents. Kalambrosides A–C (patuletin-acetyl-di-O-rhamnosides), isolated from *K. brasiliensis* Camb., were found to show potent inhibitory effects on PHA-induced human lymphocyte proliferation in vitro. In this assay the structurally related, but non-acetylated patuletin-3,7-di-O-rhamnoside (also isolated from *K. crenata*) was devoid of any activity. The ethanol extract of *K. laciniata* has also been found to exhibit cytotoxic effect against CA-9 KB cells. Furthermore, *K. crenata* is reported to cause poisoning in sheep, but the toxic principle is not known. Cotyledonosis (or 'krimpsieke') is a neurotoxic syndrome in animals and, like cardiac glycoside poisoning can be caused by *Crassulaceae*-bufadienolides e.g. isolated from *K. lanceolata* (Forssk.) Pers. (3-O-acetylhellebrigenin, lanceotoxin A, lanceotoxin B) or from several *Bryophyllum* species.

Adulterations and substitutes *Bryophyllum pinnatum* (Lamk) Oken has comparable medicinal uses.

Description Shrubs or shrublets up to 2 m tall, with branches spreading, fleshy but somewhat woody towards base, often regenerating from base. Leaves opposite, simple, from entire to crenate and pinnatifid, free or slightly fused at base, fleshy, persistent or deciduous. Inflorescence terminal, usually consisting of many-flowered corymbose or paniculate cymes, peduncle present or absent with gradual transition from leaves to shorter bracts below the flowers. Flowers bisexual, spreading or stiffly erect, 4-merous; calyx 4-partite; corolla with petals fused into a tube longer than the lobes; stamens 8 in 2 whorls, filaments glabrous and fused to corolla tube at about the middle, anthers usually included, with terminal appendage; ovary superior, consisting of 4 free carpels, gradually constricted into styles and with terminal stigmas. Fruit a many-seeded follicle. Seeds ellipsoidal, with a constriction and abruptly widening at blunt proximal end.

Growth and development All *Kalanchoe* species have the Crassulacean Acid Metabolism (CAM) pathway, enabling them to fix CO_2 at night and to photosynthesize with closed stomata during daytime, to minimize water loss. *K. crenata* flowers and fruits freely in South-East Asia.

Other botanical information In the past *Kalanchoe* was enlarged to incorporate other closely related genera, and then split up again. Some taxonomists include *Bryophyllum* in the genus, but here *Bryophyllum* is considered to be a separate genus. A recent taxonomical publication has resulted in nomenclatural changes affecting South-East Asian species. One such change is that the widespread Malesian species known under the name *K. laciniata* is now called *K. ceratophylla*; the true *K. laciniata* is indigenous in India and Thailand. The Malesian species known as *K. integra* is now called *K. crenata*.

Ecology *Kalanchoe* species are mainly found in dry rocky or sandy, sunny or slightly shaded locations. *K. ceratophylla* is grown in gardens or as a pot plant in lowland regions. *K. crenata* is found up to an altitude of 2000 m in sunny, stony or rocky sites, even on almost bare rocks. It is locally abundant in light *Casuarina* forest.

Propagation and planting *Kalanchoe* plants are easy to propagate from seed and cuttings.

Diseases and pests In Japan, *K. laciniata* is reported to be susceptible to grey mould caused by *Botrytis cinerea*.

Harvesting The leaves are plucked and used fresh.

Genetic resources and breeding The *Kalanchoe* species used medicinally are grown as ornamentals and, in general, the harvested material originates from such plants. The natural resource as such is therefore not directly threatened in the Malesian region.

Prospects *Kalanchoe* species will remain of some importance for home consumption, as a readily available traditional antiseptic. It is unlikely that this importance will increase in the near future.

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Selection of species

Kalanchoe ceratophylla Haw.

Rev. pl. succ.: 23 (1821).

Synonyms *Bryophyllum serrata* Blanco (1845), *Kalanchoe laciniata* auct. non (L.) DC.

Vernacular names Malaysia: sedingin, setawar kampong, chakar bebek. Philippines: siempreviva (Sp, Tagalog). Thailand: khong saamyaan (central), hom haem (northern). Vietnam: s[uwf]ng h[uw][ow]u, c[af] kheo, tr[uw][owf]ng sanh r[as]ch l[as].

Distribution From the Himalayas, through Assam (India) and Burma (Myanmar) to southern China (Yunnan), Taiwan, peninsular Thailand and Peninsular Malaysia. Cultivated in Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam; also cultivated in Africa, South and Central America.

Uses The leaves or the juice pressed from the leaves of *K. ceratophylla* have widespread application in the topical treatment of ulcers and to relieve headache.

Observations An erect, unbranched or sparingly branched shrub, 30–125 cm tall, stems terete, lower internodes short, intermediate and higher ones gradually becoming longer; leaves numerous, very variable, the lowest simple, ovate and undulate-dentate, median ones deeply pinnatifid or bipinnatifid, 8–15 cm long, pale glaucous-green, tinged with purple when young, petiolate, upper leaves much smaller, narrow, often almost entire; inflorescence 10–30 cm long, glabrous; flowers with calyx variable in size, 4–10 mm long, segments erect or erecto-patent, ovate-lanceolate, acute, corolla salver-shaped, tube distinctly widened downwards, about 1.3 cm long, green at the base, yellowish upwards, lobes 4, widely patent, bright yellow, ovate or ovate-oblong, acute, about 1 cm long, anthers slightly exserted, carpels lanceolate, 5–6 mm long, glabrous, green, styles glabrous, 2–4 mm long. *K. ceratophylla* is found in gardens at lower elevations, and commonly grown as a pot plant.

Selected sources 95, 97, 202, 979, 1126, 1128, 1178, 1476, 1568.

Kalanchoe crenata (Andrews) Haw.

Syn. pl. succ.: 109 (1812).

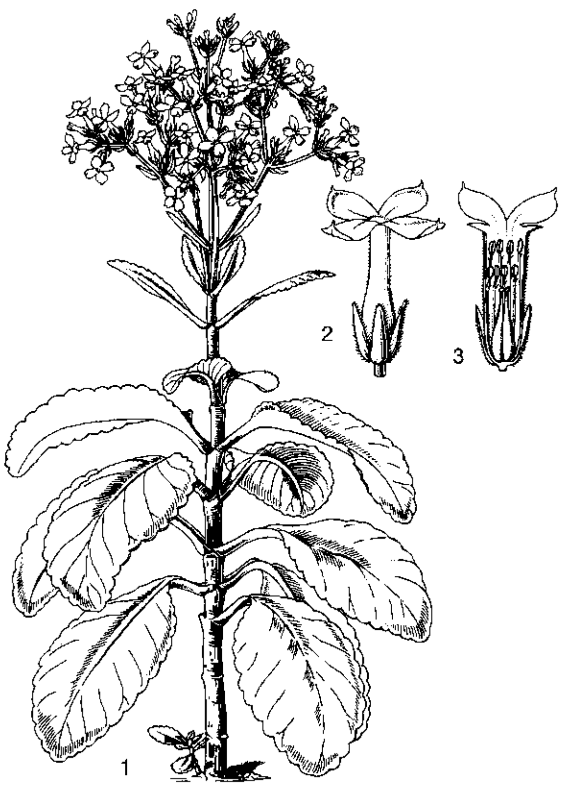
Synonyms *Cotyledon crenata* (Andrews) Vent. (1804), *Kalanchoe spathulata* DC. (1811), *Kalanchoe integra* auct. non (Medic.) O. Kuntze.

Vernacular names Indonesia: kayu urip (Javanese), buntiris (Sundanese), tampu taura (southern Sulawesi). Thailand: kong saamyaan, thong saamyaan (central). Vietnam: tr[uw][owf]ng sinh l[as] to.

Distribution Probably native to tropical and South Africa, naturalized in Brail and South and South-East Asia. In Java mostly found in the east, on the hot and dry eastern slopes of the mountains.

Uses The juice of the leaves is generally used for its antiseptic, anti-inflammatory and counter-irritant properties.

Observations An erect or ascending shrub, 30–200 cm tall, usually unbranched, with a strong



Kalanchoe crenata (Andrews) Haw. – 1, plant habit; 2, flower; 3, flower in longitudinal section.

taproot, stems terete or obtusely quadrangular; leaves ovate or obovate-oblong to spatulate, 4–30 cm × 2.5–20 cm, base cuneate, apex obtuse, thickly coriaceous, margins crenate, pale green, glaucous or variably tinged with purple, petiolate; inflorescence up to 30 cm long; flowers with calyx lobes fused basally, 4–12 mm × 3–4 mm, acute to attenuate, corolla tube 8–16 mm long, distinctly widened downwards, (orange–)yellow above the greenish base, corolla lobes oblong-lanceolate to elliptical, (4–)8–12 mm × (2–)3–4(–5) mm, patent or subreflexed, after anthesis erect and twisted together, mucronate, anthers either all included or those of the upper series slightly exserted, carpels free or subconnate at the base, glabrous. *K. crenata* is a very variable, and widespread species known under a multitude of synonyms. It can be found in a wide range of open, dry, stony habitats up to 2000 m altitude, sometimes abundant in light *Casuarina* forest.

Selected sources 66, 67, 95, 97, 202, 286, 1126, 1128, 1178, 1179, 1476, 1523, 1536, 1569.

Kalanchoe laciniata (L.) DC.

Hist. pl. Grass. 2: 100 (1802).

Synonyms *Cotyledon laciniata* L. (1753), *Kalanchoe craibii* Raymond-Hamet (1914).

Vernacular names Thailand: khong saamyaan, thong saamyaan (Bangkok).

Distribution Southern India and Thailand, South and East Africa and the Arabian peninsula. In Malesia locally cultivated, but not found wild.

Uses In view of the considerable overlap in chemical constituents found in *Kalanchoe* and the morphological similarity with *K. ceratophylla* which makes it difficult to distinguish between the 2 species, it is presumed that this species is used for the same purposes as *K. ceratophylla*.

Observations An erect shrub, 40–100(–150) cm tall, usually unbranched, stems terete, glabrous; leaves numerous, undivided or 3-lobed to seemingly compound, median leaves mostly 3-foliolate or 3-ternate, with linear-lanceolate leaflets, terminal leaflets 2–5(–8) cm long, with a crenate to dentate margin, green, petiolate; inflorescence an oblong cyme, glandular-pubescent; flowers with a subcampanulate calyx, 2.5–9 mm long, green, with lanceolate lobes, corolla salver-shaped, tube distinctly widened downwards, about 1 cm long, lobes 4, ovate-lanceolate to oblong, about 5–10 mm long, acute, cream to yellow, anthers included within the tube, carpels ovate-lanceolate, up to 9 mm long, glabrous, green. *K. laciniata* is found in open, rather dry, stony, habitats at 400–2000 m altitude.

Selected sources 1179, 1568, 1569.

Wardah & J.L.C.H. van Valkenburg

Lantana L.

Sp. pl. 2: 626 (1753); Gen. pl. ed. 5: 275 (1754).

VERBENACEAE

$x = 11$; *L. camara*: $2n = 22, 33, 44, 55, 66$; *L. trifolia*: $2n = 48$

Major species *Lantana camara* L., *L. trifolia* L.

Vernacular names Sage, wild sage (En).

Origin and geographic distribution *Lantana* consists of approximately 150 species, and is native to tropical and subtropical America, the West Indies and Africa. Several species are well-known ornamentals, some are noxious weeds and have spread throughout the tropics and subtropics. *L. camara* and *L. trifolia* were introduced in Malesia in the 19th Century.

Uses In Indonesia, Malaysia and Thailand *L. camara* is assumed to have antiseptic properties, and so pounded leaves are applied to cuts and ulcers; a decoction of the leaves is used for the same purpose in the Philippines. In Java, the pounded leaves are applied to swellings to make them disappear; also a lotion or fomentation is made from them to treat rheumatism. A decoction of the leaves is used to treat constipation or as an emetic. In Indonesia and the Philippines a decoction or infusion of the leaves and flowers is used as a febrifuge, a diaphoretic and stimulant, and to relieve catarrh and bronchitis. A decoction of the fresh roots is used as a gargle to treat toothache in the Philippines and Thailand, and in Indonesia as a remedy for gonorrhoea and leucorrhoea. The ripe fruits are widely eaten by children.

In Central America a decoction is taken as a stomachic and remedy for rheumatism. A strong decoction is taken as an antidote for snakebites, whereas the crushed leaves are poulticed on the wound. A decoction of leaves or flowers is considered a remedy for colds or fever and employed for its diuretic and sudorific properties and as an emmenagogue. It is sometimes taken as a tonic and to treat hypertension in Costa Rica.

In Malaysia, *L. trifolia* is reported to be used in a similar way as *L. camara*. In Cuba, a decoction of the plant is applied externally to relieve rheumatism and is used as an eyewash in ophthalmia. In Colombia a decoction of the plant is used as an emmenagogue and sudorific. In Burundi the plant is used as a traditional remedy against gonorrhoea and applied to treat theileriasis in livestock.

In general, *L. camara* is widely grown for its colourful flowers; several forms and varieties are in cultivation. Despite its weedy nature it can be used to stabilize slopes for erosion control and as an undemanding hedge in nurseries.

Properties The leaves of *L. camara* contain an essential oil, which is rich in sesquiterpenes. Furthermore, 6 compounds have been isolated and identified on the basis of chemical and spectral analysis: oleanonic acid, lantadene A, lantadene B, lantanilic acid, icterogenin and camaroside (4',5-dihydroxy-3,7-dimethoxyflavone-4'-O-β-D-glucopyranoside). Lantadene C (22-β-2-methylbutanoyloxy-3-oxo-olean-12-en-18-oic acid), also isolated from the leaves of *L. camara* has been found to be identical with dihydrolantandene A. Lantadene C resembles lantadene A in the pentacyclic part of the molecule, but differs in the side chain region. Atom C-34 is cis to C-35 in lantadene C, but is trans in lantadene A. Semisynthetic lantadene C has been prepared by catalytic hydrogenation of lantadene A: it appears in two forms, crystalline and amorphous. Furthermore, the two (pentacyclic triterpene acid) isomers lantadene A and lantadene B are the causal agents of most of the toxic effects.

Six oligosaccharides and six iridoid glucosides isolated from the ethanolic extract of *L. camara* roots have been identified as stachyose, verbascose, ajugose, verbascotetracose, lantanose A, lantanose B, and the glucosides theveside, 8-epiloganin, shanzhsid methyl ester, theviridoside, lamiridoside and geniposide.

Eight triterpenoids have been isolated from the roots of *L. camara*. On the basis of their chemical properties and spectral data, they have been identified as lantanolic acid, 22 β-O-angeloyl-lantanolic acid, oleanolic acid, 22 β-O-angeloyl-oleanolic acid, 22 β-O-senecioyl-oleanolic acid, 22 β-hydroxy-oleanolic acid, 19 α-hydroxy-ursolic acid and 3 β-isovaleroyl-19 α-hydroxy-ursolic acid (lantaiursolic acid). A bioactive triterpene, 22 β-acetoxylantic acid, was also isolated from *L. camara*; it showed antimicrobial activity against *Staphylococcus aureus* and *Salmonella typhi*, as well as antimutagenic activity.

The extract of root-bark of *L. camara* showed in vitro antimalarial activity in a test using the K1 strain of *Plasmodium falciparum* that is resistant to several drugs. *L. camara* leaves have been shown to contain water-soluble factors which caused isolated guinea-pig ileum to contract. The inhibitory effects of lantadenes and related triterpenoids from *L. camara* on the Epstein-Barr virus suggest potential against tumours. Verbascoside isolated from *L. camara* has in vitro antitumour activity, possibly at least partly due to inhibition of protein kinase C.

Potent inhibitors of human thrombin were demonstrated to be present in methanolic extracts from *L. camara* leaves. These were shown to be 5,5-trans-fused cyclic lactone-containing triterpenes. A methanol extract (0.05 μg/ml) of aerial parts of *L. trifolia* produced bronchodilation of isolated guinea-pig trachea comparable with that of salbutamol (0.05 μg/ml). The extract (0.1 μg/ml) reduced bronchoconstriction of isolated guinea-pig trachea induced by histamine, 5-hydroxytryptamine (serotonin) or acetylcholine. Physostigmine (2–4 μg/ml) failed to inhibit neuromuscular blocking activity of the extract (9 mg/ml) on rat phrenic nerve diaphragm. Using a disk diffusion method a methanolic extract of the leaves was found active against *Neisseria gonorrhoea* and *N. meningitidis*. The active component is probably the flavonoid umuhengerin (5-hydroxy-6,7,3',4',5'-pentamethoxyflavone).

All parts of *Lantana* except the flowers are toxic to livestock. *Lantana* poisoning in cattle, sheep, buffalo and guinea-pigs causes obstructive jaundice, photosensitization and raises serum glutamicoxaloacetic transaminase activity. The symptoms can be reproduced in sheep by administering purified lantadene A. The organs most affected during *Lantana* poisoning are the liver and kidneys. Intoxicating guinea-pigs with *L. camara* leads to marked alterations in major tissue constituents in these organs. Hepatic and renal xanthine oxidase activity is also elevated during poisoning. *Lantana* toxicity is manifested in three phases: the release and absorption of toxins in the gastro-intestinal tract, the hepatic phase resulting in cholestasis, hyperbilirubinaemia, hyperphylloerythrinaemia, and finally the tissue phase in which cell injury results from the accumulation of bilirubin and phylloerythrin. Thus, therapeutic measures should be aimed at arresting one or more of these phases. No antidote is available against the toxic section of *L. camara*. Symptomatic treatments have been proposed, with limited success. Unlike lantadene A (with a toxic and non-toxic form), both the crystalline and amorphous forms of lantadene C elicited strong hepatotoxic response in guinea-pigs associated with decrease in faecal output, feed intake, hepatomegaly, hepatic injury at the cellular and subcellular level, and increase in plasma bilirubin, and acid phosphatase activity. All the clinical signs, hepatic lesions, and changes in blood plasma typified *Lantana* toxicity. Water extracts of leaves of *L. camara* showed antifungal activity against rice blast (*Piricularia oryzae*) and brown spot of rice (*Helminthosporium oryzae*) in vitro, and antibiotic activity against gram-positive bacteria.

The crude extract of *L. camara* flowers is toxic against cotton stainer (*Dysdercus cingulatus*), housefly (*Musca domestica*) and corn weevil (*Sitophilus zeamais*). The oil from *L. camara* flowers is toxic to cotton stainer, housefly, corn weevil, black army worm (*Spodoptera exempta*) and lesser grain borer (*Rhizopertha dominica*). Flower extracts of *L. camara* showed a repellent effect against *Aedes* mosquitoes.

Adulterations and substitutes Lantadene A is identical to rehmanic acid isolated from *Lippia rehmanii* Pears.

Description Herbs or shrubs, sometimes subscandent, usually subscabrous and hirtous-pubescent or tomentose with simple hairs. Leaves opposite, sometimes in whorls of 3, simple, dentate, often rugose, petiole usually present; stipules absent. Inflorescence a dense cylindrical spike or contracted to form heads, usually axillary, pedunculate. Flowers bisexual, sessile, borne in the axil of solitary bracts, which are often ovate, acuminate, and subimbricate or spreading; calyx small, membranous, truncate or sinuate-dentate; corolla with a cylindrical, slender tube, actinomorphic or obscurely 2-lipped, 4–5-fid, lobes broadly obtuse or retuse, spreading, red, yellow or white often fading to other colours; stamens 4, didynamous, inserted at about the middle of the corolla tube, included, anthers ovate; ovary superior, 2-locular with 1 ovule in each cell, style usually short, stigma rather thick, oblique or sublateral. Fruit drupaceous, the exocarp subfleshy, endocarp hard, 2-celled or splitting in 2 parts. Seeds exalbuminous.

Growth and development The *Lantana* species in Malesia are evergreen and flower throughout the year. The flowers are mainly pollinated by moths and butterflies. The seeds are dispersed by fruit-eating birds.

Other botanical information *Lantana* is closely related to *Lippia* and *Verbena* and placed in the subfamily *Verbenoideae*. Various authors disagree whether the observed variation in growth habit, armature of the branches, indumentum of the leaves and changes in flower colour during anthesis of *L. camara* and *L. trifolia* is sufficient support for a further subdivision of these taxa in varieties or formae.

Ecology *Lantana* prefers rather open not too moist habitats, and occurs naturally from latitude 45°N to 45°S. As open habitats are often man-induced, some species have spread as a weed in cropped land and infested abandoned fields and pastures. *L. camara* is somewhat shade-tolerant and can become the dominant understorey in open forests or in tropical tree crops. Moderately fertile and well-drained soils are favoured.

Propagation and planting *L. camara* can be grown from seed but can also easily be propagated from cuttings 7.5 cm long.

Husbandry When grown as a pot plant, *L. camara* can easily be pruned into a desirable shape.

Diseases and pests *L. camara* often poses a serious problem in plantation crops and pastures. Conventional control methods such as burning, slashing and digging result in the regrowth of even more shoots. Therefore great effort has been put in finding methods for biological control. The most important biological control today is by the *Lantana* defoliator caterpillar *Hypena strigata*.

Genetic resources and breeding As both Malesian *Lantana* species have a pantropical distribution as a weed, there is no risk of genetic erosion. Furthermore, both species are grown as ornamental.

Prospects The reported antitumour, antibiotic and bronchodilatatory activities of *Lantana* seem to justify more research, which might result in future applications in modern medicine. The potential as a biological insecticide also deserves attention. Applications for erosion control should be limited to areas where livestock numbers are low. *L. camara* in particular is a popular pot plant with a wide range of cultivars.

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Selection of species

Lantana camara L.

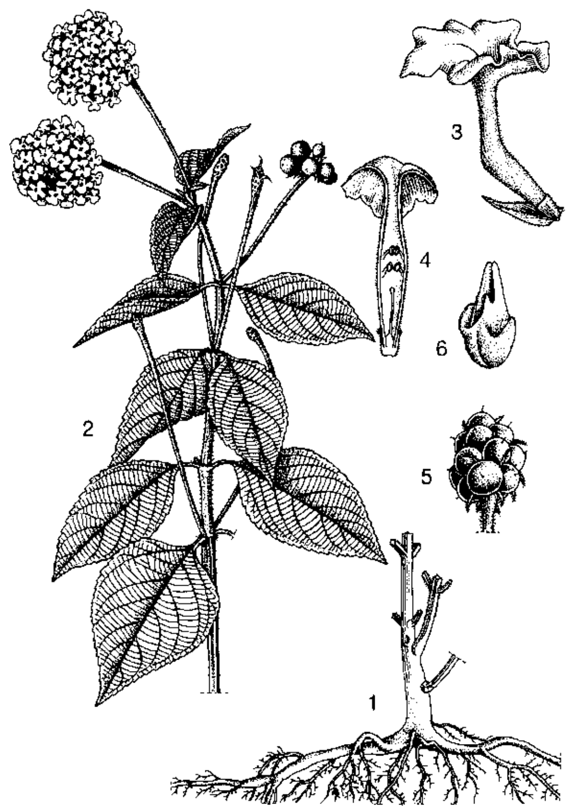
Sp. pl. 2: 627 (1753).

Synonyms *Lantana aculeata* L. (1753).

Vernacular names Sage, wild sage (En). Indonesia: kembang telek, tembelekan (Javanese), saliara (Sundanese). Malaysia: bunga pagar, bunga tahi ayam, jebat harimau (Peninsular). Philippines: koronitas, kantutay (Tagalog), baho-baho (Bisaya). Thailand: kaam kung (Mae Hong Son), khee kae (Pranchin Buri), yeesun (Trang). Vietnam: c[aa]y tr[aa]m [oor]i, c[aa]y b[oo]ng [oor]i, c[aa]y t[uws] qu[is].

Distribution Native to tropical America, but introduced and naturalized throughout the tropics and subtropics.

Uses In South-East Asia the leaves (and sometimes the wet, ground roots) are applied to cuts, ulcers, swellings and to treat rheumatism, a decoction of the leaves and flowers is used to treat



Lantana camara L. – 1, root system; 2, flowering and fruiting twig; 3, flower with bract; 4, flower in longitudinal section; 5, infructescence; 6, seed.

constipation, as a febrifuge, diaphoretic and stimulant, and to relieve catarrh and bronchitis. A decoction of the roots is used to treat toothache, headache, inflammation, gonorrhoea and leucorrhoea. *L. camara* is used as an ornamental and in hedges.

Observations An erect or subscandent much-branched shrub, up to 5 m tall, stems square or 3-angled, often bearing hooked prickles, highly aromatic; leaves opposite or rarely in whorls of 3, ovate to oblong-ovate, 5–8 cm × 3–5.5 cm, petiole 1.5–3 cm long; inflorescence flat or hemispherical subcapitate; flowers with corolla tube extending to 12 mm long during anthesis, often slightly curved, orange-yellow or orange to pink, white, or variegated, changing to red or scarlet; fruit a globose glossy drupe, deep blue when ripe. *L. camara* occurs from sea-level to 1700 m altitude in relatively open and disturbed, not too moist habitats. It is mainly a weed of plantation crops and pastures. Due to the toxicity of leaves and seeds it is a serious threat to sheep and cattle.

Selected sources 92, 97, 129, 202, 332, 350, 468, 578, 650, 968, 979, 1035, 1065, 1089, 1106, 1107, 1108, 1126, 1128, 1178, 1213, 1321, 1322, 1323, 1558, 1561, 1572.

Lantana trifolia L.

Sp. pl. 2: 626 (1753).

Vernacular names Indonesia: tahi ayam (general), puyengan (Javanese), mandakaki (Sundanese). Malaysia: bunga pagar puteh (Peninsular). Thailand: phakaa krong.

Distribution Native to the West Indies and South America, common in tropical Africa and introduced and naturalized in India, Peninsular Malaysia and Java.

Uses In Malaysia and South America *L. trifolia* is used in a similar way as *L. camara*. In Burundi it is also applied to treat theileriasis in livestock.

Observations An erect shrub up to 3 m tall, stems angular, with white hairs but not prickly, faintly aromatic; leaves mostly in whorls of 3, sometimes opposite or 4-whorled, oblong-lanceolate to elliptical-lanceolate, 5–12 cm × 2–6 cm, petiole 5–12 cm long; inflorescence spicate, subcapitate when young, later elongated to 5 cm long; flowers with a corolla tube extending to 7 mm long during anthesis, pink, lavender, purple or white; fruit a sweet, juicy drupe, globose or obovate, purplish-red or white. *L. trifolia* occurs in open disturbed habitats from sea-level to 800 m altitude, prefering dry thickets.

Selected sources 92, 97, 101, 202, 968, 979, 1267, 1505.

Florentina Indah Windadri &
J.L.C.H. van Valkenburg

Melochia corchorifolia L.

Sp. pl. 2: 675 (1753).

STERCULIACEAE

$2n = 46$

Synonyms *Melochia concatenata* L. (1753).

Vernacular names Chocolate-weed, redweed (En). Indonesia: orang-aring (general), jaring (Sundanese), gendiran (Javanese). Malaysia: lemak ketam, lemak kepiting, bayam rusa (Peninsular). Philippines: bankalanan (Iloko), kalingan (Panay Bisaya). Thailand: khaang paak put (Chiang Mai), sa aeng bai mon (Chai Nat), seng lek (Ang Thong). Vietnam: tr[uws]ng cua, v[ai]i gi[aas]y.

Origin and geographic distribution *Melochia* consists of approximately 55 species and is largely confined to the tropics, although some species reach subtropical regions. The greatest diversity in species is found in Central and South America. Only 2 or 3 species are native to South-East Asia. *M. corchorifolia* is a weed throughout the tropics and subtropics, including South-East Asia. It originates from the Old World tropics and has been introduced in the Americas.

Uses Traditional uses of *M. corchorifolia* in South-East Asia are only reported for Malaysia. The leaves are used for poulticing sores and swellings of the abdomen, and the sap is applied as an antidote to wounds caused by arrows poisoned with *Antiaris toxicaria* Lesch. Leaves and roots are used for poulticing in cases of smallpox. A decoction of the leaves and roots is used internally to treat dysentery, and a decoction of the leaves to stop vomiting. A leaf decoction is prescribed in a compound mixture against urinary disorders. A decoction of the plant is applied in folk medicine in India as a cure for abdominal swelling, dysentery and snake bites.

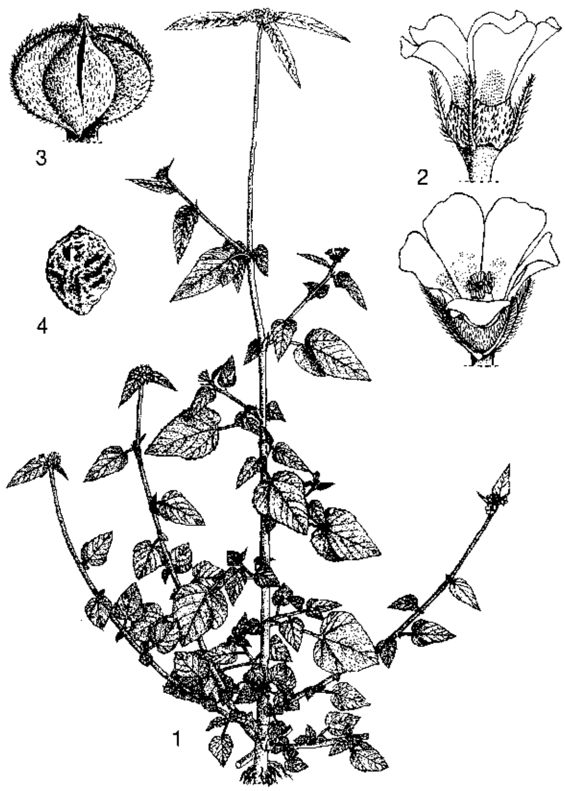
In Papua New Guinea, the leaves of an unidentified *Melochia* species are applied to the forehead to treat headache, and the fruit is eaten. The leaves of *M. corchorifolia* are sometimes eaten in Indo-China and India. The plant yields a beautifully silvery-white, fine and strong fibre, but in too small quantity to be important.

Properties A phytochemical investigation of extracts from the dried, powdered aerial parts of

M. corchorifolia revealed the presence of the triterpenes friedelin, friedelinol and β-amyrin, the sterol β-sitosterol together with its stearate and β-D-glucoside, the aliphatic compounds ethylstearate, tetratriacontanol, nonacosylnon-4-enoate, 24-ethyl-2-methyltritetracont-1-ene-3,23-diol and 27-methyloctacosane-1,3-diol and the flavonoids vitexin and robunin. Furthermore several alkaloids have also been reported in similarly prepared extracts: franganine, frangufoline adouetine-y' and melofoline (cyclopeptide alkaloids), melochicorine (a pseudo-oxindole alkaloid) and 6-methoxy-3-propenyl-2-pyridine carboxylic acid (a pyridine alkaloid). The latter compound may be of significance, since related pyridine derivatives (e.g. pyridoxine, 4'-methoxypyridoxine, nicotinic acid) are physiologically active. The flavonol glycosides hibifolin, triflin and melocorin have been isolated from the leaves.

The main alkaloid in *M. pyramidata* L., American in origin but naturalized in many tropical and subtropical regions including South-East Asia, is (–)-(R)-melochinine. This compound has been shown to produce paralysis, bradypnea, bradycardia and hypotension in laboratory animals, and ingestion of plant material by cattle may cause paralysis. The mechanism of action of this alkaloid can be described as in general non-specific. It may be partly explained by an unspecific interaction with membranes, partially responsible for a calcium-antagonistic effect. Unlike its structural analogue piercidin A, a well-known inhibitor of the mitochondrial respiratory chain, melochinine does not show insecticidal activity.

Description A perennial herb or subshrub up to 130 cm tall, erect or spreading and often widely branched, with tough bark. Leaves arranged spirally, simple, triangular or broadly ovate to lanceolate, lower leaves often slightly 3-lobed, 1–9 cm × 0.5–5 cm, margin crenate-serrate, 3-veined or 5-veined from the base, pubescent on the veins, green or with purplish tinge; petiole 0.3–4.5 cm long, sparsely pubescent to subvillose; stipules about 5 mm long, present on young twigs. Inflorescence an axillary or terminal head-like cyme, rarely less compact, subtended by 1–4 leaves with their stipules forming a kind of involucre, many-flowered. Flowers with pedicel bearing 3–4 pilose bracteoles at apex, bisexual, actinomorphic, 5(–7)-merous; calyx campanulate, about 2.5 mm long, with teeth much shorter than tube, pubescent; petals obovate-spatulate, 4–7 mm long, lilac or white with a yellow spot at base, soon withering; stamens opposite the petals, filaments connate to halfway or more, anthers broad, 2-lobed; ovary superior, 5-celled, densely pilose, each cell with 1–2 ovules, styles 5, united at base. Fruit a small globose capsule, 3.5–5 mm in diameter, green, whitish, pink to purplish-black, loculicidal but valves easily septicidal dehiscent, each cell 1–2-seeded. Seeds small, wingless; endosperm abundant; embryo straight, cotyledons flattened. Seedling with epigeal germination; cotyledons suborbicular, foliaceous.



Melochia corchorifolia L. – 1, flowering plant; 2, flowers viewed from different angles; 3, fruit; 4, seed.

Growth and development *M. corchorifolia* is reported to flower and fruit all year round. The flowers are probably pollinated by small insects.

Other botanical information *M. corchorifolia* is extremely variable morphologically and numerous varieties have been distinguished.

Roots of *M. tomentosa* L. have been used in Curaçao to relieve throat inflammation. However, the root extract was reported to be tumorigenic. *M. umbellata* (Houtt.) Stapf is a small tree indigenous from India to New Guinea for which no medicinal uses have been recorded.

Ecology *M. corchorifolia* is a common weed in many regions in sunny or slightly shaded, usually humid localities, at watersides and in fields, waste places and open forest, up to 700 m altitude in Java. Although it is adapted to xerophytic conditions, *M. corchorifolia* has retained its ability to grow in mesophytic and hydrophytic habitats. In the Philippines, it is reported as one of the dominant weeds in upland rice, together with *Echinochloa colona* (L.) Link. In Thailand and Indonesia it is also a weed in lowland rice, moreover it is also recorded as such in soya bean.

Propagation and planting Scarification of seed improves germination considerably. Scarified seed germinates best at a temperature of 35–40°C. Seed buried to a depth of 1–5 cm gave a germination rate of 80–90% after 7 days; when planted at the soil surface or deeper than 8 cm the seed did not germinate.

Genetic resources and breeding Since *M. corchorifolia* shows a very extensive geographical distribution, occurring in anthropogenic habitats, it is not liable to genetic erosion.

Prospects Although some research has been done on the phytochemistry, very little is known about the pharmacological properties and activity of *M. corchorifolia* and its compounds. The fact that tumorigenic and toxic activity has been reported from some other *Melochia* spp. should lead to caution in using *M. corchorifolia* in phytotherapy as so little is known about its biological activity.

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Other selected sources 97, 185, 1126, 1178.

M.C. Ysrael

Mentha arvensis L.

Sp. pl. 2: 577 (1753).

LABIATAE

$2n = 36, 72, 96$

Vernacular names Mint, field mint (En). Baume des champs (Fr). Indonesia: daun poko (general), bijanggut (Sundanese), janggot (Javanese). Malaysia: pohok. Philippines: polios (Sp, Tagalog). Singapore: pokok kepari. Cambodia: chi poho. Thailand: min indoneesia (Bangkok). Vietnam: b[aj]c h[af], b[aj]c h[af] nam.

Origin and geographic distribution *Mentha* includes about 30 species and numerous hybrids, and mainly occurs in the temperate parts of the northern hemisphere; the centres of diversity are located in Europe and northern and central Asia. Mint has been known as a kitchen herb and medicinal plant since ancient times. It has been found in pyramids in Egypt and is described in old Chinese literature. Only *M. arvensis* occurs in South-East Asia, but some other species and hybrids are cultivated in kitchen gardens and in pots.

M. arvensis is native to Europe and northern and central Asia and is cultivated in many parts of the world. Var. *arvensis* has also been introduced in Malesia from Europe. The Spaniards introduced it in the Philippines, where its cultivation is now widespread, but where it does not flower; it is also cultivated as a pot-herb in Peninsular Malaysia and Singapore. It is cultivated throughout Vietnam, whereas wild forms of *M. arvensis* are also found in northern Vietnam. Var. *javanica* (Blume) Hook.f. (synonym: *Mentha javanica* Blume) occurs in Sri Lanka and the Malesian area (Peninsular Malaysia, Sumatra, Java, Timor, north-eastern Sulawesi, Banda in the Moluccas and the Philippines). It is often cultivated.

Var. *piperascens* Malinv. ex Holmes (Japanese mint) has been introduced into northern Thailand where since 1973 it has been grown on a commercial scale, mainly in Nan Province, for the extraction of mint oil.

Uses Most *Mentha* species are very fragrant and used as a condiment, medicinal plant and as a source of essential oil. The most important use of mints today on a world scale, is as a source of essential oil, which is used in medicinal preparations (ointments, itch-relieving creams, cough syrups, cough lozenges, tablets), as a flavouring agent in toothpastes, mouthwashes, confectionery, candies, chewing gums, beverages and cigarettes, and in the perfume industry (for lotions, soap and cologne). In South-East Asia, however, mints are mainly used to flavour food and for medicinal purposes. However, commercial mint oil production is developing as well, e.g. in Thailand and Indonesia (West Java).

Leaves, whole plants and the oil extracted from *M. arvensis* are all reported as having medicinal properties. They are used as a carminative, stomachic, antispasmodic, stimulant, sedative, sudorific, emmenagogue, astringent (externally) and refrigerant (externally) all over the world. They are administered internally to treat indigestion, flatulence, gastro-intestinal atony, colic and diarrhoea, or externally in the treatment of colds, influenza, fever, sinusitis, nose and throat complaints (all e.g. as nasal drops), headache, facial neuralgia and insect stings (e.g. as rubefacient). In Indonesia, pounded leaves are used externally against headache, and an infusion of the leaves as sudorific and expectorant to treat cough, as a carminative, and as antispasmodic in gastro-enteritis. Although the main use in the Philippines is reportedly as a culinary herb, an infusion of the leafy stems is also used as carminative, and pounded leaves are used to treat insect stings. Mint leaves in the form of tea or tablets are used in the Philippines as an analgesic, particularly in dental surgery. In Thailand, *Mentha* is widely used as a culinary herb but also as a medicine for its carminative, stomachic and expectorant properties.

Compared with other *Mentha* spp., South-East Asian mint is usually mild in flavour and the young leaves are also eaten raw as a side dish; except those of Japanese mint (*M. arvensis* var. *piperascens*), which are rich in menthol.

Production and international trade World production of *Mentha* oil is estimated at 6500–8000 t/year. Japanese mint (*M. arvensis* var. *piperascens*) contributes the greatest part, with 4000–4500 t/year (and a value of about US$ 43 million/year) in the period 1990–1995. The main producing countries are China, Brazil and India. Small amounts of mint oil are produced in Thailand and Vietnam; the current production in Vietnam is about 100 t/year, and the production in Thailand in 1975 was estimated at about 15 t. The world production of peppermint oil is 2000–2500 t/year, with the United States as the main producer. World production of spearmint oil is about 1000 t/year.

Properties Mint oil is a complex mixture of numerous constituents. In general, the different *Mentha* species contain characteristic monoterpenes as main components, but several species also have divergent chemotypes. The characteristic 'cool taste' is due to (–)-menthol ((1R,3R,4S)-menthol), a monoterpenoid alcohol; other optically active isomers of menthol (e.g. (1R,3S,4S)-neomenthol) do not have the same organoleptic characteristics.

Mint oil is obtained from the flowering tops of Japanese mint (*M. arvensis* var. *piperascens*); leaves can contain over 5% (in general 1–1.8%), but at least 0.8% V/w of essential oil on a moisture-free basis according to the Chinese Pharmacopoeia. Japanese mint oil can contain as much as 92.5% (–)-menthol. Very slow cooling of the essential oil (e.g. from 35°C to 5°C at 2°C/day) induces part of the menthol to crystallize. An additional quantity of menthol can be recovered by saponifying (–)-menthyl acetate and by hydrogenating (–)-menthone.

After some of the menthol has been removed, the average composition of the essential oil (referred to as 'rectified' or more often 'dementholized') used for e.g. pharmaceutical or cosmetic products is 30–45% (–)-[1R,3R,4S]-menthol, 17–35% (–)-[1R,4S]-menthone, 5–13% (+)-[1R,1R]-isomenthone, 2–7% menthyl acetate (mainly (–)- or (1R,3R,4S)-), 1.5–7% limonene and 2.5–4% (+)-[1R,3S,4S]-neomenthol. About 30 minor terpenoid constituents have also been identified. They include piperitone (0.5–4%), pulegone (0.2–3.5%), β-caryophyllene (2–5%), β-caryophyllene-epoxide (0.5–2%), α-pinene (2–4%), β-pinene (2–4%), germacrene D (0.1–1.3%), 1,8-cineole (<1%), linalool (<1%), menthofuran (<1%) and camphene (<1%). The oil of *M. arvensis* var. *javanica* from Java has been reported as bitter with a low menthol content and a high pulegone content, but with an agreeable aromatic odour.

The pharmacology of *Mentha* drugs has not been explored much. Mint oil showed a significant in vitro spasmolytic activity on isolated guinea-pig ileum. It is possible that this activity is linked to an inhibition of calcium entry into the cells. The usefulness of the essential oil in cases of 'irritable colon' has been demonstrated in some studies, but in others there was no improvement. Although the oil is the major constituent of several over-the-counter remedies for symptoms of irritable bowel syndrome (a common disorder with a psychophysiological basis), its role in the symptomatic treatment has so far not been established beyond reasonable doubt. Oil from Indian mint showed strong in vitro fungitoxic activity against the dermatophytes *Trichophyton rubrum* and *Microsporum gypseum*, and also against *Aspergillus* spp. The oil was able to cure experimentally induced ringworm in guinea-pigs within 2 weeks. Antibacterial activity of mint oil was also demonstrated in vitro and in foods to which the oil had been added; the growth of *Salmonella* and *Listeria* bacteria was inhibited. In tests in Taiwan an aqueous extract of *M. arvensis* markedly inhibited the growth of both gram-positive and gram-negative bacteria too.

Mint oil is not without toxicity. High doses of menthol are toxic; there is a risk of spasm of the glottis (asphyxia) in young children and asthmatic patients.

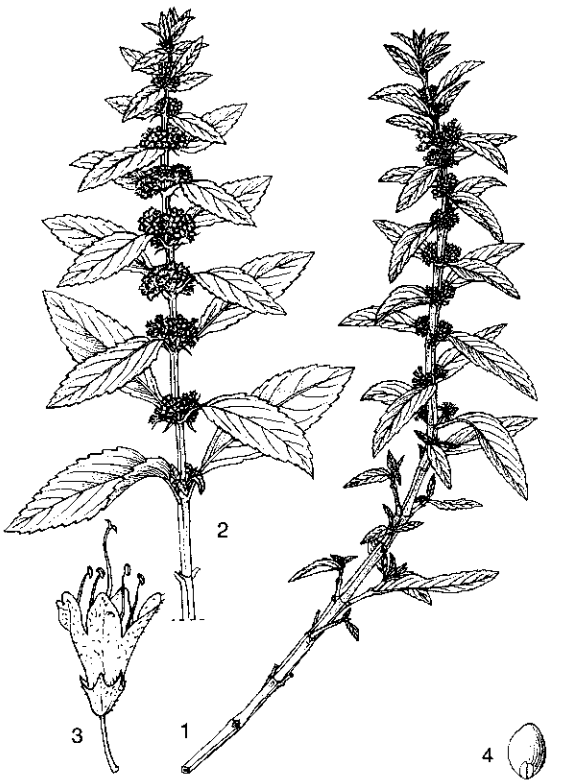
The traditional use of *M. arvensis* as carminative and stomachic has been verified by pharmacological evidence of the carminative effect of the essential oil and antispasmodic and choleretic activity. In tests with rats in India a 50% ethanolic extract of mint leaves has been found to reduce the fructose synthesis in seminal vesicles: male sterility occurred until 30 days after the last treatment. Subcutaneous administration to rats in early pregnancy caused a significant number of abortions.

Peppermint oil showed anti-inflammatory effect in xylene-induced ear oedema in mice and in a cotton pellet granuloma test in rats. Moreover, it showed anti-nociceptive effect against acetic acid-induced writhing and hot plate-induced thermal stimulation in mice. Tablets of 'yerba buena' (*M.* ×*cordifolia* Opiz ex Fresen) tested in the Philippines did not possess direct DNA damaging capacity. They were not mutagenic before and after metabolic activation and they did not possess chromosome-breaking effects. They exhibited antimutagenic effects against dimethylnitrosamine, mitomycin C, N-nitrosopyrrolidine and tetracycline; they reduced the formation of micronucleated polychromatic erythrocytes induced by these compounds.

Mint oil was found to be effective as a fumigant against rice weevil (*Sitophilus oryzae*) in stored sorghum grain, without affecting the germination capacity of the grain. However, it did affect the taste of boiled sorghum.

Adulterations and substitutes Several other *Labiatae* have essential oil with similar or related compounds and with similar applications, i.e. mainly for minor digestive disturbances, in dermatology and hygiene, and in perfumery, cosmetology and confectionery. Examples include the genera *Lavandula*, *Ocimum* and *Salvia*.

Description An aromatic, stoloniferous herb up to 60 cm tall, often rooting on lowest stem parts; stem prostrate, quadrangular, pubescent with appressed hairs. Leaves decussately opposite, simple, lanceolate to broadly lanceolate, 2.5–4.5(–7) cm × 1–2.5(–3) cm, long-cuneate at base, acute at



Mentha arvensis L. – 1, flowering plant; 2, upper part of flowering stem; 3, flower; 4, nutlet.

apex, serrate but entire at base, membranaceous, sparingly hairy above, glabrous beneath; petiole 0.5–1 cm long; stipules absent. Inflorescence consisting of short, fascicled cymes in the axils of the leaves forming a verticillaster; bracts linear or subulate. Flowers small, bisexual; pedicel 2–2.5 mm long; calyx tubular-campanulate, 2–3 mm long, 5-toothed, appressed hairy; corolla funnel-shaped, 4.5–5 mm long, 4-lobed, faintly 2-lipped due to the broader, emarginate upper lobe, puberulent outside, violet or lilac; stamens 4, slightly didynamous, filaments inserted on the corolla tube, erect, anthers 2-celled; disk entire and uniform; ovary superior, consisting of 2 carpels each of which is 2-celled, style with 2 short branches. Fruit consisting of 4 dry 1-seeded schizocarpous nutlets enclosed in the persistent calyx; nutlets ellipsoid, about 1 mm long, finely granular, often pointed at apex and with a large lateral scar below. Seedling with epigeal germination; cotyledons petiolate, circular-oblong, rounded to truncate at apex; hypocotyl elongate, epicotyl nearly absent.

Growth and development In Vietnam, new shoots of *M. arvensis* normally arise from cuttings within 5–10 days after planting. Flowering starts 80–100 days after planting, and although plants usually blossom profusely they rarely set seed. Except for *M. arvensis*, all *Mentha* spp. in the Malesian region do not flower, or flower rarely.

Other botanical information *Mentha* is taxonomically rather complex. Identification is often difficult since, apart from their phenotypic plasticity and genetic variability, most species hybridize easily with each other; polyploidy is common. *M. arvensis* is a complex species with a very large area of distribution, which has resulted in a confusing infraspecific taxonomy. The widespread var. *javanica* is reported as possibly indigenous to the Malesian region. Var. *javanica* differs from var. *arvensis* mainly in the almost filiform or mucronate calyx teeth, which are separated by wide bays; the calyx teeth of var. *arvensis* are triangular without distinct mucronate apices. The assumption that var. *javanica* is of hybrid origin and was originally imported from Europe, just like var. *arvensis*, has not been proved. The relationship between *M. arvensis* var. *javanica* and other taxa such as *M. haplocalyx* Briq. (synonym: *M. arvensis* subsp. *haplocalyx* (Briq.) Briq.), *M. canadensis* L. and *M. arvensis* var. *piperascens* Malinv. ex Holmes is still unclear, but all these are at least closely related.

A hybrid, named *M. ×cordifolia* Opiz ex Fresen, is also cultivated in Java, the Philippines and Thailand. The correct name might be *M. ×villosa* Huds., which is a hybrid between *M. spicata* L. and *M. suaveolens* Ehrh. It originates from northern temperate regions, never flowers and is propagated vegetatively. It can be distinguished from *M. arvensis* by its rounded to truncate or shallowly cordate leaf bases and less hairy stems. *M. ×cordifolia* is commonly cultivated for medicinal purposes and for use as flavouring throughout the Philippines and Thailand. It is likely that this taxon has been often confused with varieties of *M. arvensis*, particularly in the Philippines where they all appear to occur.

M. pulegium L. (pennyroyal), also a native of northern temperate regions, is cultivated locally in gardens in Java as a culinary herb. *M. aquatica* L. (water mint) is cultivated in Vietnam and Thailand. *M. ×piperita* L. (peppermint, a hybrid between *M. aquatica* and *M. spicata*) is cultivated for its essential oil throughout the temperate regions of the world; it has been introduced very locally in Indonesia (Java, Timor). *M. ×rotundifolia* (L.) Huds. (apple-mint, a hybrid between *M. longifolia* L. and *M. suaveolens*) is cultivated and naturalized in Vietnam. *M. spicata* L. (spearmint) is a well-known medicinal plant in India, used to treat fever, bronchitis and aphthae; it is not reported for South-East Asia.

Ecology Most *Mentha* spp. originate from temperate regions and grow best under cool conditions. They are probably quantitative long-day plants and usually do not flower in tropical regions, although some species have been found flowering at higher altitude. *M. arvensis* var. *javanica* occurs in open, mostly humid localities, e.g. in borders of rice fields, at 150–1200 m altitude. It is found flowering throughout the year. At least some cultivars of Japanese mint (*M. arvensis* var. *piperascens*) are better adapted to tropical climates. In greenhouse experiments, this species even came into flower under the minimum photoperiod of 10 hours, which is much less than for other species such as peppermint (*M. ×piperita*) and spearmint (*M. spicata*). In northern Thailand, cv. So Wo 1 of Japanese mint outyielded spearmint and peppermint production (in both dry matter and mint oil production) in the lowlands, but in the highlands other cultivars of Japanese mint and a cultivar of spearmint performed better. Unfavourable climatic conditions can cause excessive levels of undesirable compounds or low levels of desirable compounds in the oil of commercially grown mint taxa, resulting in oil of poor quality.

In peppermint (*M.* ×*piperita*), for instance, it is known that long days and cool nights lead to higher yields of oil and to an increase in the menthofuran level, and that cold nights favour the formation of menthol. Japanese mint can thrive in the Philippines in well-watered, well-drained soils in the dry season (September to April). Mints grow best in deep soils rich in humus, with a pH of 6–7.5.

Propagation and planting Mints are usually propagated vegetatively by stolons. Cuttings should preferably be taken from one-year-old plants, and cut into pieces of 4–5 cm long with 3–4 nodes. Japanese mint is usually planted in northern Vietnam in January–April (spring). The cuttings are planted 12–20 cm apart in shallow furrows 7–10 cm deep and 45–60 cm apart. For planting one ha, 400–450 kg of stolons are required.

Tissue culture of mints is possible. Callus cultures of Japanese mint have been established in India, using standard medium with some modifications. The plantlets produced were transplanted to soil and had a high rate of survival. Before planting, the land should be cleaned as thoroughly as possible. In Thailand, Japanese mint is intercropped with teak (*Tectona grandis* L.f.) seedlings.

The crop responds favourably to the application of 20–30 t/ha of manure or compost to the field before planting. Green manuring may also be practised.

In vitro production of active compounds A suspension culture of *Mentha* has been established from callus formed on the tips of young shoots. Cells were grown in B-5 liquid medium supplemented with 1 mg/l 2,4-dichlorophenoxy acetic acid in the dark, and subcultured at intervals of 2 weeks. The cell suspension has been maintained for up to 4 years. The culture released a large amount of extracellular polysaccharides.

Husbandry Although a peppermint crop can be ratooned for 3 years, Japanese mint is usually planted every year. Weeding should be carried out regularly. When plants are grown for oil production it is especially important to avoid contamination with weeds, because of the risk of off-flavours. The crop should be watered liberally to support the profuse vegetative growth. Application of fertilizers (up to 160 kg N and 60 kg P_2O_5 per ha under northern Vietnamese conditions) increases crop and essential oil yields.

Diseases and pests Mint crops are affected by a number of fungal diseases, particularly when grown in regions with a warm and humid climate. Severe leaf shedding is caused by the mint rust *Puccinia menthae* and *Fusarium* spp. Powdery mildew caused by *Erysiphe cichoracearum* appears to be the most serious problem in India. *Verticillium* wilt is the major disease in peppermint and spearmint crops in the United States. Collar rot developed in an experimental plantation of Japanese mint in Papua New Guinea, resulting in the wilting and death of shoots; it was caused by *Marasmiellus epochnous*. Mints are reported to be attacked by a large number of insect pests, the most serious of which are moths.

Harvesting In Vietnam, 2–3 harvests per year can be obtained from Japanese mint. The first harvest is 100–130 days after planting, when the lower leaves turn yellow and the crop is flowering, the second harvest is carried out 80–100 days after the first, and the third 80–90 days after the second. If harvesting is delayed and leaves start falling, oil yields will be lower. The oil content decreases rapidly after the full bloom stage.

Yield A good crop of Japanese mint may produce 40–45 t/ha of fresh material in 2 cuttings. Fresh plant material contains 0.4–0.8% essential oil, but the oil yield and quality largely depend on field conditions, plant age, and the presence of weeds, diseases and pests. In India the highest yields of fresh mint (53 t/ha) and oil (270 kg/ha) were obtained when the crop was planted at 60 cm row spacing and fertilized with 240 kg N/ha.

The yield of oil from *M. arvensis* cv. Jombang in Indonesia is reported at 30.5 l/ha.

In India, tetraploid plants of Japanese mint contain more oil than diploid ones. However, the menthol content of oil from tetraploid Japanese mint was lower and the menthone content higher. Moreover, it was inferior in growth habit and more susceptible to diseases, which made the quality and total yield of oil lower compared with diploid plants.

In the Philippines, oil yield of *M.* ×*cordifolia* reaches a peak in the period March–June, with a secondary peak in December. Heavy rains in July–September depress growth and oil yield.

Handling after harvest Mint oil is obtained by distillation of fresh or slightly dried plant material. The crop should not be excessively dried in the sun. To obtain good quality oil, the herb is distilled as rapidly as possible to prevent hydrolysis of esters and alteration of other constituents by excessively long exposure to steam. It usually takes 1.5–2 hours to complete the process of distillation in a well-designed still with good steam pressure. In the case of small-scale farming a direct-fired still can be used, but the oil yield depends on the efficiency of distillation equipment.

Genetic resources and breeding In recent years, *Mentha* germplasm has been collected in Russia, Ukraine, China, Japan, India, United States and Brazil. In India, breeding work is done at the Central Institute of Medicinal and Aromatic Plants in Lucknow, with the aim of developing cultivars that combine excellent oil quality and a wide range of maturity dates with resistance against diseases.

Prospects Successful mint cultivation in South-East Asia partly depends on the availability and maintenance of certified plant material. However, the climatological conditions are a serious drawback for commercial mint growing. Some regions at the edge of South-East Asia, such as northern Vietnam and northern Thailand, may have promissing prospects for large-scale production of good-quality mint oil. In the Malesian region, the role of mint will probably remain limited to the use of imported mint oil and to grow plants as a pot herb or occasionally as a medicinal herb. However, when better adapted cultivars become available, which do not suffer a decrease in oil quality in tropical conditions, there might also be a future for commercial mint oil production in Malesia. Recent developments are encouraging.

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Other selected sources 79, 178, 179, 190, 202, 211, 212, 231, 332, 350, 382, 431, 513, 526, 534, 549, 580, 803, 858, 900, 1035, 1126, 1142, 1178, 1387, 1482, 1508, 1534.

La Dinh Moi

Mimosa pudica L.

Sp. pl. 1: 518 (1753).
LEGUMINOSAE
$2n = 52$

Vernacular names Sensitive plant (En). Sensitive (Fr). Brunei: puteri malu, rumput malu, sopan malu (Malay). Indonesia: putri malu (general), jukut riyud (Sundanese), pis kucing (Javanese). Malaysia: memalu, malu-malu. Papua New Guinea: matmat (Gunantuna, New Britain). Philippines: makahiya (Tagalog), torog-torog (Bikol), babain (Ilokano). Cambodia: smau bânla, bânkrap. Laos: f'a:z langab, th'üb nhub. Thailand: ka-ngap (peninsular), maiyaraap (central), yaa pan yot (northern). Vietnam: c[aa]y m[aws]c c[owr], c[aa]y x[aas]u h[oor], c[aa]y trinh n[uwx].

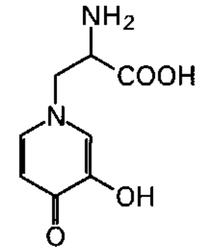
Origin and geographic distribution Sensitive plant probably originated in South America but is now pantropical. It occurs commonly throughout South-East Asia, usually along roadsides and on wasteland.

Uses In Indonesia, Malaysia and Thailand, sensitive plant was traditionally used to treat insomnia. Twigs were placed under the sleeping mats of children, and they were also used as a decoction to prepare a bath for children with sleeping problems. This use was probably based on signature: the leaves 'go to sleep' in the evening. At the beginning of the 20th Century, twigs were being sold for this purpose in Java, but there is no recent

confirmation of this traditional use. In Vietnam, however, the leaves are considered in folk medicine to be sedative and hypnotic, and an infusion of the leaves is still regarded beneficial for patients suffering from insomnia. Test with mice seem to confirm this activity.
Other uses reported are the treatment of haematuria (all parts of the plant, Indonesia and Thailand) and as a poultice to treat swellings (pounded leaves, Indonesia, Malaysia and Thailand). In Brunei, a root decoction is drunk to relieve asthma and diarrhoea. The most extensive use of the plant in South-East Asia is in the Philippines, where a decoction of the entire plant is considered anti-asthmatic and a root decoction is given as a diuretic and also to treat dysmenorrhoea. In Thailand, the whole plant is used as a diuretic. The leaves are used externally to treat dermatitis, wounds and ulcers. The roots are traditionally used in Vietnam to treat arthritis. In India, a root decoction is used to treat urinary complaints and as an aphrodisiac, whereas it is considered emetic in South America and is also used there to treat diarrhoea and dysentery. In India, crushed leaves are applied as an emollient to glandular swellings, and an infusion of the leaves is used in Vietnam to treat febrile stiffness. In New Britain, roots and leaves have been used externally to treat swollen testicles. In Indo-China seeds are considered to be emetic; in India they are also used to treat sore throat and hoarseness. In the traditional pharmacopoeia of La Réunion, the stems, leaves and roots are mentioned as a calming remedy against insomnia, spasms and convulsions of children.
Sensitive plant contains tannins that can be used in the production of leather. Young stems and leaves are useful as forage. When the prickles on the stem and the fruits become too hard, they can cause intestinal inflammation in animals. Moreover, the mimosine present in the plant may cause poisoning. Sensitive plant is often considered as a noxious weed. In areas where other leguminous plants establish with difficulty, it can be of use as a cover crop or green manure. In Thailand, it is used as ground cover on road verges.

Production and international trade Sensitive plant is harvested in small amounts for personal use, and is only very rarely traded.

Properties Sensitive plant contains mimosine (N-(3-alanyl)-3-hydroxy-4-pyridone), an amino acid which is biosynthetically derived from lysine. This compound is reported as being toxic to several animal species, including pigs and rabbits, and to a lesser extent, ruminants such as cattle. Mi-



mimosine

mosine is reported to have depilatory properties, and prolonged use may lead to alopecia. The intoxication also manifests itself by loss of appetite and weight, and retarded growth. These symptoms are accompanied by an enlargement of the thyroid gland, and lowered serum thyroid hormone levels. Mimosine itself inhibits the synthesis of proteins and nucleic acids, but is not known as a goitrogen. Gut bacteria, however, transform mimosine enzymatically into 3-hydroxy-4(1H)-pyridone (= 3,4-dihydroxypyridine, DHP), which is a potent goitrogen able to cause hypo-thyroidism. Oral application of 1 ml of a DHP solution (0.25 mmol) in the rat has been found to significantly inhibit ^{125}I uptake by the thyroid gland. Bacteria able to further metabolize DHP into non-goitrogenic compounds have been isolated from the gut of various animals, including Indonesian goats. When these bacteria were transferred into Australian cattle, the cattle were able to feed on mimosine-containing forage without suffering toxicological reactions.
Mimosine has been demonstrated to reversibly block cell cycle progression in mammalian cells in culture. It also, through iron chelation, blocks cell cycle progression in asynchronous human breast cancer cells. In addition to mimosine, two C-glycosylflavones have been isolated from the aerial parts of the plant, and identified as 2'-O-rhamnosyl-orientin and 2'-O-rhamnosyl-isoorientin.
In Vietnam, a significant hypotensive effect has been reported in experiments with dogs injected with a 10% infusion of leaves. Sedative, anti-inflammatory, anti-implantation and anti-arthritic effects have also been reported. Tests with mice showed prolongation of the time spent sleeping. An alcoholic extract, a petroleum-water extract and quaternary alkaloids isolated from whole dried plants in Thailand lowered blood sugar in diabetic rats, beginning in the second hour after single oral application and reaching a maximum after 6 hours; no abnormal symptoms were observed. The total alkaloidal extract of the roots

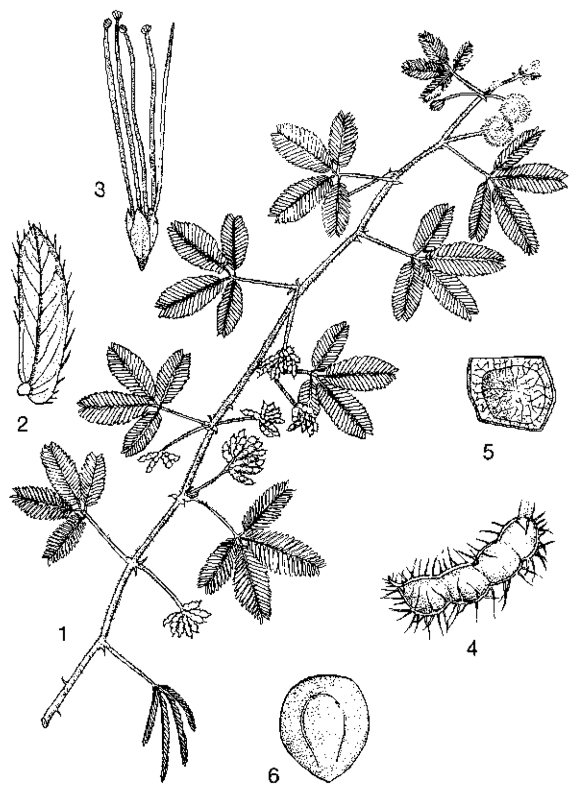
was found to be antagonistic to both acetylcholine and histamine on isolated guinea-pig ileum. In tests with rats in India extracts were not effective in preventing bladder stone deposition or in dissolving preformed stones. The methanol extract of aerial parts showed diuretic activity and some protection against the injurious effect of radiations.

In tests in Nigeria, the extract exhibited antimicrobial activity against *Vibrio cholerae*, but the potential in the control of cholera needs to be determined. An in vitro bioassay of an aqueous methanol extract of green leaves in Jamaica showed that the extract inactivated 50% of the filariform larvae of the nematode *Strongyloides stercoralis* (causing strongyloidiasis) in less than 1 hour. The root extract is also nematicidal. At a concentration of 300 ppm it completely inhibited egg hatch of *Meloidogyne incognita*, and also significantly affected the infectivity and development of larvae. A crude ethanol extract of the leaves was found to have insecticidal activity against adult *Tribolium confusum* when sprayed as a 10% concentrate; it killed 60% of the beetles.

Very little is known about the forage quality of sensitive plant. It is likely that the quality of any sample would vary considerably with the leaf/stem ratio.

Adulterations and substitutes Mimosine and its optically inactive form leucaenine are also known from *Leucaena leucocephala* (Lamk) de Wit.

Description An annual or perennial herb, sometimes woody at base and then subshrubby, up to 1(–1.5) m tall, often prostrate or straggling; stem usually sparsely armed with recurved prickles up to 5 mm long, glabrous to densely hispid. Leaves alternate, bipinnate, unarmed, sensitive; petiole (1.5–)3–5.5 cm long, hispid, rachis very short, giving the two pairs of pinnae a subdigitate position; stipules caducous; leaflets 10–26 pairs per pinna, oblong to subfalcate, 0.6–1.5 cm × 0.1–0.3 cm, margins setulose. Inflorescence an axillary globose head, about 1 cm in diameter, 1–2(–5) together per axil; peduncle up to 4 cm long. Flowers bisexual, 4-merous, sessile, lilac, pink or blue-purple; calyx inconspicuous, about 0.1 mm long; corolla narrowly campanulate, 2–2.5 mm long, with obtuse to rounded lobes; stamens free, much longer than corolla; ovary superior, glabrous, style long and slender. Fruit a flattened oblong pod, 1–1.8 cm × 0.3–0.5 cm, several together in a cluster, densely setose, prickly on margins, consisting of 3–5 1-seeded joints which break away from the persistent sutures. Seeds suborbicular to broadly ellipsoidal, flattened, 2.5–3 mm long, pale brown, surface finely granular. Seedling with epigeal germination, smelling like garlic; cotyledons ovate, sagitate at base, truncate to emarginate at apex, glabrous; hypocotyl up to 15 mm long, hairy, epicotyl absent; first leaf solitary, with 3 pairs of leaflets.



Mimosa pudica L. – 1, flowering and fruiting stem; 2, leaflet; 3, flower; 4, pod; 5, one-seeded pod segment; 6, seed.

Growth and development Sensitive plant flowers throughout the year and it can complete its life cycle in 3 months. The leaves are extremely sensitive to the touch. At nightfall the leaflets fold up and the rachises bend down.

Other botanical information Within the subfamily *Mimosoideae*, *Mimosa* is classified in the tribe *Mimoseae*. It is a large genus of about 400 species mainly occurring in tropical America.

Four varieties of *M. pudica* are distinguished: var. *pudica* (only known from the sterile type specimen, no distinction possible); var. *hispida* Brenan (corolla in bud densely grey puberulous; heads in bud densely bristly; stipules 8–14 mm long); var.

tetrandra (Humb. & Bonpl. ex Willd.) DC., synonym: *Mimosa tetrandra* Humb. & Bonpl. ex Willd. (corolla in bud densely grey puberulous; heads in bud sometimes sparsely bristly; stipules 4–8 mm long); var. *unijuga* (Duchass. & Walp.) Griseb., synonym: *Mimosa unijuga* Duchass. & Walp. (corolla in bud glabrous; heads in bud not bristly; stipules 4–8 mm long). The three latter varieties are all pantropical and occur throughout South-East Asia.

Ecology Sensitive plant is common in wasteland, disturbed areas and overgrazed sites with moderately to poorly fertile soils. It occurs in the humid tropics and tolerates waterlogging but is not well adapted to the seasonally dry tropics. In the Malesian region, sensitive plant is found up to 1000 m altitude. It is regarded as a weed in upland field crops, in rainfed wetland rice and in plantation crops where it is reasonably tolerant of shade. It occurs over a wide range of soils, but iron chlorosis has been noted on coralline soils with a high pH.

Propagation and planting The persistence and spread of sensitive plant is aided by its prolific seed set. There are approximately 110 seeds/g.

Husbandry Sensitive plant is not sown deliberately, nor is its establishment or spread promoted. On the contrary, it is usually regarded as a noxious weed. It tends to invade pastures of declining soil fertility and is less common where soil fertility is good and pastures are not overgrazed. Sensitive plant has been eliminated from pastures where soil fertility is very poor and grazing pressure is very high. It grows with a wide range of grasses, including signal grass (*Brachiaria decumbens* Stapf) provided that grass is not too vigorous. It can hamper the establishment of improved species. Sensitive plant is more readily accepted if it is grazed continuously rather than rotationally. Observations suggest that it may at times stimulate growth of associated grasses.

Diseases and pests *M. pudica* plants in Bogor (Indonesia) are often found attacked by a fungus (*Ramularia mimosae*) which grows on the upper surface of the leaflets, forming irregular white spots. This fungus originates from tropical America and is also reported on *M. pudica* in India.

Harvesting Sensitive plant is harvested from populations in the wild.

Handling after harvest In the Philippines, harvested plants intended for preparing an ointment or cream for external use against skin complaints are air dried, cut into small pieces and ground in a grinding machine. The powdered plant is subsequently submerged in 80% ethyl alcohol, and the mixture heated for one hour. The extract obtained is a yellowish-green syrupy substance with a bitter taste. Powdered dried roots should be stored in airtight containers, preferably in sterilized bottles.

Genetic resources and breeding Being a common weed, sensitive plant is not at risk of genetic erosion. There are no known germplasm collections of sensitive plant, nor breeding programmes.

Prospects Very little research has been done on the medicinal properties of sensitive plant. The scarce information from research suggests interesting possibilities as an anti-microbial, nematicidal and insecticidal agent, but the true value of the plant should be established by further investigations. Other attributed properties, such as the sedative activity, seem to have some scientific basis, but the indications are still vague.

Although sensitive plant can provide useful forage, it will continue to be primarily regarded as a weed. Although more appropriate management may promote its use, it would be preferable to grow forages that are more readily accepted by grazing animals or more suited to cut-and-carry feeding systems.

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Other selected sources 202, 306, 569, 580, 597, 691, 788, 1126, 1177, 1178, 1214, 1434, 1550, 1579.

Erlin Rachman

Momordica L.

Sp. pl. 2: 1009 (1753); Gen. pl. ed. 5: 440 (1754).
CUCURBITACEAE

x = 7, 11, 14; *M. charantia*: $2n$ = 22, *M. cochinchinensis*: $2n$ = 28

Major species *Momordica charantia* L., *M. cochinchinensis* (Lour.) Spreng.

Vernacular names Momordica (En).

Origin and geographic distribution *Momordica* comprises some 45 species and is confined to the Old World tropics, except for the few species introduced into the New World tropics. The majority of species are found in the warmer parts of Africa; Asia harbours only 5–7 species, 3 of which are reported from the Malesian region. *M. charantia* was probably first domesticated in eastern India and southern China, and then taken to other regions in tropical Asia and Africa from which it occasionally naturalizes. It is thought to have been introduced into Brazil from Africa with the slave trade, and that bird dispersal of the seeds accounts for its spread within South America. *M. cochinchinensis* occurs wild and cultivated from India to Japan and throughout Malesia.

Uses A decoction of the root, stem, leaves and fruit of *M. charantia* may be used as a febrifuge. Most plant parts act as a laxative. Juice from various plant parts is used externally to treat skin disorders, abscesses and burns, and also as a cure for children with diarrhoea and stomach-ache. Leaf juice has been applied as a gargle against sprue, to treat jaundice, and for 'female disorders', whereas the flowers are part of a mixture to treat asthma. In Peninsular Malaysia, a decoction of the leaves has been used as an abortifacient. In Indonesia, it is considered to be appetizing, depurative, mildly laxative, useful in treating liver diseases and biliousness; it is also used as a vermifuge to treat pinworms. A little leaf juice is given orally to new-born babies to cleanse the stomach and bowels. Fruits are considered tonic, stomachic, carminative and cooling, and are applied in the treatment of inflammation, rheumatism, gout, pruritus, dermatitis and liver and spleen diseases. The fruits, leaves and roots have long been used in India and Puerto Rico as a folk medicine for diabetes mellitus, though large doses are toxic. In the Philippines, the fruit and young shoots, either in the form of a decoction or as tablets, are used for mild non-insulin dependent diabetes mellitus.

Seeds of *M. cochinchinensis* are used in local medicine in Burma (Myanmar), Thailand and the Philippines to treat chest complaints, whereas in China and Peninsular Malaysia they are a remedy for abdominal pains, dysentery, mesenteric enlargements, obstructions of liver and spleen and haemorrhoids. They are further used to treat chronic malaria, and after being ground and soaked in alcohol or water they are applied externally to wounds, bruises, burns, skin trouble, ulcers, breast cancer, abscesses, mumps and lumbago. Seeds are indicated as cooling, resolvent, laxative and poisonous. The root is used as an expectorant. Roots and leaves have been reported to be useful in the treatment of oedema of the legs, a kind of rheumatism.

The immature fruits of *M. charantia* and *M. cochinchinensis* are a well-known vegetable, whereas leaves and flowers are also eaten as a vegetable or flavouring agent.

Production and international trade *Momordica* fruits or any of its derived products for medicinal applications are only traded locally.

Properties The seeds and the fruit wall of *M. charantia* are reported to contain a resin, a saponin glycoside of the cucurbitacin type, and alkaloids that may cause vomiting and diarrhoea. Furthermore, several proteins that display a variety of pharmacological effects can be isolated from *Momordica*.

The proteins α-momorcharin and β-momorcharin, from seeds of *M. charantia*, have been found to show a hepatotoxic effect on isolated rat hepatocytes. Several immunotoxins were prepared by linking the type 1 ribosome-inactivating protein momordin I to antibodies specific to various cell lines, e.g. bladder carcinoma antibody, CD5-, and CD22-monoclonal antibodies. Treatment with these immunotoxins significantly inhibits tumour development in vitro, e.g. CD5- or CD22-expressing cell lines, with IC_{50} values generally at picomolair scale. The treatment alone, or in combination with a general cytostatic significantly inhibits tumour development in vivo, e.g. in mice with transplanted CD22-expressing cells.

The glycoprotein momorcochin-S, purified from the seeds of *M. cochinchinensis*, shows ribosome-inactivating effects. The protein was linked to a monoclonal antibody (8A) against human plasma cells, and the resulting immunotoxin was found selectively toxic to the target cells. Furthermore, τ-momorcharin, a small ribosome-inactivating protein, can inhibit the protein synthesis in the rabbit reticulocyte cell-free system with an ID_{50} of 55 nM.

Momordin-folate, the conjugate of folic acid with the cytotoxic protein momordin, can selectively kill HeLa and KB cells, two malignant human cell lines, in co-cultures with W138 and Hs67 cells, two normal human cell types. The in vivo antitumour activity of a crude extract from *M. charantia* was significant for several types of tumour cells in mice at an optimum dose of 8 μg protein administered biweekly and intraperitoneally. It is thought that in vivo enhancement of immune functions may contribute to the antitumour effects of the *M. charantia* extract.

Expressed juices from *M. charantia* fruits appreciably reduced the incidence of skin tumours in mice initiated by dimethylbenz[a]anthracene and promoted by croton oil. The extracts of the peel, pulp, seed and whole fruit of *M. charantia* exhibited marked anti-carcinogenic activity against mouse skin papilloma genesis when applied topically at 100 μm/animal. In vitro and in vivo tests with aqueous and ethanolic extracts of *M. cochinchinensis* also showed marked antitumour activity.

MAP30, an antiviral protein (30 kDa) from *M. charantia*, may regulate Herpes simplex virus (HSV) replication in concert with dexamethasone and indomethacin, which are inhibitors of prostaglandin synthesis. EC_{50} values for MAP30 were 0.1 μM for HSV-2 and 0.3 μM for HSV-1 in human lung WI-38 fibroblasts. MAP30 is also capable of inhibiting infection of HIV-1 in T lymphocytes and monocytes, as well as replication of the virus in infected cells. It was found not toxic to normal uninfected cells; the peptide is probably unable to enter healthy cells. It exhibits a dose-dependent inhibition of integration of viral DNA into the host chromosomes (HIV-1 integrase), which is a vital step in the replicative cycle of the AIDS virus.

M. charantia trypsin inhibitor-II prolonged the prothrombin time of human plasma. Furthermore, a glycoprotein isolated from fresh tuberous roots of *M. cochinchinensis* was capable of inducing mid-term abortion in mice.

Acylglucosylsterols isolated from the green fruits of *M. charantia* showed antimutagenic activity and reduced the number of micronucleated polychromatic erythrocytes induced by the well-known mutagen mitomycin C by about 80% in mice, at a dosage range of 12.5–50 μg extract/g. Powder and defatted extract from *M. charantia* leaves reduced the genotoxic activity of dimethylnitrosamine, methylmethanesulphonate and tetracycline as shown by the reduction of chromosome-breaking effects. *M. charantia* has also been screened for its genotoxic activity using a plate incorporation assay involving *Aspergillus nidulans*. The aqueous extract of *M. charantia* leaves resulted in a significant increase in the frequency of segregant sectors per colony.

Bitter gourd (*M. charantia*) is often used in folk medicine to treat diabetes. However, its hypoglycaemic activity seems contradictory. The hypoglycaemic activity of bitter gourd in experimental animals is also contradictory. The pulp juice of *M. charantia* lowered fasting blood glucose levels in normal rats; the effect was more pronounced using saponin-free methanol extract of the pulp juice. The hypoglycaemic effect was also significant in normal rats fed glucose 45 minutes after the extract had been administered. In the insulin-dependent diabetes mellitus model rats, the pulp juice had no significant effect on blood glucose levels in the fasting, and postprandial states. In the non-insulin dependent model rats, however, the saponin-free methanol extract of juice produced a significant hypoglycaemic effect in both these states. Seed and whole plant extracts showed a small but consistent tendency to increase blood glucose levels in the normal rats. In normal mice, an aqueous extract of bitter gourd lowered the glycaemic response to both oral and intraperitoneal glucose, without altering the insulin response. This aqueous extract and the residue after alkaline chloroform extraction had reduced the hyperglycaemia in diabetic mice after 1 hour. The results suggest that bitter gourd extracts administered orally lower glucose concentrations independently of intestinal glucose absorption and involve an extrapancreatic effect. Two glycosides isolated from the tuber of *M. cochinchinensis* containing oleanolic acid as aglycone showed hypoglycaemic activity in streptozotocin-induced diabetic rats at a dose of 25 mg/kg; intraperitoneal administrations showed higher activity than oral administration. The alcoholic extract of *M. charantia* administered orally to female Wistar rats at 500 mg/kg reduced glucose levels by 10–16% and 6% after 1 and 2 hours, respectively, in normal rats and by 26% after 3.5 hours in streptozotocin-induced diabetic rats. The extract increased the rate of glycogen synthesis from 14C-glucose in the liver of normally-fed rats by 4–5 times, suggesting that the extract may act at least in part by enhancing glucose utilization in the liver. In normal mice, intraperitoneal administration of a concentrated aqueous extract of bitter gourd improved glucose tolerance after 8 hours, and in streptozotocin-induced diabetic mice the level of hyperglycaemia was reduced by 50% after 5 hours. The bitter gourd extracts did not significantly alter plasma insulin concentrations, suggesting that they may exert an extrapancreatic effect to promote glucose disposal. Oral administration of the aqueous extract (0.5 g/kg) of bitter gourd reduced the fasting glucose levels of hyperglycaemic and normoglycaemic mice; the ethanol extract had no significant effect on glucose levels. The water extract did not improve the tolerance of mice to oral glucose.

In conclusion, a significant number of studies have established the hypoglycaemic activity of bitter gourd; its effect appears to be more acute and transient than cumulative. The fresh aqueous extract of the whole fruit is more effective than dried powder, or dietary consumption. Some studies found that the seed also contained hypoglycaemic principles. In most of the cases where hypoglycaemic activity could not be demonstrated, normoglycaemic animals were experimented upon. The mechanism of hypoglycaemic activity remains unclear. If the hypoglycaemic action of bitter gourd is mediated through its effect on glucose absorption and alterations to the activities of enzymes involved in glucose metabolism, it would be beneficial to both insulin-dependent as well as non-insulin-dependent diabetics. If, however, it has an insulin secretagogue effect, only non-insulin-dependent diabetics would benefit from it.

Nine diabetic patients underwent 3 glucose tolerance tests with 50 g of glucose, 50 ml bitter gourd juice, and a test after 8–11 weeks of consuming fried bitter gourd (250 g) daily. The results indicated that fresh bitter gourd juice brought about a significant reduction in plasma glucose concentration, and an improvement in the response to an oral glucose load. The effect of fried bitter gourd was not so pronounced, although it was significant. A cumulative and gradual hypoglycaemic effect was found in diabetic patients using the aqueous extract at the end of a 3-week trial. When 8 non-insulin dependent diabetes mellitus patients consumed bitter gourd cooked and then fried in oil along with their regular meal, their plasma glucose levels were significantly reduced after 1 hour as compared to those whose meal was not supplemented with bitter gourd. However, improvement in glucose tolerance was not significant. Contradictory to these findings, however, is a study in which bitter gourd in the form of fresh juice, dried powder or the powder given as a tablet did not have any beneficial influence on diabetic patients.

No antimalarial activity could be demonstrated in mice infected with *Plasmodium berghei* when extracts of *M. charantia* were administered orally at 1 g/kg for 5 consecutive days. *M. charantia* fruits and seeds contained components that inhibited hormone-induced lipolysis in isolated rat adipocytes. The haemolytic activity of a fraction obtained from fresh tubers of *M. cochinchinensis* can be attributed to a sterol-glycoside. The crude saponin (4–6% in dry roots) obtained from *M. cochinchinensis* also showed haemolytic activity.

Extracts of *M. charantia* were effective in treating *Ascaridia galli* worms in birds. Oral administration of *M. charantia* extract containing 100 mg iron was as effective as a commercial preparation to prevent anaemia in piglets. Chitinase isolated from *M. charantia* fruits may be strongly bacteriostatic. Pollen from *M. charantia* completely inhibited spore germination of the pathogenic fungi *Cochliobolus lunatus*, *Cylindrocarpon lichenicola*, *Fusarium solani* and *Myrothecium leucotrichum*.

Momordicines I and II were isolated from dried leaves of *M. charantia*. Momordicine I at 0.5 mg/ml and 1 mg/ml showed about 33% and 59% inhibition of *Colletotrichum gloeosporioides*, respectively, whereas momordicine II at 0.25 mg/ml and 0.5 mg/ml showed about 17% and 23% inhibition, respectively. Against *Cladosporium cucumerinum*, momordicine I exhibited activity at 0.5 mg/ml, whereas momordicine II did not show any activity up to 1 mg/ml. It was suggested that the difference in activity between the 2 compounds could be due to the higher lipophilicity of the aglycone. The leaf extracts were also effective against *Botryodiplodia theobromae*, *Curvularia lunata*, *Phytophthora colocasia* and *Sclerotium rolfsii*. The active constituents of the leaves of *M. charantia* were extracted by cold maceration using 95% ethanol. This extract has antimicrobial activity against *Escherichia coli*, *Salmonella paratyphi* and *Shigella dysenteriae*. Seed extracts of *M. charantia* resulted in high mortality of the nematodes *Meloidogyne incognita* and *Rotylenchulus reniformis*. The petroleum ether extract of *M. charantia* was active against the bean weevil *Callosobruchus chinensis*.

Adulterations and substitutes Extensive studies on immunotoxic and anti-HIV potential of proteins from *Momordica* may lead to substitution for *Trichosanthes* and vice versa.

Description Monoecious or dioecious, annual or perennial herbs, with climbing or trailing stems. Tendrils lateral, one at each node, simple or bifid. Leaves alternate, blade simple or palmately lobed to 3–7(–15)-foliolate, petiolate, exstipulate. Inflorescence axillary. Flowers unisexual, actinomorphic, often subtended by a conspicuous bract. Male flowers solitary, umbellate or in short racemes or fascicles; hypanthium shallow; calyx 5-lobed; petals 5, free, white to yellow, 1–3 of them with a scale at base; stamens 3, inserted towards the base of the hypanthium, 2 bilocular, 1 unilocular, locules curved or flexuose; pistillode absent. Female flowers solitary; perianth usually similar to the male flowers; staminodes 3; ovary inferior, oblong to fusiform, 3-locular with many horizontal ovules, stigmas 3, entire to 2-lobed. Fruit a berry (pepo), ovoid-ellipsoid to elongate-fusiform, fleshy, ornamented with tubercles, spines, wings or ridges, indehiscent or dehiscent by 3 valves and exposing the seeds enveloped in pulp. Seeds arillate, usually compressed, with sculptured testa and grooved margins.

Growth and development Flowering of *M. charantia* starts within 2 months from sowing, that of *M. cochinchinensis* after about 2 months. Flowers of *M. charantia* start opening early in the morning. Anthers dehisce about 2 hours before anthesis. Flowers of *Momordica* are pollinated by insects, especially bees. Indehiscent *Momordica* fruits may be shattered and eaten by large birds or mammals. Seeds within dehiscent fruits of *M. charantia* strongly contrast with the large red aril and are thus easily spotted by birds who eat and disperse them. At higher latitudes, plants of *M. cochinchinensis* remain dormant in winter and regrow from the tuberous root in spring. They fruit mainly during the rainy season.

Other botanical information *Momordica* belongs to the tribe *Joliffieae* of the subfamily *Cucurbitoideae*. The tribe contains the least specialized genera of the *Cucurbitoideae*. *Momordica* is closely related to *Thladiantha*, but the latter has 5 stamens or staminodes and straight or only slightly curved anther locules.

Ecology *M. charantia* grows well in tropical and subtropical climates. It is adapted to a wide range of environments and can be grown year-round, but is usually cultivated during the warmer season, up to an altitude of 1500 m. It is sensitive to waterlogging. It tolerates a wide range of soils but it thrives in a well-drained sandy loam, rich in organic matter. *M. cochinchinensis* prefers a warm humid climate with temperatures ranging from 20–35°C and an average rainfall of 1500–2500 mm. It does not tolerate waterlogging and grows well in fertile, well-drained, sandy loams with pH near neutral.

Propagation and planting *M. charantia* is most commonly propagated by seed. Pre-germinated seed results in even establishment. Optimum plant density differs per cultivar, but ranges from 6500–11 000 plants per ha. *M. cochinchinensis* is mainly propagated by its tuberous roots. Since it is dioecious, tubers from male and female plants should be planted together. About 50 000 sprouted tubers per ha are required, but in India a spacing of 1.5 m × 2.5 m is adopted. Mean germination of the seeds of *M. cochinchinensis* is 50%, and germination may take up to 1 year; cuttings root for about 80%.

In vitro production of active compounds The antiviral protein MAP30, from *M. charantia*, has been cloned and expressed. It has similar anti-HIV, anti-viral and anti-tumour activity as the natural MAP30.

Husbandry Fertilization and furrow irrigation if necessary are important cropping techniques when growing *M. charantia* on trelises. Wild *M. charantia* can become a troublesome weed in large-scale plantations of e.g. rubber and oil palm in Indonesia and possibly in other South-East Asian countries too.

Diseases and pests Serious diseases of bitter gourd are *Cercospora* leaf spot, downy mildew (caused by *Pseudoperonospora cubensis*) and bacterial wilt (caused by *Pseudomonas solanacearum*). Fruit fly (*Dacus cucurbitae*) is the most destructive insect pest of bitter gourd, whereas root-knot nematodes (*Meloidogyne incognita*) also attack the crop.

Harvesting *M. charantia* usually takes 15–20 days after fruit set to mature, whereas *M. cochinchinensis* fruits are harvested when they turn yellow or red.

Yield A fruit yield of 20–30 t/ha is considered satisfactory for *M. charantia*. Some F_1 hybrids yield up to 40 t/ha. The number of fruits per plant may reach 20–25 during the cropping period. *M. cochinchinensis* may yield 30–60 fruits per plant, each weighing 1–3 kg. In Japan, the yield of dry roots of 5-year-old plants of *M. cochinchinensis* was about 10 t/ha.

Handling after harvest Mature fruits are split and seeds and fruit pulp are separated. Fruit pulp is dried at low temperatures, and an oil can be extracted. This oil, which is rich in β-carotene, is used to treat rachitis, xerophtalmia and night blindness. Seeds are dried in the sun or in ovens. The oil that can be extracted from the kernel is used to treat skin disorders. Roots are washed and dried in the sun or oven, and stored for later use.

Genetic resources and breeding The world collection of *Momordica* germplasm is held at NBPGR, New Delhi, India. In South-East Asia, collections are available in the Philippines (NPGRL-IPB, Los Baños) and in Thailand (Department of Horticulture, Kasetsart University, Bangkok). Elsewhere, collections are held in several institutes in India, South Africa, Taiwan and the United States. In many South-East Asian countries, commercial F_1 hybrids often twice as productive as the traditional open-pollinated cultivars, have been released.

Prospects Since the results with *M. charantia* in the treatment of diabetes are still somewhat contradictory, more research needs to be done on its hypoglycaemic activity. Furthermore, several compounds from *Momordica* show interesting pharmacological activities, e.g. immunotoxic and anti-HIV, which merit further research, and may have potential in the development of future medicines.

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Selection of species

Momordica charantia L.

Sp. pl. 2: 1009 (1753).

Synonyms *Momordica indica* L. (1754), *Momordica elegans* Salisb. (1796), *Momordica chinensis* Spreng. (1891).

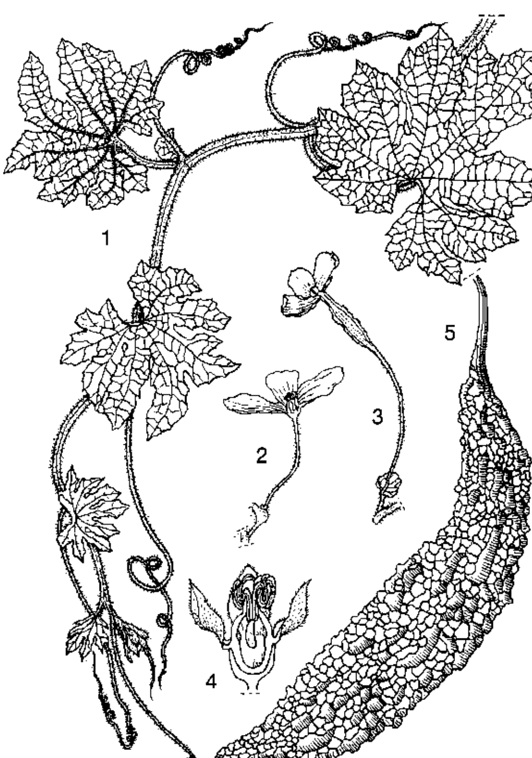
Vernacular names Bitter gourd, bitter cucumber, balsam pear (En). Bitter melon (Am). Margose, paroka (Fr). Indonesia: paria (general), pare

(Javanese), papari (Moluccas). Malaysia: peria, peria laut, periok. Philippines: ampalaya (Tagalog), paria (Ilocano), palia (Bisaya). Cambodia: mreah. Laos: 'hail, 'phak 'ha, sail. Thailand: mara (general), maha (northern), phakha (north-eastern). Vietnam: m[uw] [ows]p d[aws]ng, m[uw] [ows]p m[ur] (northern), kh[oor] qua (south).

Distribution *M. charantia* was possibly first domesticated in eastern India and southern China. It now has a pantropical distribution, with wild and cultivated populations.

Uses See under genus treatment for the numerous medicinal uses. The immature fruits are a well-known vegetable. The pulpy arils can be eaten as a sweet. The seed mass of the ripe fruit can be used as a condiment. *M. charantia* is occasionally planted as an ornamental.

Observations A monoecious, annual vine up to 5 m long, stem 5-ridged, tendrils simple; leaf blade broadly ovate to suborbicular or ovate-reniform in outline, 2.5–10 cm × 3–12.5 cm, deeply palmately (3–)5(–9)-lobed, deeply cordate at base, lobes obovate and sinuate-lobulate or sinuate-toothed, glabrous or sparsely pubescent; flowers solitary, 2–3.5 cm in diameter, yellow; male flowers on a 0.5–3 cm long peduncle bearing an apical bract of up to 2.2 cm long, pedicel 2–5.5 cm long; female flowers on a 0.2–5 cm long peduncle bearing an apical bract of up to 1.2 cm long, pedicel 1–10 cm long; fruit 3–11(–45) cm × 2–4(–8) cm, irregularly warty, orange, dehiscing; seeds 8–16 mm × 4–10 mm × 2.5–3.5 mm, brown, testa ornamented. *M. charantia* is found in lowland rain forest, riverine forest, thickets, hedges, waste places and roadsides and may be locally abundant.



Momordica charantia L. – 1, leafy shoot; 2, male flower in longitudinal section; 3, female flower in longitudinal section; 4, male flower in cross section with petals removed; 5, fruit.

Selected sources 48, 97, 103, 109, 110, 136, 170, 176, 177, 209, 234, 257, 287, 324, 340, 470, 498, 515, 563, 680, 707, 721, 808, 830, 835, 836, 847, 886, 946, 1024, 1027, 1035, 1086, 1121, 1128, 1134, 1143, 1144, 1153, 1164, 1178, 1196, 1216, 1341, 1362, 1443, 1485, 1540, 1589.

Momordica cochinchinensis (Lour.) Spreng.

Syst. veg. 3: 14 (1826).

Synonyms *Muricia cochinchinensis* Lour. (1790), *Momordica mixta* Roxb. (1832), *Momordica meloniflora* Hand.-Mazz. (1921).

Vernacular names Sweet gourd, spiny bitter cucumber, giant spine gourd (En). Muricie (Fr). Indonesia: pupia (Malay, Moluccas), torobuk, toropu (North Halmahera). Malaysia: teruah. Philippines: buyok-buyok (Tagalog), paruk-paruk (Ilocano), taboguak (Bikol). Cambodia: makkao. Laos: khua mak 'khao[2], cup 'khoa[2] 'nhai[1]. Thailand: fak-khao (central), phak-khao (northern), khika-khrua (southern). Vietnam: d[aa]y g[aas]c (general), tr[as]i g[aas]c, m[ooj]c mi[ees]t t[uwr].

Distribution *M. cochinchinensis* is found wild and cultivated from India to Indo-China, China, Japan, Taiwan, Thailand, scattered throughout the Malesian region (reported from Peninsular Malaysia, the Philippines, Sulawesi, Bali and the Moluccas, but probably present elsewhere as well) and in northern Australia (Cape York peninsula).

Uses See under genus treatment for the numerous medicinal uses. The immature fruits are a well-known vegetable. The seeds contain an oil which is used as an illuminant in Indo-China and may be applied in the formulation of paint and varnishes. The roots froth in water and may be used as a soap and to kill head lice. In Vietnam the aril of the seeds is used as a colouring agent for rice, called 'steamed momordica glutinous rice'.

Observations A dioecious, perennial vine arising from a tuberous root; stem robust, angular, tendrils simple; leaf blade suborbicular in outline, 12–20 cm in diameter, deeply palmately 3(–5)-lobed, cordate and with some glands at base, lobes subovate with entire or subdentate margins, glabrous, petiole with 2–5 glands near the middle; flowers solitary, about 8 cm in diameter, yellow, but blackish at base inside; male flowers on a peduncle 5–30 cm long bearing an apical, suborbicular, sessile bract, 3–4 cm × 4–5 cm, pedicel 3–10 mm long; female flowers similar but with a smaller bract; fruit 10–20 cm × 6–10 cm, yellow, turning red at maturity, densely covered with small tubercles; seeds about 25 mm × 20 mm × 5 mm, brown, testa sculptured. *M. cochinchinensis* is locally abundant in forest margins, along rivers, in open places, and in disturbed locations, at low altitudes.

Selected sources 169, 287, 363, 721, 776, 1000, 1024, 1026, 1035, 1128, 1178, 1216, 1223, 1443, 1629.

Nguyen Huu Hien & Sri Hayati Widodo

Morus L.

Sp. pl. 2: 986 (1753); Gen. pl. ed. 5: 424 (1754).

MORACEAE

x = 14; *M. alba*: n = 14, *M. australis*: n = 14, *M. nigra*: $2n$ = 89–106, 154, 308

Major species *Morus alba* L., *M. nigra* L.

Vernacular names Mulberry (En). Mûrier (Fr). Moral, morera (Sp). Indonesia: murbei (general). Malaysia: bebesaran (general). Philippines: amoras (Filipino). Cambodia: moon. Laos: mon. Thailand: mon. Vietnam: d[aa]u t[awf]m, d[aa]u t[af]u, t[awf]m tang.

Origin and geographic distribution *Morus* comprises 10–15 species and is distributed in all tropical and temperate regions; in the tropics, mainly in montane habitats. Only one species (*M. macroura* Miq.) is native to the Malesian region; several others have been introduced and have occasionally naturalized.

Uses In most parts of South-East Asia it seems to be more important to cultivate mulberry trees (most often *M. alba*) for their leaves, which are used to rear silkworms (*Bombyx mori*), than for their medicinal application. Trials have been done on the species discussed below and (in Sumatra and Java) on *M. cathayana* Hemsl. and *M. latifolia* Poir. to ascertain their suitability for raising silkworms. Furthermore, the tasty fruits are highly valued and made into juice, wine, jam, etc. In India the fruits are also used as a dye.

In general, the root bark, twigs and fruits are used as restorative, tonic, pectoral, diuretic, and are prescribed to treat cough, asthma, phthisis, and other chest complaints, dropsy and rheumatism. The leaves are depurative, cooling and resolvent. The syrup made of fresh *Morus* fruits is used as a refrigerant in fevers and as an expectorant in coughs and sore throats. A drink made of it has similar applications. A decoction of the leaves of *Morus* is used for its blood-purifying properties as a febrifuge, diuretic and galactagogue. The leaves, bruised or withered over a fire and covered in coconut oil, are used to cover wounds and against insect bites, apparently for their anti-inflammatory properties. The root-bark is used in various applications for its general restorative properties, as a remedy against toothache and as emmenagogue, and furthermore in Vietnam for similar applications as the leaves, as diuretic, antitussive and expectorant and prescribed in oedema, high blood pressure, cough, bronchitis and asthma. The bark of *Morus* is used as a purgative and vermifuge. Root-bark, leaves and fruits of various *Morus* species are considered a remedy for diabetes. The root-bark of *M. alba* and possibly other *Morus* species is also known as the oriental drug 'sohakuhi', which has long been used for anti-inflammatory, diuretic, antitussive and antipyretic purposes in oriental medicine.

M. alba yields an attractive wood, and is also used in agroforestry. It is occasionally planted as a roadside tree. Its fibrous bark has been used to make paper. *M. macroura* wood yields a medium-quality firewood.

Properties Preliminary pharmacological investigations of n-butanol and water-soluble fractions of *M. alba* root showed cathartic, analgesic, diuretic, antitussive, antioedemic, sedative, anticonvulsant and hypotensive actions in mice, rats, guinea-pigs and dogs. These experimental results seem to show some correlation with the traditional clinical applications in Chinese medicine.

The anti-inflammatory activity of the methanol extract of *M. alba* root has been studied in rats using the following methods: rat paw oedema, inflammatory exudation, carrageenin-induced pleurisy, cotton pellet granuloma and chronic experimental arthritis. The extract has been found to be effective in carrageenin-induced oedema and this was not due to a counter-irritant effect. It was also effective against mediator-induced (histamine, serotonin, bradykinin) oedema; it reduced the intensity of peritoneal inflammation and also inhibited the migration of leukocytes, suggesting an anti-exudative effect. The extract reduced the formation of granulation tissue and inhibited experimental arthritis, suggesting its effect on proliferative phases of inflammation and in arthritic conditions. Antipyretic studies revealed its potential to reduce body temperature in pyretic rats. The extract further possessed analgesic activity.

A series of flavone derivatives have been isolated from the root-bark of *M. alba*: mulberrin, mulberrochromene, cyclomulberrin, cyclomulberrochromene, mulbeeranol, and phenolic compounds albactalol, albanol A and albanol B. The flavone morin (2',3,4',5,7-pentahydroxyflavone, an isomer of quercetin) has been identified in the heartwood. Morin shows anti-angiotensin properties, with activity on blood pressure and isolated tissues of the rat. The latter effect of morin seems to be a direct action on the muscle-relaxing system. Morusinol, an isoprene-substituted flavone is found in the root-bark of *M. alba* together with a number of related compounds. In general these flavones are known to have some anti-tumour activity.

Eighteen N-containing sugars have been isolated from the roots of *M. alba*, including seven that were isolated from the leaves of *M. bombycis* Koidz. These N-containing sugars are: 1-deoxynojirimycin, N-methyl-1-deoxynojirimycin, fagomine, 3-epi-fagomine, 1,4-dideoxy-1,4-imino-D-arabinitol, 1,4-dideoxy-1,4-imino-D-ribitol, calystegin B_2 (= 1α,2β,3α,4β-tetrahydroxy-nor-tropane), calystegin C_1 (=1α,2β,3α,4β,6α-pentahydroxy-nor-tropane), 1,4-dideoxy-1,4-imino-(2-O-β-D-glucopyranosyl)-D-arabinitol, and nine glycosides of 1-deoxynojirimycin. These glycosides consist of 2-O- and 6-O-α-D-galactopyranosyl-1-deoxynojirimycins, 2-O-, 3-O- and 4-O-α-D-glucopyranosyl-1-deoxynojirimycins and 2-O-, 3-O-, 4-O- and 6-O-β-D-glucopyranosyl-1-deoxynojirimycins. Due to the presence of nitrogen in the molecules, some authors also refer to these compounds as alkaloids instead of N-containing sugars; this makes 3-epi-fagomine a new member of the polyhydroxylated piperidine alkaloids. Furthermore, the isolation of 1,4-dideoxy-1,4-imino-D-ribitol is the first report of its natural occurrence.

It has recently been found that the polyhydroxy-nor-tropane alkaloids possess potent glycosidase-inhibiting activities. Inhibition of glycosidases might be part of the mechanism involved in anti-hyperglycaemic effects. Calystegin A_3 (from *Calystegia sepium* (L.) R. Br., Convolvulaceae) is an example of a trihydroxy-nor-tropane, and the calystegins B_1 (from *C. sepium*) and B_2 (from *C. sepium* and *M. alba*) are examples of tetrahydroxy-nor-tropanes. Calystegin C_1 (*M. alba*) is a new member of the calystegins, the first naturally occurring pentahydroxy-nor-tropane. The inhibitory activities of 3-epi-fagomine, calystegin B_2, calystegin C_1, and four glycosides of 1-deoxynojirimycin have been investigated against rat digestive glycosidases and various commercially available glycosidases. Calystegin C_1 was found to be a particularly potent inhibitor of rat digestive glycosidase. The β-D-glucoside of 1,4-dideoxy-1,4-imino-D-arabinatol, which is known to be a potent inhibitor of yeast α-glucosidase and mouse intestinal isomaltase, completely lost inhibitory activity against rat glycosidases. When compared with the commercially available glycosidases, calystegin B_2 performed better than calystegin C_1.

Diabetic patients experience xerostomia, a feeling of thirst and the need to frequently drink water. This syndrome is believed to be partially related to a reduced flow rate of saliva and an accompanying decrease in salivary protein components. Furthermore, many of these salivary protein constituents possess local antimicrobial properties and promote local wound healing and epidermal tissue generation. Hot water extracts and six N-containing sugars derived from *M. alba* leaves, have been investigated on pilocarpine-induced saliva secretion in streptozocin-induced diabetic mice. Hot water extracts (100 and 200 mg/kg, intraperitoneal) significantly potentiated the pilocarpine-induced salivary flow, but not the protein content. The N-containing sugars (37.5–300 μmol/kg) potentiated the saliva secretion, and the order of potency was 1,4-dideoxy-1,4-imino-D-arabinitol > fagomine > 2-O-α-D-galactopyranosyl-1-deoxynojirimycin. Only fagomine significantly increased the protein content in the saliva.

An aqueous methanol extract of the root of *M. alba* showed a hypoglycaemic effect on intraperitoneal administration in normal mice. The active component was found to be a glycoprotein called moran A. A dose-dependent activity for the purified compound was furthermore established on intraperitoneal injection in both normal and alloxan-induced diabetic mice, 7 and 24 hours after administration. The hypoglycaemic activity is also found in an ethanol extract of the leaves of *M. alba*. The aqueous extract of the leaves of *M. alba* also exhibited uterine stimulant and estrogenic activity. Clinical study of aqueous extracts of the fruits showed laxative, central nervous sytem depressant and cholecystokinin receptor binding activities. Hypoglycaemic activity in humans is not only for *M. alba* but also for orally administered *M. nigra* leaf extracts.

Morusin and kuwanon C, isolated from root bark of *M. australis* showed significant effects in platelet aggregation assays. An aqueous extract of *M. australis* showed significant antibacterial activity against *Streptococcus mutans* with a minimal inhibitory activity of less than 7.8 mg/ml. Small pieces of *M. alba* leaves inoculated with *Fusarium solani* f. sp. *mori* produced new antifungal substances. These substances can be extracted by methanol, ethanol or acetone but not with chloroform or water. An acetone extract of the non-infected leaves showed antibacterial activity against *Staphylococcus* species.

Description Dioecious or monoecious shrubs or trees up to 35 m tall; bark surface fissured, exuding white or yellowish-white latex. Leaves alternate, simple or 3–5-lobed, dentate, palmately 3–5-veined; stipules lateral, caducous. Inflorescence axillary, spicate. Flowers unisexual, small, with 4, free or basally united, imbricate tepals; male flowers in long catkin-like inflorescences, with 4 exserted stamens and top-shaped pistillode; female flowers in short to capitate inflorescences, tepals accrescent and succulent in fruit, ovary included, 1(–2)-locular with a single ovule, style 2-partite, staminodes absent. Fruit a juicy syncarp, composed of many achenes enclosed in the succulent tepals; endocarp woody. Seed subglobose, with endosperm. Seedling with epigeal germination; cotyledons emergent; hypocotyl elongated; first leaves often palmately or pinnately lobed.

Growth and development Growth of *M. alba* is initially rapid but slows down abruptly after about 10 years. Pollination is probably by wind. *Morus* fruits may be set without pollination and are eaten by birds, the seeds defecated and thus dispersed; dispersal by water is also known. Vesicular-arbuscular mycorrhizae are present in *M. alba*, *M. australis* and *M. nigra* but the degree of colonization varies.

Other botanical information It are the light-coloured buds of *M. alba* that account for its name rather than the colour of its fruit, which can be almost any colour including white, lavender, red and black. The leaves may be entire to variously lobed on the same plant.

The number of *Morus* species is often greatly overestimated because many cultivated forms that have arisen through hybridization have been described as species. *M. bombycis* Koidz. is sometimes thought to be conspecific with *M. australis*.

Ecology Most mulberry species occur in warm temperate to subtropical regions, and in tropical highland areas. In temperate regions white mulberry is the most frost-hardy *Morus*, though some clones are damaged at 6°C whereas others can stand temperatures of −40°C. In India, white mulberry has invaded irrigated plains very rapidly. Although black mulberry seems to be much less cold-tolerant, this may vary among clones, with absolute minimum temperatures between −18°C and −12°C. In general, *Morus* prefers well-drained, loamy soils, but white mulberry, for example, is quite tolerant of drought and poor soils.

Propagation and planting *Morus* can be propagated by seed and by cuttings, grafting and air-layering. Hardwood, softwood and root cuttings can all be used for vegetative propagation. Seeds are extremely small and the 1000-seed weight is 2.2–2.3 g. In India, *M. alba* is raised from seed which germinates in 9–14 days. Seedlings are pricked out when 10–15 cm tall. All but a few terminal leaves are stripped ('striplings') before seedlings are planted during the cold season or at the beginning of the rains. Cuttings with 3–4 buds are used for the production of leaves to feed silkworms. They are buried for 15–20 cm of their length, including 2 buds. The rooted cuttings are planted out in the field after two months. Spacing depends on the method of harvesting leaves and is variable, being (0.5–)0.8(–1.2) m × (1.5–)1.8–2.0(–2.5) m. When planted in paired rows, the distance between pairs is about 1.8 m, about 0.6 m within one pair, with 0.5 m in the row. Grafted *M. alba* gives higher leaf yields than plants raised from seedlings or cuttings, resulting in silkworm cocoons of superior quality. Experimental micropropagation was quite successful in India where shoot tip and nodal explants from a 12-year-old black mulberry tree were multiplied. Nodal explants from seedlings of white mulberry raised in vitro all rooted and were successfully transferred to a 1:1 sand-vermiculite mixture.

In vitro production of active compounds *M. alba* callus cultures from the leaves give rise to cell lines, which are reported to produce a variety of compounds e.g. prenylated chalcones and phytosteroids. The yield of these Diels-Alder adducts is higher than in the intact plant.

Husbandry *Morus* trees are pruned to maintain an adequate framework for effective branching. *M. alba* is grown as a tree, a bush or as an espalier aiming at optimum leaf production. Low cutting ('bush type') is generally practised, but semi-low and medium cutting (at 1 m height) are also known. When grown as a bush, white mulberry in India is productive for about 15 years after which period the crop is replaced. Black mulberry is pruned to a height of 1 m during the resting period; this promotes vigorous growth and the production of large-sized fruits.

Diseases and pests The major diseases of *Morus* as observed in India are: powdery mildew (*Phyllactinia corylea*, also found in Indonesia), leaf spot (*Cercospora moricola*, *Pseudocercospora mori*) and leaf rust (*Cerotelium fici*). The stem borer *Batocera rufomaculata* is an important pest. In Thailand, the nematode *Hoplolaimus seinhorsti* is often found in *M. alba* plantations and probably associated with a root-rot disease which is widespread in the north-eastern part of the country.

Harvesting Mature leaves of *M. alba* are harvested either by plucking and leaving a few terminal leaves, or by pruning, coppicing or pollarding. For harvesting there seems to be no standard procedure with regard to frequency and cutting height. In a pruning experiment with *M. nigra* in Indonesia neither total leaf production nor the chemical composition of the leaves was affected by the height of pruning (20, 70 and 120 cm) and the frequency (3–4 months). The roots are simply dug up.

Yield An annual yield of 25 t fresh leaves per ha is considered acceptable for *M. alba*.

Handling after harvest Harvested roots of *Morus* are washed and the rough part is scraped off. Then a longitudinal incision is made, the bark pounded lightly and separated from the wood, tied in bundles and dried in the sun. Harvested leaves for feeding silkworms are stored in loose heaps in cool rooms and heating, fermentation and drying-out are prevented.

Genetic resources and breeding There are over 1000 races of *M. alba*, mainly to produce fodder for silkworms. In India, the techniques to induce tetraploidy in *M. alba* have recently been standardized and diploids, autotriploids and tetraploids are being studied, to assess their relative advantages.

Prospects The hypoglycaemic properties of *Morus* deserve further attention for their possible application in diabetes. Furthermore, the anti-inflammatory properties and the wide range of traditional clinical applications warrant continuing interest in *Morus*.

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Selection of species

Morus alba L.

Sp. pl. 2: 986 (1753).

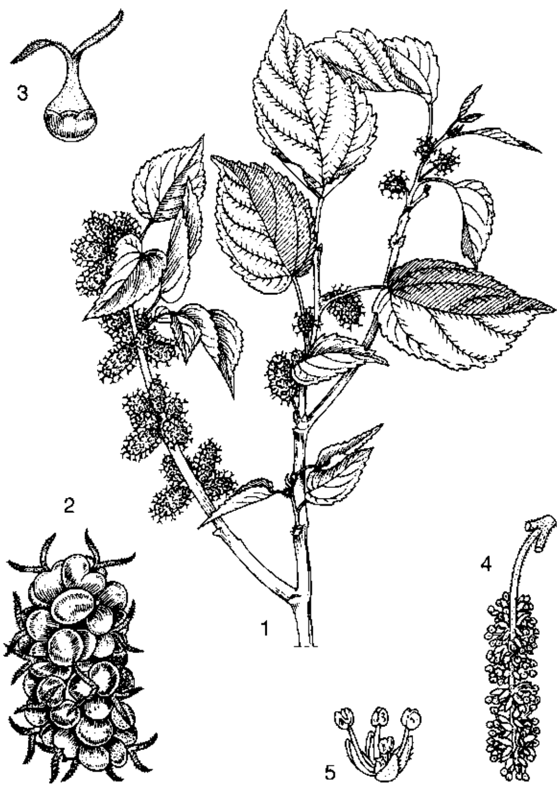
Synonyms *Morus indica* L. (1753), *Morus atropurpurea* Roxb. (1832), *Morus morettiana* Jacq. ex Burr. (1873).

Vernacular names White mulberry (En). Mûrier blanc (Fr). Moral blanco, morera blanca (Sp). Indonesia: murbei (general), besaran (Javanese). Philippines: amoras (Filipino), amingit (Igorot), mora (Ibanag). Burma (Myanmar): posa. Cambodia: mon. Vietnam: d[aaj]u t[aaf]m, tang.

Distribution Native of China, now widely cultivated in temperate and tropical regions; in Malesia occasionally naturalized, i.e. in the Philippines (Batan Island and Cagayan Province) where it was introduced in 1780.

Uses Most of the medicinal applications of *M. alba* are reported from China. Elsewhere it seems to be more often cultivated for its edible fruits and leaves that are fed to silkworms. In Vietnam the root bark is used as a diuretic, antitussive and expectorant and prescribed in oedema, high blood pressure, cough, bronchitis and asthma.

Observations A small to medium-sized tree up to 15(–20) m tall, bole up to 70 cm in diameter, bark surface dark grey-brown, with horizontal lenticels; leaves ovate to broadly ovate, 5–16 cm × 4–12 cm, rounded to shallowly cordate at base, acute to acuminate at apex, pubescent on the main veins, with a slender, 1–3.5 cm long petiole; male spikes 1–1.5(–2) cm long, female spikes ovoid, 0.5–1.3 cm long; syncarp ovoid, 1.5–2.5 cm long. The native and subspontaneous habitats of *M. alba* are generally moist places in mountains and thickets along rivers. In subtropical or dry tropical regions, *M. alba* can be cultivated at 0–3500 m altitude, but in the humid tropics it does not produce good fruit when planted at sea-level.



Morus alba L. – 1, fruiting twig; 2, infructescence; 3, female flower; 4, male inflorescence; 5, male flower.

Selected sources 78, 175, 190, 202, 244, 335, 350, 396, 478, 540, 580, 584, 717, 900, 1035, 1048, 1128, 1178, 1212, 1252, 1276, 1316, 1317, 1336, 1345, 1392, 1405, 1470, 1478, 1613.

Morus australis Poir.

Lamk, Encycl. 4: 380 (1797).

Synonyms *Morus acidosa* Griffith (1854), *Morus cavaleriei* H. Lév. (1911), *Morus inusitata* H. Lév. (1914).

Vernacular names Korean mulberry (En). Mûrier (Fr). Vietnam:d[aaj]u t[awf]m, d[aaj]u t[af]u, d[aa]u ta.

Distribution Originally from China, Korea, Japan and Taiwan; cultivated in Indo-China, the Philippines and Java, occasionally naturalized.

Uses In Java *M. australis* is used to feed silkworms; medicinal applications are mainly reported from its native region. In Vietnam a decoction of the leaves is used in the treatment of coughs and colds, and insomnia. A decoction of the root-bark is used against asthma, rheumatism and oliguria.

Observations A large shrub or small tree up to 10 m tall; leaves ovate to broadly ovate, 5–20 cm × 3–12 cm, rounded to shallowly cordate at base, long acuminate at apex, nearly glabrous to soft-hairy below, with a 1–4 cm long petiole; male spikes 1.5–3 cm long, female spikes erect or patent, broadly oblong, 1–2 cm long; syncarp oblong to ellipsoid, 1.5–3.5 cm long. In its natural habitats, *M. australis* is fairly common at low and moderate altitudes.

Selected sources 97, 364, 753, 856, 900, 1126, 1252, 1276.

Morus nigra L.

Sp. pl. 2: 986 (1753).

Synonyms *Morus laciniata* Miller (1768), *Morus scabra* Moretti (1841).

Vernacular names Black mulberry, common mulberry, sycamine (En). Mûrier noire (Fr). Moral negro, morera negra (Sp). Vietnam: d[aa]u g[ur]a den.

Distribution Originating from western Asia, but much cultivated in that region and the Mediterranean since ancient times. Nowadays cultivated and occasionally naturalized in most tropical and temperate regions, though in the tropics only at higher elevations. Only occasionally planted in Malesia.

Uses *M. nigra* is most commonly cultivated for its tasty fruits, which are also applied medicinally. The leaves are fed to silkworms, but generally considered inferior to those of the white mulberry.

Observations A small to fairly large tree up to 35 m tall; leaves broadly ovate, 5–16 cm × 5–16 cm, deeply cordate at base, shortly and bluntly acuminate at apex, rough above, pubescent below, with a striate, 2–3.5 cm long petiole; male spikes 1.5–2.5 cm long, female spikes ovoid, 1–2 cm long; syncarp ovoid, 1.5–2.5 cm long. *M. nigra* is cultivated in humid regions, up to 2000 m altitude.

Selected sources 131, 478, 580, 900, 1178, 1252, 1275, 1276, 1470, 1521.

D.S. Alonzo

Oldenlandia L.

Sp. pl. 1: 119; Gen. pl. ed. 5: 55 (1754).

RUBIACEAE

$x = 9$; *O. affinis*: $2n = 18$, *O. brachypoda*: $2n = 32$, 54, *O. corymbosa*: $2n = 18$, 36, 54, *O. herbacea*: $2n = 18$, 36

Major species *Oldenlandia brachypoda* DC., *O. capitellata* (Wallich ex G. Don) O. Kuntze, *O. corymbosa* L.

Origin and geographic distribution *Oldenlandia* consists of approximately 100 species (but estimates of up to 300 species have also been made), and is distributed in all tropical and subtropical regions.

Uses In many areas whole *Oldenlandia* plants are used internally in a decoction to treat fever, stomach disorders and diarrhoea. Externally they are commonly used pounded in poultices to treat ulcers, wounds, bruises, snake bites, insect stings, broken bones, rheumatism, lumbago and ague. In traditional medicine in India, *O. corymbosa* is used in the treatment of jaundice and gonorrhoea. The aerial parts of *O. brachypoda* and *O. corymbosa* are used in Chinese medicine to treat tumours in liver, lungs and rectum, and as an antiphlogistic.

In India, the bark of the roots of *O. umbellata* L. was much used to prepare a red dye before the large-scale production of synthetic dyes started at the end of the 19th Century. A decoction of its leaves and bark is considered expectorant and is prescribed in cases of bronchial catarrh, bronchitis and asthma, and is also used as a wash for poisonous bites.

Production and international trade *Oldenlandia* is usually collected in the wild, and because it often acts as a weed, it is usually available in sufficient amounts for private use. There is no real international trade, although small amounts of dried plants are exported from China.

Properties Tests with *O. brachypoda* showed inhibition on aflatoxin B1-induced mutagenesis using *Salmonella typhimurium* TA 100 as the bacterial tester strain and rat liver supernatant as the activation system. This suggests that it possesses mutagenic activity and possibly cancer chemopreventive properties. In tests with mice in Indonesia, *O. corymbosa* leaves caused humoral immune response stimulation and suppression on the phagocytosis system. The water-soluble fraction administered intraperitonially had no influence on cellular immune responses, but the residue fraction given orally caused stimulation. *O. brachypoda* markedly stimulated murine spleen cells to proliferate in in vitro studies. This suggests that it has immunomodulatory activity.

Nine iridoid glucosides have been isolated from the aerial parts of *O. corymbosa*, among which asperuloside, asperulosidic acid and scandoside methyl ester. Some iridoids are known to have antiphlogistic activity.

Description Annual herbs or sometimes herbaceous perennials; stem erect or procumbent. Leaves opposite, simple and entire, sessile or petiolate; stipules interpetiolar and adnate to leaf-bases. Inflorescence terminal or axillary, cymose and paniculate or corymbose, sometimes flowers in fascicles or solitary. Flowers bisexual, protandrous, small, 4-merous, homostylous or heterostylous; calyx with turbinate, globose or oblong tube, and distinct lobes; corolla hypocrateriform or narrowly infundibular, with valvate lobes, white, pale mauve, blue or pink; stamens with filaments attached at the corolla tube between the lobes, anthers dorsifixed; ovary inferior, 2-locular, with 2–many ovules, style terete or filiform, stigma usually bifid but sometimes capitate. Fruit a crustaceous capsule, loculicidally dehiscent at apex, usually many-seeded. Seeds obconical, meniscoid, scutelliform, cerebriform or obovoid, with variously patterned surface. Seedling with epigeal germination; cotyledons very small, ovate.

Growth and development Most *Oldenlandia* species are annual and complete their lifespan from seed to seed in a short period, which is in accordance with their status as weed. Some species are perennial, e.g. *O. capitellata*.

Other botanical information *Oldenlandia* is often included in *Hedyotis*. However, recent studies in northern America, Australia and India have shown that there are differences in habit and morphology of inflorescences, flowers, fruits and seeds, as well as in cytology, embryology and palynology, so *Oldenlandia* has been kept separate here.

Several *Oldenlandia* species are difficult to distinguish and often confused. The correct name for the taxon usually referred to as *O. diffusa* is *O. brachypoda* DC., although some caution is needed as the 'true' *O. diffusa* (Willd.) Roxb. is also a widespread weed.

Ecology *Oldenlandia* often occurs in disturbed locations such as grasslands and roadsides. Several species are common weeds in fields; *O. corymbosa* is particularly common in e.g. cassava, pineapple and maize throughout the tropics.

Propagation and planting In *O. corymbosa* three plant types have been determined: a type in which almost all seeds are non-dormant and germinate immediately in light at 35–40°C, a type in which almost all seeds are dormant and need a pre-germination treatment at 12°C for 7 days, and a type in which approximately 50% of the seeds are dormant and the remainder are non-dormant.

Tests with the Indian species *O. umbellata* showed promising results for in vitro propagation. Direct somatic embryogenesis and subsequent plant formation were achieved by using leaves, pieces of stems, axillary buds and developing fruits. The best results were obtained in half-strength Murashige and Skoog basal medium containing only 12% of the usual N content, supplemented with 0.2 mg/l benzyladenine, 0.1% ascorbic acid and 1.5% sucrose under diffuse light (300 lux). Rooting was achieved in the same medium, but with naphthalene-acetic acid instead of benzyladenine.

Harvesting For personal use, whole plants of *Oldenlandia* are usually harvested in small amounts, when needed.

Handling after harvest Freshly harvested *Oldenlandia* plants are often used immediately, but sometimes they are dried and stored for later use or trade.

Genetic resources and breeding In South-East Asia the medicinally used *Oldenlandia* species are common weeds and widely distributed, so there is no danger of genetic erosion.

Prospects Several tests on the mutagenic activity and possible cancer chemopreventive properties of *Oldenlandia* have given positive results; animal tests on immune response stimulation and suppression on the phagocytosis system have also been promising. The antiphlogistic properties attributed to *Oldenlandia* are interesting. More research is needed to establish the definite medicinal value of these plants.

Taxonomic research on *Oldenlandia* and related genera on a worldwide basis is desirable. Species and genus concepts and delimitations differ greatly, resulting in much confusion in floras of the various regions.

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Selection of species

Oldenlandia affinis (Roemer & Schultes) DC.

Prodr. 4: 428 (1830).

Synonyms *Hedyotis affinis* Roemer & Schultes (1818), *Hedyotis dichotoma* Heyne ex Roth (1821), *Oldenlandia dichotoma* (Heyne ex Roth) Hook.f. (1880).

Vernacular names Thailand: ya thopthaep (Tak).

Distribution Tropical Africa, Madagascar, the Comoro Islands, India, Thailand, Peninsular Malaysia and Singapore.

Uses *O. affinis* was reported to be used medicinally in Peninsular Malaysia, without specification.

Observations A slender much-branched annual or perennial herb up to 50(–120) cm long; leaves narrowly oblong-lanceolate to linear, up to 3(–6) cm long; flowers in a lax paniculate cyme, dichotomously branched, corolla with spreading lobes, bluish or pinkish-white; fruit subglobular. *O. affinis* occurs in Malaysia in dry, often sandy locations, usually near the sea; in India it is commonly found on slopes of hills up to 1200 m altitude.

Selected sources 202, 921.

Oldenlandia biflora L.

Sp. pl. 1: 119 (1753).

Synonyms *Hedyotis biflora* (L.) Lamk (1792).

Vernacular names Philippines: pisek (Ivatan), dalumpang (Subanun), palarapdap (Samar-Leyte Bisaya). Thailand: phak khuang, mak dip nam khang, sadao din (Bangkok). Vietnam: an di[eef]n hai hoa, mai h[oof]ng.

Distribution From Sri Lanka, India and Indo-China to Samoa and eastern Australia; throughout Malesia.

Uses In the Philippines, the plants are pounded and applied to wounds, and a decoction is administered internally to cure diarrhoea. Besides these uses, traditional doctors in Thailand also use the whole plant for its anti-amoebic and antipyretic properties. In India, it is used to treat fever and stomach complaints. In Vietnam, it is applied to treat snake bites.

Observations An erect or prostrate to decumbent, divaricately branched annual herb up to 50 cm long, branches obtusely or acutely 4-angled; leaves oblong, elliptical to narrowly elliptical, up to 8 cm long; flowers in 3–7-flowered cymes, corolla with geniculate lobes, white or occasionally pale blue; fruit turbinate-obovoid; seeds transversely ellipsoid. *O. biflora* occurs in sunny or slightly shaded locations, often as a weed, in fields, gardens, roadsides, river banks and open spots in forest up to 300 m altitude.

Selected sources 97, 537, 921, 1178.

Oldenlandia brachypoda DC.

Prodr. 4: 424 (1830).

Synonyms *Hedyotis brachypoda* (DC.) Sivar. & Biju (1990), *Hedyotis diffusa* auct. non Willd., *Oldenlandia diffusa* auct. non (Willd.) Roxb.

Vernacular names Malaysia: bunga chakar ayam, rumput angga (Peninsular). Philippines: ulasiman-kalat (Tagalog), daniri (Bisaya). Thailand: hom chaeo naa (Khon Kaen).

Distribution From Sri Lanka, India, southern China and Japan to Malesia; also in tropical America.

Uses In Malaysia, the plant is used for poulticing, apparently against lumbago. In India, a decoction of the whole plant is used to treat biliousness, fever and gonorrhoea.

Observations A prostrate annual herb up to 45 cm long, usually branched from the base, branches terete; leaves linear-lanceolate, up to 4 cm long; flowers axillary, solitary, sometimes 2–3 together, corolla white to purplish; fruit subglobose; seeds reticulate. *O. brachypoda* usually occurs in humid or swampy locations such as rice fields and along streams, up to 1100(–1500) m altitude. It has been very often confused with *O. diffusa* (Willd.) Roxb., which is also a common weed, and which possibly has comparable uses and properties.

Selected sources 97, 202, 627, 921, 1178, 1373, 1587, 1588, 1637.

Oldenlandia capitellata (Wallich ex G. Don) O. Kuntze

Revis. gen. pl.: 292 (1891).

Synonyms *Hedyotis capitellata* Wallich ex G. Don (1834), *Oldenlandia recurva* (Korth.) Miq. (1859).

Vernacular names Indonesia: akar kemenyan hantu (Sumatra). Malaysia: seketan, akar patah bubul, akar patah gogoh (Peninsular). Thailand: kamlang hualamaan (Chiang Mai), tong haeng (peninsular), yan bueang thuai (Narathiwat). Vietnam: c[aa]y lo[es]t m[oof]m, c[aa]y d[aj] c[aar]m.

Distribution Eastern India, Indo-China, southern China, Burma (Myanmar), Thailand, Peninsular Malaysia, Singapore, Sumatra, Borneo; once collected in Java.

Uses Leaves are used in Malaysia for poulticing to treat snake bites, broken bones, bruises, rheumatism, lumbago and ague, and internally for treating kidney complaints. A decoction of the root is administered to women after childbirth, and also used against constipation, indigestion, gastric vertigo and dysentery. In Vietnam, leaves and young stems are used in decoction to treat ulcers in the mouth, glossitis, pharyngitis and peptic ulcers.

Observations A sprawling perennial herb up to 2 m long, branches 4-angled or terete; leaves oblong to lanceolate, up to 11(–15) cm long; flowers in a paniculate inflorescence composed of peduncled heads, corolla cream-coloured; fruit obovoid. *O. capitellata* is a common climber over bushes and hedges up to 1200 m altitude.

Selected sources 97, 202, 580, 1035.

Oldenlandia corymbosa L.

Sp. pl. 1: 119 (1753).

Synonyms *Hedyotis corymbosa* (L.) Lamk (1792).

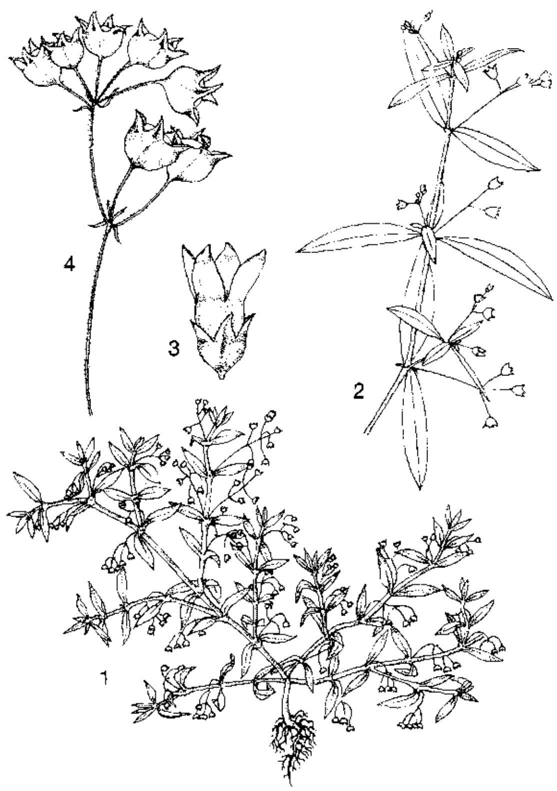
Vernacular names Malaysia: siku-siku, siku dengan, pokok telur belangkas (Peninsular). Philippines: malaulasiman, ulasiman-aso (Tagalog). Thailand: yaa linnguu (Bangkok). Vietnam: l[uw][owx]i r[aws]n, c[os]c m[awr]n.

Distribution Probably native to Africa and India, but now with pantropical distribution; throughout Malesia.

Uses The leaves are commonly used for poulticing to treat sores and sore eyes. The entire plant is used in decoction as a febrifuge and stomachic. In Indo-China, it is also used as antirheumatic. In India, the plant is a common ingredient in mixtures used internally to treat fever and as a tonic. It is also used to treat jaundice. The roots are reported to have vermifuge properties.

Observations A prostrate to decumbent, divaricately branched annual herb up to 60 cm long, branches 4-angled; leaves narrowly elliptical to linear-lanceolate, up to 3(–5) cm long; flowers in a (1–)3–8-flowered umbel-like corymb, corolla with spreading lobes, white or pinkish; fruit depressed obovoid or broadly obovoid; seeds obconical to depressed obconical, laterally compressed. *O. corymbosa* is a weed in fields, roadsides, lawns and gardens, preferably in not to wet, sunny, stony locations, usually up to 800 m altitude, but sometimes up to 1500 m.

Selected sources 97, 202, 279, 537, 921, 1035, 1094, 1178, 1373, 1423.



Oldenlandia corymbosa L. – 1, plant habit; 2, flowering and fruiting stem; 3, flower; 4, infructescence.

Oldenlandia herbacea (L.) Roxb.

Fl. ind. 1: 445 (1820).

Synonyms *Hedyotis herbacea* L. (1753).

Vernacular names Vietnam: an di[eef]n c[or].

Distribution Tropical and subtropical Africa and Asia, including the whole of Malesia.

Uses *O. herbacea* has been reported to be used medicinally in Peninsular Malaysia, without specification.

Observations An erect or ascending slender annual or perennial herb up to 50(–60) cm long, usually much-branched, branches 4-winged; leaves linear-lanceolate to linear, up to 3(–5.5) cm long; flowers axillary, solitary, sometimes 2(–4) together, corolla white to purplish; fruit subglobular, small, about 2.5 mm long; seeds ovoid to ellipsoid, reticulate. *O. herbacea* occurs in open places such as fields, grasslands and roadsides, often on stony or sandy soils, up to 1500 m altitude.

Selected sources 97, 202, 921.

N.O. Aguilar & R.H.M.J. Lemmens

Orthosiphon aristatus (Blume) Miq.

Fl. Ind. Bat. 2: 943 (1858).
LABIATAE
$2n = 48$

Synonyms *Orthosiphon stamineus* Benth. (1831), *Orthosiphon grandiflorum* auct. non Terrac., *Orthosiphon spicatus* auct. non Benth.

Vernacular names Java tea (En). Thé de Java (Fr). Indonesia: kumis kucing (general), kumis ucing (Sundanese), remuk jung (Javanese). Malaysia: kumis kucing. Philippines: balbas-pusa (Tagalog), kabling-gubat. Cambodia: kapen prey. Laos: hnwàd mêew. Thailand: yaa nuat maeo. Vietnam: r[aa]u m[ef]o.

Origin and geographic distribution Java tea is distributed from India, Indo-China and Thailand, through Malesia to tropical Australia. As a wild plant, it occurs throughout Malesia, but is apparently rare in Borneo, Sulawesi and the Moluccas. It is now grown in South-East Asia (in Java since 1928), Africa, Georgia (Caucasus) and Cuba.

Uses In Malesia, Thailand and Vietnam the leaves are used as a diuretic in teas and infusions against various kidney complaints and illnesses, renal calculi, phosphaturic catarrh of the bladder, gout, and also, in combination with other drugs, to stimulate the kidneys and as a medicine for nephritis, gallstones and diabetes. For these purposes, Java tea is sometimes mixed with the leaves of *Sonchus* or *Barleria*.

In Europe, the therapeutic indications for *Orthosiphon* are: diuresis and irrigation of the urinary tract, especially in cases of inflammation and renal gravel, and as an adjuvant in treatment of bacterial infections of the urinary tract. The drug is normally taken as an infusion of 2–3 g dried material in 150 ml water, 2–3 times per day. *Orthosiphon* is also included in the form of an extract in instant preparations, which are used accordingly. In Indonesia, it is used to treat jaundice in a mixture with leaves of *Blumea balsamifera* (L.) DC. and *Phyllanthus fraternus* Webster and rhizomes of *Curcuma xanthorrhiza* Roxb., and to treat diabetes together with the leaves of *Andrographis paniculata* (Burm.f.) Nees. In mixtures with leaves of other plants it is also used against gout, rheumatism and arteriosclerosis. *Orthosiphon* preparations are on the market in Indonesia as capsules, pure or in combination with other ingredients. The crude herb is said to cause vomiting. In gardens the plant is also cultivated as an ornamental.

Production and international trade Indonesia is the main producing country (Java, Sumatra, North Sulawesi). Before the Second World War about 80 t/year of dried leaves was exported to the Netherlands, Germany, France, Japan and the United States. After the war interest waned because more modern diuretics became available. However, Indonesian exports to Europe and other parts of the world are again substantial. In the period 1991–1995 an average of 170 t/year of dried leaves was exported. The average value in 1995 was US$ 1.3/kg. The main importing country is Germany.

Properties 'Orthosiphonis Folium' or Java tea consists of the dried leaves and stem tips of *O. aristatus* collected shortly before flowering. It contains up to 12% minerals with a high proportion of potassium (600–700 mg per 100 g fresh leaf), approximately 0.2% lipophilic flavones including sinensetin, flavonol glycosides, caffeic acid derivatives (mainly rosmarinic acid and 2,3-dicaffeoyltartaric acid), inositol, phytosterols (β-sitosterol), saponins and up to 0.7% of essential oil. Analysis revealed caffeic acid derivatives like rosmarinic acid (and 2,3-dicaffeoyltartrate) to be predominant components in a hot water extract prepared comparable to that of a herbal tea.

Various tests have been performed to demonstrate the diuretic activity of *Orthosiphon* extracts both in animals and man, and to establish the source of this effect. Diuretic effects were observed in rabbits, dogs and rats; oral application of 750 mg/kg body weight lyophilized aqueous *Orthosiphon* extract enhanced ion excretion (K^+, Na^+, Cl^-) in rats, whereas no increase in urine output was observed. Similar effects were reported in man, such as increased diuresis and elimination of chlorides and urea. In a placebo-controlled double-blind cross-over study with 40 volunteers, however, no influence on urine output or Na^+/K^+ excretion was recorded with a daily dose of 600 ml of an infusion equivalent to 10 g of dried leaves.

Although the possible diuretic compounds of *Orthosiphon* extracts are not yet known, it has been postulated that the effects could be partially due to the high content of potassium in the leaves and the presence of inositol (and possibly saponins), as well as to the isolated flavones sinensetin and 3'-hydroxy-5,6,7,4'-tetramethoxyflavone which exhibited a diuretic activity in rats after intravenous administration of 10 mg/kg body weight. The total activity of *Orthosiphon* leaves should not be attributed to these flavones, however, since it has also been shown that only minute amounts of these lipophilic compounds are extracted by (hot) water when an aqueous infusion is prepared. The highest content of sinensetin (up to almost 0.4%) was found in old leaves of forms with bluish-violet flowers, and the lowest content (about 0.1%) in young leaves of forms with white flowers.

In tests with healthy volunteers in Thailand, *Orthosiphon* extracts increased excretion of citrate and oxalate. Although a higher level of oxalate may increase the risk of kidney stones, the increased citrate output helps prevent stone formation.

It has been demonstrated that Java tea has antimicrobial properties. In in vitro tests, aqueous extracts markedly inhibited the growth of both gram-positive and gram-negative bacteria. Saponins may play a role in bacteriostatic activity in vitro. Caffeic acid derivatives (which represent as much as 95% of the phenolic substances present in a hot water extract) may also be responsible for the antibiotic activity.

The lipophilic flavonoids present in *O. aristatus*, of which sinensetin and tetramethylscutellarein are the most abundant, have shown inhibitory effect against Ehrlich ascites tumour cells in vitro. Additionally, the lipophilic flavonoids may be partially responsible for anti-inflammatory effects, since flavonoids are inhibitors of cyclo-oxygenase and lipoxygenase.

Doses of less than 1 g/kg body weight have been found to be lethal for rats and mice after intraperitoneal injection, but no injurious effects were found after feeding up to 5 g/kg body weight orally.

In patients, increased choleresis and cholekinesis have been reported, together with an antibacterial action in cholecystitis and cholangitis, after oral administration of a Java tea extract. However, in vivo studies in rats with the isolated flavones sinensetin and 3'-hydroxy-5,6,7,4'-tetramethoxyflavone administered intravenously at a dose of 10 mg/kg body weight did not confirm these findings.

Adulterations and substitutes It is reported that Java tea is adulterated with leaves of *Ageratina riparia* (Regel) R.M. King & H. Robinson (*Compositae*). Among the many South-East Asian plants with diuretic activity are *Clerodendrum*, *Desmodium*, *Ludwigia* and *Sida* species. Species which, like Java tea, combine diuretic activity and antimicrobial activity, belong to, among others, the genera *Artemisia*, *Cassia*, *Elephantopus*, *Phyllanthus* and *Plantago*. *Acorus calamus* L. and *Mentha arvensis* L. are examples of species important for their antibacterial activity.

Description A perennial herb, 25–200 cm tall, with quadrangular, poorly ramified, ascending stem. Leaves decussately opposite, ovate or rhombic, 2–9(–12) cm × 1.5–5 cm, cuneate at base, acute or acuminate at apex, serrate, glabrous or minutely pubescent, glandular-punctate; petiole 0.5–2 (–4.5) cm long; stipules absent. Inflorescence an opposed cyme arranged in terminal racemes, 7–29 cm long. Flowers pedicellate; calyx 2.5–4.5 mm long (up to 12 mm in fruit), bilabiate, gland-dotted; corolla 10–20 mm long, tubular, bilabiate, white or (pale) lilac; stamens 4, long-protruding from the corolla tube; ovary superior, style long-protruding, slender, with enlarged, club-shaped and shallowly cleft stigma. Fruit splitting into 4 oblong-ovoid nutlets, 1.5–2 mm long, brownish, rugose.

Growth and development The flowers are sometimes cleistogamous, in which case the corolla is hidden in the calyx. The ovary is normal and develops into normal nutlets.

Other botanical information *Orthosiphon* comprises approximately 40 species with an Old

Orthosiphon aristatus (Blume) Miq. – 1, flowering stem; 2, flower; 3, fruiting calyx and nutlet.

World distribution. In Malesia, only 2 species occur. The wild relative *Orthosiphon thymiflorus* (Roth) v.d. Sleesen is rare in Malesia (central and eastern Java), more common from India and Sri Lanka to Indo-China. Three cultivars of *O. aristatus* are distinguished: one with bluish-violet and two with white flowers. The white-flowered cultivar with reddish stems, petioles and leaf veins appears to possess the best diuretic qualities.

Ecology Java tea occurs in the wild in thickets, regrowths, grasslands and along forest borders and roadsides, often in shaded not too dry localities, but also in sunny places, up to 1000 m altitude.

Propagation and planting Propagation is by stem cuttings, 15–20 cm long, which have some buds. Cuttings are usually planted in shade, with 40–60 cm between plants and rows. Often 4–6 cuttings are placed in one hole. Direct planting in the field or in the backyard, as is most common, can be done all the year round, but the usual time of planting is at the beginning of the rainy season. For plantations, planting in a nursery for a period of 45 days with the cuttings placed vertically with only one bud visible is preferred.

In vitro production of active compounds Cell suspension cultures of *O. aristatus* have been shown to accumulate rosmarinic acid. The accumulation of rosmarinic acid in the cell suspension cultures could be increased by adding yeast extract to the culture medium.

Husbandry Regular weeding is necessary. Inflorescences should be removed. Manuring is advantageous; the standard application per ha is of 200 kg triple superphosphate, 100 kg potassium salt and 15 t manure. It is advised to add a nitrogenous fertilizer at the rate of 100 kg/ha after each harvest.

Diseases and pests Fungal diseases that have been reported to cause losses in Java tea are *Botrytis cinerea*, *Corticium rolfsii*, *Moniliopsis aderholdii* and *Pythium debaryanum*. Nematodes may cause galls to develop on the roots, but no standard treatment is practised to limit their damage. Insecticides are usually applied to the planting holes in order to prevent termite attack.

Harvesting Harvest usually starts 8–10 weeks after planting, at the beginning of flowering. Every 2–3 weeks the upper 4–10 leaves of shoots are plucked by hand.

Yield Annual yields of dry leaves amount to 1500 kg/ha.

Handling after harvest Smallholders usually sun-dry leaves. In estate farming artificial drying is practised. To obtain a high-quality product, the leaves are first withered in the air, and then dried at 45–50°C. Dried leaves of good quality are green (a blackish colour is due to overheating or contact with metal containers), have a good aroma, a moisture content below 14%, a bitter taste, an ash content of about 10%, a contamination content of less than 2%, and do not contain insects or fungi. Properly dried leaves should be pressed as soon as possible to prevent moisture uptake. They are packed in ordinary tea chests, each containing up to 50 kg of leaves; aluminium foil is used to prevent moisture uptake.

Genetic resources and breeding As no germplasm collections exist, plant material should be collected from all growing regions.

Prospects Java tea shows promising medicinal properties. More research is needed to confirm the activities reported and to determine and isolate the active constituents. For a good quality product a survey on market requirements and potential for expansion is needed.

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B. Dzulkarnain, Lucie Widowati,
A. Isnawati & H.J.C. Thijssen

Oxalis corniculata L.

Sp. pl. 1: 435 (1753).

OXALIDACEAE

$2n = 24, 28, 44, 48$

Synonyms *Oxalis repens* Thunb. (1781), *Oxalis javanica* Blume (1825).

Vernacular names Indian sorrel, creeping wood-sorrel, procumbent yellow sorrel (En). Indonesia: daun asem kecil (Sumatra), calingcing (Sundanese), semangnen (Javanese). Malaysia: sikap dada (Peninsular). Papua New Guinea: kokavu (Kami, Eastern Highlands), akler (New Britain). Philippines: taingan-daga (Tagalog), marasiksik (Iloko), daraisig (Bikol). Singapore: sikap dada. Burma (Myanmar): hmô-gyin. Cambodia: chantoe phnom kok. Laos: som ten kalm. Thailand: phak waen (central), som sangka (Chiang Mai), som din (Mae Hong Son). Vietnam: me d[aas]t, chua me ba ch[if]a, toan t[uw][ow]ng th[ar]o.

Origin and geographic distribution *Oxalis* consists of about 700 species and has its centres of diversity in South America and South Africa. Only a few species occur in South-East Asia; in Malesia there are 3 native species and 5 introduced ones, 4 of which have naturalized, sometimes becoming weeds. *O. corniculata* is a cosmopolitan weed of unknown origin, although a southern European origin has been postulated. It occurs throughout South-East Asia, but is scarce in Peninsular Malaysia, Borneo and Sulawesi.

Uses *O. corniculata* is considered a good medicine against scurvy, e.g. in the Philippines, India and China. The juice of the leaves is used for cleansing wounds and to treat itch, burns, sores, insect and scorpion stings, and for removing warts. A poultice of the leaves relieves pain due to swellings. The leaves are taken as a good remedy in cases of intestinal complaints, and are applied externally to treat miliaria. A decoction of the leaves is sometimes used as a gargle against sore mouth and gums, and to treat cough, fever and dysentery. The whole plant is used as a diuretic and to treat opacity of the cornea. In Thailand, the aerial parts are used as an emmenagogue and to treat cough. In Korea, the entire plant is used in the treatment of dysentery, haemorrhoids and as an antidote. In China, it is considered to be cooling, emmenagogic, anthelmintic and lithotriptic. In Papua New Guinea and East Africa, the pounded plant is applied to remove ringworm.

O. corniculata is sometimes used to remove rust and ink stains, and to scour copper, due to the presence of oxalates (mainly potassium) and their ability to form metal complexes. The use as an antidote to mercury or arsenic poisoning is also sometimes reported. Small amounts of leaves have been added to food as a seasoning, but larger amounts can be toxic. Although it is usually a serious weed, it may sometimes serve as a valuable cover crop in preventing soil erosion in perennial crops such as tea and coconut.

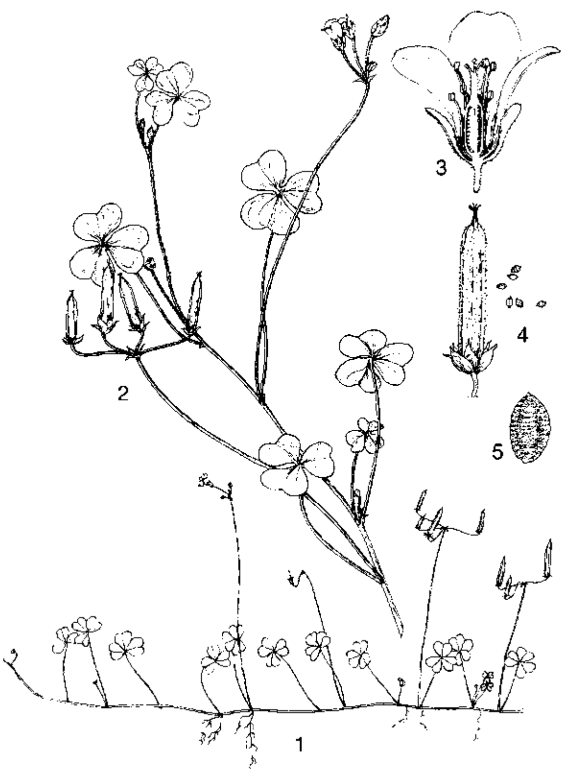
Production and international trade *O. corniculata* is only used locally and has no importance on the market.

Properties *Oxalis* derives its acid taste from the presence of oxalates (mainly in the form of soluble potassium salt). Oxalates are toxic in high doses. They combine with serum calcium to form insoluble calcium oxalate. The reduction in available calcium leads to violent muscular stimulation with convulsions and collapse. In cases of poisoning, calcium oxalate crystals are also found in the renal tubulus; acute renal failure may occur from blockage of the renal tubuli. The principal manifestation of oxalate poisoning is anuria. In laboratory animals, the symptoms of acute poisoning are enlarged, pale kidneys, loss of control of fore or hind quarters and tetany.

The leaves contain β-carotene, and the C-glycosyl flavonoids vitexin, isovitexin and vitexin-2'-O-β-D-glucoside. On extraction with chloroform-methanol young leaves yielded 1.5% lipids (on dry weight basis). These leaf lipids are a good source of essential fatty acids and also of β-tocopherols.

Aqueous leaf and root extracts have brought about significant reduction in seedling growth of e.g. wheat; the allelopathic activity is due to oxalic acid and fumaric acid. Tests in India showed that powdery mildew (caused by *Phyllactinia corylea*) and leaf rust (caused by *Pseudocercospora mori*) of mulberry (*Morus* spp.) were minimized by a 10% alcoholic water extract of fresh *O. corniculata* plants. The extract also has insecticidal property.

Description A perennial, creeping or ascending small herb, with stems up to 50 cm long, rooting at the nodes; main root fibrous, in old plants sometimes developing into a thickened and woody rootstock; stems several from the main root, branching, puberulous. Leaves alternate, digitately 3-foliolate, petiole 1–5.5(–10) cm long, stipules small, up to 3 mm long; leaflets broadly obcordate to elliptical-obcordate, 4–20(–25) mm × 5–18(–25) mm, pubescent to sericeous beneath. Inflorescence cymose to pseudo-umbellate, pedunculate, 1–6 (–8)-flowered; bracts 2–several, subopposite to whorled. Flowers bisexual, actinomorphic, 5-merous, usually homostylous with mid-styled form, rarely with long-styled form; pedicel up to 20 mm long, articulate at base and beneath the calyx; sepals imbricate, short connate at base, lanceolate, 2–6 mm × 0.5–2 mm, sparsely puberulous to sericeous; petals contorted, coherent above the claw, spatulate-oblong to spatulate-lanceolate, 3.5–10 mm × 1–7 mm, glabrous, yellow; stamens 10, with 5 longer and 5 shorter filaments connate at base, the shorter rarely with rudimentary anthers; ovary superior, 5-celled, styles 5, free, with small, cylindrical stigmas. Fruit a linear-cylindrical, sometimes ellipsoid, pentagonal capsule, 9–20(–24) mm × 2–4 mm, pubescent, green, opening by longitudinal loculicidal slits, many-seeded. Seeds flattened-ovoid, about 1 mm long, red-brown; testa with about 3 regular rows of 7–10 transversally connected rows of ridges; aril bivalved, membranous, white. Seedling with epigeal germination; cotyledons leafy, with cuneate base and rounded apex, glabrous; hypocotyl elongated, epicotyl absent.



Oxalis corniculata L. – 1, creeping stem with flowers and fruits; 2, part of stem with flowers and fruits; 3, flower in longitudinal section; 4, fruit with seeds; 5, seed.

Growth and development In the evening the leaves of *O. corniculata* fold down around the leaf stalk. Plants usually flower throughout the year in the tropics. It is reported to be a facultative self-pollinator. Plants may produce seed about 20 weeks after germination. The seeds are forcefully ejected from the fruit in dry weather by the elastic aril.

Other botanical information Some other *Oxalis* species are occasionally used for medicinal purposes, e.g. *O. magellanica* J.G. Forster to aid conception in Papua New Guinea. *O. corymbosa* DC. is also used medicinally, e.g. in Vietnam and India, but its main use is as a culinary herb.

Ecology *O. corniculata* is a common weed in gardens, fields, grassland, in roadsides, on river banks and on walls, up to 3000 m altitude. It thrives best in warm, moist, freely drained and fertile soils with a pH of 3.5–6.5. It is commonly found in vegetables, groundnut, maize, soya bean and root crops in the Philippines, and is a weed in tea and rice in Indonesia. In temperate regions, *O. corniculata* is mainly a problem in greenhouses, but sometimes escapes to establish locally outdoor populations. Its prostrate habit helps to protect it from being mowed in lawns.

Propagation and planting A single plant of *O. corniculata* may produce up to 26 000 seeds. Seed viability is approximately 95%, and seeds require low levels of light for germination. When stored under dry conditions, they may retain germination rate of over 80% until 8 months, and of 50% after 15 months.

Diseases and pests *O. corniculata* may act as a host for several pathogenic organisms, e.g. *Botry-*

tis, *Fusarium*, *Microsphaera* and *Puccinia* species, and for organisms feeding on crops, e.g. *Meloidogyne* nematodes and insects of the genera *Ovarus* and *Argynnis*.

Harvesting *O. corniculata* is common around houses and on agricultural land. It is collected whenever the need arises.

Genetic resources and breeding *O. corniculata* is extremely widespread and occurs in anthropogenic habitats, making it not at risk of genetic erosion. There is even much effort to eradicate it as a noxious weed, but it seems well able to survive since it is often resistant to hormone-type herbicides.

Prospects Since hardly any information is available on the pharmacological activity of *O. corniculata* and its compounds it is impossible to indicate its future importance as a medicinal plant in modern phytotherapy.

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R.C.K. Chung

Papaver L.

Sp. pl. 1: 506 (1753); Gen. pl. ed. 5: 224 (1754).

PAPAVERACEAE

$x = 7, 14$; *P. rhoeas*: $2n = 14$ *P. somniferum*: $2n = 20, 22, 36, 44$

Major species *Papaver somniferum* L.

Vernacular names Poppy (En).

Origin and geographic distribution *Papaver* consists of about 100 species, most of which are found in the Mediterranean region. The most important species is *P. somniferum* (opium poppy), the source of opium. The cultivation of *Papaver* for medicinal purposes dates to about 2000 BC in Mesopotamia. The cultivation of *P. somniferum* has been prohibited in many countries due to the misuse of opium and its deleterious effects on human health.

Uses About 2350 years ago, the Greek physician Hippocrates mentioned poppy juice ('opium') as a cathartic, hypnotic, narcotic and styptic. *P. somniferum* is the only source of opium, which is the dried, alkaloid-containing latex obtained from the immature capsules of the plant. When the surface of these unripe fruits is damaged, e.g. by making incisions with a specially designed knife, latex oozes out in the form of white droplets which quickly turn brown and become semi-solid. Commercial opium is used medicinally, as a starting material for the extraction of several medicinally important alkaloids, or as a narcotic.

The only *Papaver* species with medicinal use in South-East Asia are *P. somniferum* and *P. rhoeas*. The dried fruit without the seed of *P. somniferum* is the 'anh tuc xac' of the traditional Vietnamese Pharmacopoeia, used to treat cough and diarrhoea. Dried fruits have also been used to treat cough in Europe and diarrhoea and cough in China. In northern Thailand, as well as in many other countries worldwide, opium is used to treat pain, diarrhoea, cough and insomnia, or as a narcotic. It is sometimes taken orally, but also often smoked, which is habit-forming and may subvert the personality. The major role of opium in medicinal practice has been for its astringent properties. Standardized opium tincture and camphorated opium are prescribed for severe diarrhoea and dysentery, as well as for pain, cough and nausea. Although still present in official pharmacopoeias of some countries, the use of opium or opium preparations has largely been superseded by its purified, extracted alkaloids, mainly morphine, codeine and noscapine (= narcotine).

The flowers and roots of *P. rhoeas* are recommended in China for treating jaundice and in Japan and the Philippines an infusion of the flowers may be used as a gargle or ingested as a bechic. The petals have a reputation as having mild sedative, antitussive, anodyne and sudorific properties. Infusions or syrups made from the petals have been used as a red colourant in pharmacy; however, they act as litmus, turning red with acid and blue with base.

P. somniferum is also a source of edible seeds and seed oil. The seeds are used in food, for instance in cakes and on bread. They are also used in bird feed. Poppy seed oil is mainly used as an edible oil, but also for the production of paint and soap. Poppy-seed cake or meal left after extraction of the oil is sweet and nutritious and used alone or mixed with other feeds, suitable as food for cattle and other animals. However, its use as animal feed has sometimes resulted in poisoning due to the presence of alkaloids arising from contamination of the seed with particles of the capsule. Some tribes in South-East Asia eat the young leaves of *P. somniferum*.

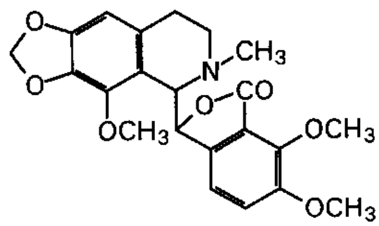
In Java, several *Papaver* species (e.g. *P. nudicaule* L., *P. rhoeas* and *P. somniferum*) used to be grown as ornamentals. They have bright flowers, ranging from white to almost black, and through various shades of yellow, pink, orange, scarlet and crimson.

Production and international trade *P. somniferum* is cultivated for the production of opium, straw for extraction of alkaloids, and/or seeds and seed oil. Poppy straw consists of the upper stalks with crushed capsules. The legal production of opium is limited to India, but extensive illegal opium production is found in the 'Golden Triangle' (the border region of Thailand, Burma (Myanmar) and Laos), the 'Golden Crescent' (Pakistan, Afghanistan, Iran), Lebanon and Mexico. Total legal opium production in 1983 was 1000 t, produced in India on about 32 000 ha. The opium-producing areas in Burma (Myanmar), Thailand and Laos were estimated at respectively 60 000 ha, 3500 ha and 3500 ha. Opium production estimates for 1989 were for Burma (Myanmar) 2000 t, for Afghanistan 800 t, for Laos 400 t, for Pakistan 130 t, and for Thailand 50 t.

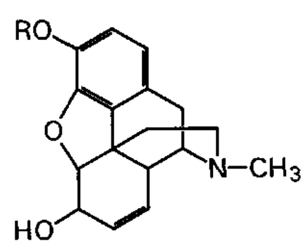
Production for straw is mainly found in the more temperate zones, being for Spain 13 700 t, for France 3700 t, for Australia 1180 t and for Turkey 940 t in 1980.

Properties A large number of alkaloids have been isolated from *Papaver*. At least 25 alkaloids that are biosynthetically derived from the amino acid tyrosine have been isolated from opium. The most important are morphine (5–25%), codeine (0.2–3%), thebaine (0.2–5%), noscapine (2–10%), narceine (0.1–0.7%) and papaverine (0.5–3%). Biosynthetical routes are extremely complex within the family of *P. somniferum* alkaloids, thus several subgroups of related compounds can be recognized. Of the 6 main alkaloids, morphine, codeine and thebaine belong to the phenanthrene (or morphinane) type, noscapine and narceine belong to the phtalide-isoquinoline type, and papaverine to the benzyl-isoquinoline type. Other alkaloids include aporeine, codamine, cryptopine, gnoscopine, hydrocotarnine, lanthopine, laudanidine, laudanine, laudanosine, meconidine, narcotoline, neopine, oxynarcotine, papaveramine, porphyroxine, protopine, reticuline, rhoeadine and xanthaline. Many of these opium alkaloids are not only present in the fruit but also in other parts of *P. somniferum*.

In opium, the alkaloids are largely present as salts of organic acids, such as meconic or lactic acid. The drug also contains sugars, salts (e.g. sulphates), free organic acids such as meconic, lactic, fumaric and oxalacetic acid, albuminous substances, colouring matters and water. Most of the world legal opium production is used to obtain morphine, codeine and noscapine, which are medi-



noscapine



morphine (R = H) and codeine (R = CH_3)

cinally the most important. A large part of the isolated morphine is converted into codeine by chemical semisynthesis, since there is much greater demand for this compound. Morphine can also be converted into heroin by addition of acetyl groups; this substance is very addictive.
Morphine (named after Morpheus, the greek god of dreams) as a pure substance is mostly applied as one of its salts (e.g. HCl or sulphate). It is a very strong analgesic, acting on the central nervous system and widely used to relieve pain. Furthermore, morphine has digestive effects leading to constipation, and it is antidiuretic. At high doses it causes depression of respiration, bradycardia, vasodilatation and hypotension, but the best known side effects are the development of psychic and physical dependence. Morphine acts by interaction with specialized receptors, called opioid receptors, of which several types (e.g. μ, κ, σ, δ) are recognized. There is also evidence of the existence of several subtypes. μ-Receptor activation in the brain is presumed to be responsible for the strong central analgesic effect. κ-receptors in the brain and spinal cord also appear capable of producing analgesia, particularly in the spine. Most of the psychomimetic effects (e.g. hallucinations) are apparently mediated by σ-receptors. The δ-receptor is presumed to be the primary receptor for endogenous opioid pentapeptides known as enkephalins. These enkephalins, together with the other endogenous opioid peptide families endorphines and dynorphines, and the opioid receptors, are believed to be responsible for the modulation of nociception, especially in cases of pain. Endogenous opioid peptides regulate respiration (μ-receptor); respiratory depression is therefore a very significant side effect of morphine, even at therapeutic levels. Some endogenous opioid peptides and receptors also exist in tissues and organs other than the brain: the gastro-intestinal tract is another principal site of action (μ-, κ-receptor; decreasing of motility).
Heroin is the diacetyl ester of morphine. The effects of heroin are similar to those of morphine, but it is more addictive and causes disruptions of blood flow, infections and collapsed blood veins. The manufacture and possession of heroin is illegal in most countries.
Codeine is the most widely used opium alkaloid, which also has some analgesic properties of its own. However, it is known to enhance the effects of other (non-opiate) analgesics, and thus it is often given in combination with e.g. paracetamol (acetaminophen). Codeine acts like morphine, but it is far less narcotic, euphoric or constipating. It has strong antitussive properties, and it is often employed in cough medicines and decongestants.
Thebaine is more a convulsant than a narcotic. It may cause tetanic spasms, which do resemble those caused by strychnine. The compound has been used as a narcotic antagonist in the treatment of heroin addiction, although better alternatives (e.g. naloxone) are available at present. Noscapine (narcotine) is not an analgesic, but a moderately strong antitussive. Like codeine, it is often used in cough medicines, especially for children. Papaverine has very little narcotic or analgesic action, but relaxes the involuntary muscles of the body and increases the blood flow by its effects on heart and blood vessels.
The leaves, stems and roots of *P. rhoeas* contain coptisine and protopine, whereas the capsules contain rhoeadine, rhoeagenine and rhoearubine. The pharmacology of the main alkaloid, rhoeadine (a tetrahydrobenzazepine) is unknown, but closely related derivatives are dopaminergic antagonists and neuroleptics. The presence of *P. rhoeas* in hay can be dangerous to animals.
The seeds of *Papaver* are rich in oil, carbohydrates, proteins and calcium. The oil content of 10 different *Papaver* species was found to range from 35% to 48%, the protein content from 21% to 28%. The fatty acids in poppy-seed oil are linoleic acid (65%), oleic acid (25%) and saturated acids (6–10%).

Adulterations and substitutes An alternative source of codeine is *P. bracteatum* Lindley, which grows wild in mountainous regions in western Asia. It contains thebaine, but no morphine or codeine. Thebaine can easily be converted into codeine and morphine by chemical methods, but is not readily converted into heroin.
Synthetic derivatives of morphine with fewer side effects have been developed, such as meperidine, methadone and fentanyl. However, the isolation of morphine derivatives from natural sources still seems easier and cheaper than synthetic production.
In Western medicine, preparations from hemp (*Cannabis sativa* L.) were extensively used between the middle of the 19th Century and the Second World War as a milder and less dangerous analgesic than opium.

Description Herbs or sometimes shrubs up to 150 cm tall, smooth or hispid, pale green or glaucous, with bitter, milky latex. Leaves arranged spirally or in a radical rosette, often deeply incised. Flowers solitary, bisexual, long pedicelled;

sepals 2–3, free, deciduous when the flower expands; petals 4–6, corrugate in bud, fugacious; stamens numerous, much shorter than corolla; ovary superior, with 4–18 parietal, much intruded placentas and many ovules, stigma sessile, peltate, rather deeply lobed, lobes as many as placentas, opposite to them, radiating. Fruit a capsule, globose, urceolate to broadly ovoid, campanulate or cylindrical-clavate, stalk-like contracted at the base, under the stigmatic shield dehiscing by transverse pores (arising by the recurving of short valves). Seeds numerous, globose to slightly reniform, reticulate. Seedling with sessile or shortly petioled, linear cotyledons, base cuneate; hypocotyl elongate, epicotyl absent.

Growth and development Most *Papaver* species are annuals or biennials, including *P. rhoeas* and *P. somniferum*. The seed of *P. somniferum* germinates in 10–15 days. The minimum temperature for germination is around 3°C. The seedling grows slowly; it takes a month to reach the rosette stage. After that, stem differentiation occurs and growth is more rapid. Reproductive buds appear at about one month from the rosette stage. About a week before flowering, the pedicel bends, but it unbends when the flower opens. Flowering occurs about 90–100 days after sowing; the petals are shed within 3 days. After fertilization, the fruit grows fast, reaching its final size within 2 weeks. In another 10–15 days, the fruits become ready for lancing and latex collection. The seeds reach maturity 2 weeks after that.

Other botanical information *Papaver* spp. have been grouped in different sections, but no consensus exists. Neither is there agreement on the relationship between *P. somniferum* and *P. setigerum* DC., which some taxonomists separate, whereas others lump them into one very variable species. Sometimes 3 subspecies are recognized: *P. somniferum* subsp. *somniferum* (opium poppy) cultivated and escaped throughout most of Europe, *P. somniferum* subsp. *songaricum* Basil. cultivated in the Balkans and Asia, and *P. somniferum* subsp. *setigerum* (DC.) Corb. (setaceous poppy) probably native in the western Mediterranean region and a weed elsewhere.

Ecology *Papaver* is found in the relatively dry temperate and subtropical parts of the Old World and does not tolerate tropical lowland conditions. In the 'Golden Triangle', opium poppy only grows well when grown above 850 m altitude, and the best opium is obtained from above 1000 m altitude. *P. somniferum* is a long-day plant. Both *P. somniferum* and *P. rhoeas* are adapted to open or disturbed habitats, and commonly found in association with cereal cropping. Regions where it may rain during the latex stage of the crop are not suitable for latex production, because exuded latex may be washed away. Windy areas should be avoided, to prevent lodging of the heavy-capsuled plants. Opium poppy can be grown on a relatively wide range of soils.

Propagation and planting Most *Papaver* species are propagated by seed. Seed is broadcast (3–4 kg/ha) and plants are thinned later to a distance of 20–25 cm when about 10 cm tall. Seedlings resent transplanting. In Tasmania, poppy is sown in rows with 100–150 plants/m^2. Some hill tribes in the 'Golden Triangle' practise staggered planting, to spread the harvest over a longer period, but others sow their fields in one go.
Seed of *P. somniferum* is very small, with a 1000-seed weight of less than 0.2 g; the colour varies from yellowish-white to purplish-black.

In vitro production of active compounds Tissue culture of both *P. somniferum* and *P. bracteatum* is possible and may serve as a future technique in commercial production of codeine.

Husbandry In northern Thailand, *P. somniferum* is usually sown in September–October after maize on recently cleared land. In India, *P. somniferum* is sown in November. *P. somniferum* has high nutrient requirements. It benefits from phosphate fertilization during early growth, whereas later on nitrogen fertilization, at 100–140 kg/ha, will help to increase opium yield and morphine content. Under Tasmanian conditions, irrigation can have a beneficial effect. The crop especially needs adequate water at the start of flowering. Because of the heavy capsules, lodging can be a serious problem at higher plant densities.

Diseases and pests In general, *P. somniferum* is not regarded as very susceptible to diseases and pests. It is reported to be susceptible to downy mildew (*Peronospora arborescens*), leaf blight (*Helminthosporum* spp.), root rot (*Rhizoctonia* sp.) and thread mould (*Dactylium roseum*). Insect pests include *Agrotis suffusa* (opium cut worm), *Agrotis epsilon*, *Aphis fabae*, *Franklinella* sp., *Heliothis armigera*, *Myzus persicae*, *Nephotettix* sp., *Pachycephus smyrnensis* and *Phytomyza horticola*.

Harvesting Latex is collected before the capsules are mature and dry. They are carefully incised; the depth of the incision is very important. It must be deep enough to reach the laticiferous ducts, but not so deep that it cuts into the endocarp, otherwise the latex flows inside the capsule.

Lancing or scarification is done in the afternoon. The exuding latex is then left to coagulate overnight, during which time it will become darker and thicker. The next morning it is collected with a special scraper and air dried. Opium collection is a labour-intensive activity. In northern Thailand, the capsules are incised when they change colour from green to slightly grey-green. The harvest period lasts from a few days up to a week after the last petals have dropped from a flower. Tapping is carried out with a special knife, consisting of several sharp blades bound together so that one stroke makes several incisions on the capsule, about 1 mm apart. The lancing and collection is repeated 3–4 times for each capsule in as many days. The capsules are then allowed to mature, and those from the most robust plants are harvested to obtain seed for the next year. The hill tribes of the 'Golden Triangle' do not use the seed for food or oil. When the crop is grown for straw extraction, the fruits are harvested after maturity with 10–30 cm of the pedicel attached. The seeds are separated and the straw is used for extraction of alkaloids. The crop can also be harvested about 3 weeks before flowering, giving 'green poppy', which is rich in alkaloids but has to be dried quickly.

When grown for seed production, the crop is harvested when the capsules turn yellow-green and the seeds inside rattle.

Yield Yield levels in northern Thailand depend on how frequently poppy has been grown on a given field. In the first year, the yield is high, but it drops the second year, and it is usually not worth planting after the third year. The yield is also influenced by the number and mode of lancing practices. The first lancing gives raw opium with a higher morphine content than subsequent lancings; thus, the raw opium obtained from different lancings is stored separately. Terminal capsules (each plant bears 5–8 capsules) yield opium of considerably higher morphine content than the lateral ones. In India, average yield of raw opium is around 30 kg/ha, but yields as high as 60 kg/ha have been reported. When poppy is grown for seed, seed yields are usually between 1.2 and 1.8 t/ha. High commercial yields are obtained in Tasmania, where average dry matter yield of poppy heads (capsules and seeds) is 2.5 t/ha. In Tasmanian field experiments, 3–4 t/ha of poppy heads have been obtained, and morphine yields of 18–30 kg/ha.

Handling after harvest In northern Thailand, the harvested opium is carefully packed in leaves before marketing. In India, the raw opium is stored in metal or earthen pots (perforated at the bottom or placed at a tilt to allow the moisture to drain off) and turned over every 10 days to give it a uniform consistency. After that, it is sun-dried and packed in sacks or jars.

Opium requires careful storage as morphine is quickly decomposed by enzyme activity on exposure to air at 15.5°C. However, storing in sealed containers at 36–37°C gave little loss. Under moist conditions, opium may become covered with mould but this does not seem to affect its morphine content. The total alkaloid content of opium may vary from 5–25%. The opium alkaloids (in particular, morphine and codeine) and their salts may be extracted from either raw opium or poppy straw, the process involving concentration of aqueous extracts to a syrupy consistency, followed by precipitation of alkaloids from concentrated extracts.

When poppies are grown for straw production, the seeds are separated from the capsules and pedicels, which are used for direct alkaloid extraction. Oil is extracted from the seeds by pressing or by solvent extraction of crushed seed.

Genetic resources and breeding Cross-pollination is common in *P. somniferum*, and a crop can contain a wide range of forms. Breeding has mainly been carried out in Europe. Until the 1970s, European breeding work was aimed at increased seed and oil yields as well as high alkaloid contents. The increasing abuse of opiates as heroin has stimulated attempts to reduce illicit traffic in opium by banning cultivation of the opium poppy, and to search for *Papaver* spp. which do not contain morphine. One of these is *P. bracteatum*, which lacks an enzyme for the demethylation of thebaine. It produces this alkaloid instead of morphine and codeine, and its content can reach up to 3.5% in the dried capsules. The amount is sufficient for economic production on a large scale; chemical demethylation of thebaine to codeine is relatively simple, demethylation of codeine to morphine, however, is not easy. For *P. somniferum*, breeding in more recent years has been aimed at creating types with a low morphine content. *P. orientale* L. and *P. bracteatum* have been crossed to develop perennial types containing thebaine but no morphine, but the resulting progenies were sterile.

Many varieties, strains and hybrids of ornamental poppy with single and double flowers and some with fringed petals have been raised.

Prospects *P. somniferum* as a medicinal crop has generally declined in importance due to its narcotic reputation and the strict regulations imposed on any such ventures. Only the production of limited quantities of drug for legitimate uses is allowed. This situation is likely to continue for the foreseeable future. Nevertheless, in South-East Asia illegal planting still exists, especially in northern Thailand, Laos and Burma (Myanmar). Opium poppy is a popular cash crop for the hill tribes in these areas. In certain areas, activities may also include illegal processing into morphine and heroin. However, there has recently been a drop in opium production in northern Thailand, mainly due to the efforts of the government to suppress opium poppy cultivation and to develop the inaccessible poppy-growing areas. Cultivation as an ornamental and for the production of edible seeds and seed oil may hold out some prospects but should be monitored closely to prevent abuse. Investigation into the potential of poppy flowers for the production of colouring agent (dye) may be worthwhile.

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Selection of species

Papaver rhoeas L.

Sp. pl. 1: 507 (1753).

Vernacular names Corn poppy, red poppy (En). Pavot, pavot rouge, coquelicot (Fr). Vietnam: h[oof]ng anh.

Distribution The origin of *P. rhoeas* is still unknown. Nowadays, it is common all over Europe, mainly along country roads and on wasteland. It is sometimes grown as an ornamental in the Malesian region.

Uses In the Malesian region, the flowers are used for their mild sedative, antitussive, anodyne and sudorific properties.

Observations An erect annual herb, 30–80 cm tall; medium and superior leaves petioled or sessile from a narrowed, non-amplexicaul base, deeply pinnatipartite-bipinnatipartite, pale green, hispid; pedicel usually with patent to erecto-patent, but sometimes appressed bristles, petals 3–5 cm long, bright or pale red to bluish, occasionally white-margined or entirely white, often with a black basal blotch, flowers sometimes double, filaments not widened at the top, stigma broader than top of fruit, stigmatic rays mostly 8–13, black-purple; fruit campanulate; seeds dark brown.

Selected sources 97, 193, 287, 376, 931, 1126.

Papaver somniferum L.

Sp. pl. 1: 508 (1753).

Synonyms *Papaver officinale* C.C. Gmelin (1806), *Papaver hortense* Hussenot (1835), *Papaver setigerum* DC. (1893).

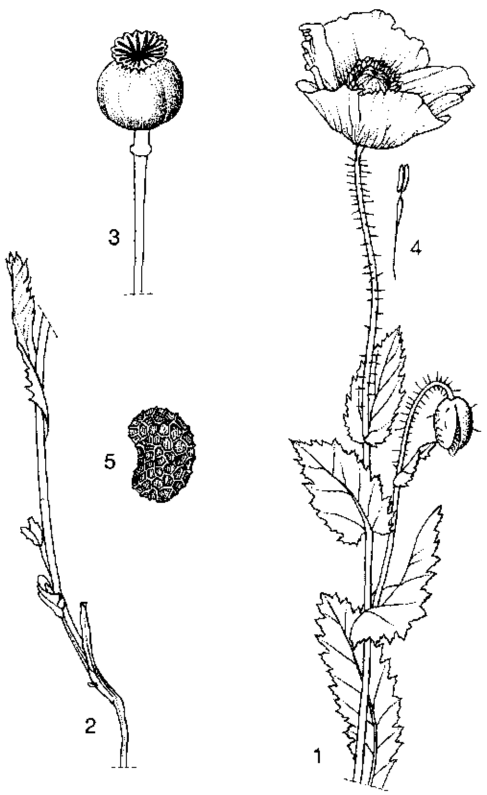
Vernacular names Opium poppy, mawseed (En). Pavot officinale (Fr). Thailand: ya pi (Akha), ya fin (Lahu). Vietnam: c[aa]y thu[oos]c phi[eej]n, c[aa]y anh t[us]c.

Distribution The origin of *P. somniferum* is not clear; suggestions range from south-western Europe to central Asia. No truly wild populations of *P. somniferum* have been found. The main areas of cultivation are in India, China, Turkey and the Balkans. In South-East Asia, it is grown in the

'Golden Triangle' (Thailand, Burma (Myanmar), Laos) and Vietnam.

Uses Opium is traditionally used for its astringent properties in the treatment of coughs and diarrhoea, and also to relieve pain and to treat insomnia.

Observations An annual erect herb, 50–150 cm tall; medium and superior leaves sessile with an amplexicaul base, varying from obovate to ovate-oblong, coarsely crenate-dentate, not deeply incised, strikingly glaucous, glabrous; pedicel glabrous or hispid, petals 3.5–8 cm long, lilac with darker base, white (with or without a dark basal blotch), red (with or without a dark basal blotch) or variously marked, entire or variably deeply incised, flowers often double, stigma much broader than top of the fruit, mostly 8–15-rayed; fruit a globose capsule, 5–10 cm wide, with copious latex; seeds blue, black, yellow or white. *P. somniferum* is an extremely variable and complex species. There is still disagreement about its intraspecific classification. It does not thrive in the per-humid tropical lowlands.



Papaver somniferum L. – 1, flowering stem; 2, stem base; 3, fruit; 4, stamen; 5, seed.

Selected sources 62, 63, 64, 97, 189, 193, 202, 265, 266, 287, 387, 555, 701, 813, 823, 900, 931, 1035, 1126, 1167, 1277, 1296, 1304, 1457.

Khozirah Shaari & M. Brink

Peperomia pellucida (L.) Kunth

Humb., Bonpl. & Kunth, Nov. gen. sp. 1: 64 (1816).

PIPERACEAE

$2n = 44$

Synonyms *Piper pellucidum* L. (1753), *Piper exiguum* Blume (1826).

Vernacular names Indonesia: ketumpangan air (Malay, Sumatra), sasaladaan (Sundanese), suruh-suruhan (Javanese). Malaysia: ketumpangan air (Malay, Peninsular). Philippines: ulasiman-bato (Tagalog), olasiman-ihalas (Cebu Bisaya), tangon-tangon (Bikol). Thailand: chaa kru-ut (peninsular), phak krasang (central), phak haak kluai (northern). Vietnam: rau c[af]ng cua.

Origin and geographic distribution *Peperomia* comprises over 1000 species. Its main centre of distribution is in Central and South America. In South-East Asia, 50–90 species occur. *P. pellucida* is native to South America but has naturalized widely in the Old World tropics. It is common in South-East Asia, occurring throughout the region.

Uses In the Philippines, the whole plant of *P. pellucida* is used as a warm poultice to treat abscesses, boils and pimples. An infusion or decoction is used against gout, kidney troubles and rheumatic pain, and externally as a rinse for complexion problems. In Peninsular Malaysia, the plant is boiled and the water drunk to relieve rheumatism and fatigue. In Java, the juice of the leaves is prescribed for colic and abdominal pains, and the bruised leaves are applied to the temples to treat headache. The plant is eaten as a salad. In West Africa, it is similarly eaten as a vegetable, and used in local medicine to treat convulsions. In Central and South America, it is widely used in local medicine in similar applications as described for the Philippines. It is recommended to eat *P. pellucida* as a culinary herb because it has an aromatic taste and stimulates appetite and digestion.

Properties *P. pellucida* contains an essential oil with apiole (a phenylpropane derivative) as the main component. Further components are the related 2,4,5-trimethoxystyrene, caryophyllene (a sesquiterpenoid), and an (unidentified) sesquiterpene alcohol. Apiole affects the kidney parenchyma; there are reports in the literature of kidney and liver damage due to apiole. The known strong diuretic activity is also probably toxic. In pure form the compound stimulates the uterus, provoking menstruation; its misuse as an abortifacient which can lead to serious intoxifications is also known.

The essential oil from the whole plant showed fungicidal activity at a minimum inhibitory concentration of 2000 ppm, with a wide range of toxicity and quick killing activity. It was thermostable, remained toxic for at least 150 days, was non-phytotoxic and non-systemic. The oil is antagonistic to the growth of *Helminthosporium oryzae* (brown spot) in rice.

An ethyl acetate extract of the air-dried plants showed antibacterial activity against *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. The antibacterial activity was more potent than the penicillin standard used. The water extract of leaves showed antimutagenic activity.

Peperomia pellucida (L.) Kunth – 1, flowering plant; 2, part of infructescence.

Several flavonoids have been isolated from the plant, including acacetin, apigenin, pellucidatin, pellucidatin-8-neohesperidoside and isovitexin.

Adulterations and substitutes Apiole, the main constituent of the essential oil, is better known from the root of parsley (*Petroselinum crispum* (Miller) Nyman ex A.W. Hill).

Description A small fleshy herb, up to 30 cm tall; stems initially erect, becoming decumbent, rooting at nodes, glabrous, internodes up to 5 cm long and 2 mm in diameter. Leaves spirally arranged, simple, ovate elliptical to broadly ovate or almost triangular, 2.5–3.5 cm × 2–3 cm, entire, membranous when dry, 5-veined, base rounded to truncate, apex acute; petiole up to 20 mm long and about 1 mm in diameter, glabrous; stipules absent. Inflorescence a terminal or axillary spike, solitary, glabrous, peduncle 0.5–1.5 cm long and about 0.5 mm in diameter, fertile axis 2–5 cm long and about 0.5 mm in diameter. Flowers bisexual, sessile, not sunken into axis, spaced 0.4–1 mm apart; floral bracts rounded, 0.3–0.4 mm × 0.2–0.3 mm; perianth absent; stamens 2, anthers oblong, about 0.1 mm × 0.1 mm; ovary superior, rounded-oblong, about 0.3 mm × 0.3 mm, 1-locular. Fruit drupe-like, subglobose, 0.5–1 mm in diameter, sticky, papillate, 1-seeded.

Growth and development *P. pellucida* is presumed to be an annual but its lifespan is unknown. The profusely produced seed is probably dispersed by rain wash and more widely by people as a contaminant in soil. Plant growth is fast under moist conditions.

Other botanical information Some botanists separate *Peperomia* from the *Piperaceae* into the *Peperomiaceae*, on the basis of the absence of stipules, the presence of two stamens and on differences in pollen morphology and anatomy.

Although there is a recent revision for Australia (and Africa), no overall revision of *Peperomia* is available for South-East Asia. It is very difficult to compare the names and species for the Philippines, New Guinea, Peninsular Malaysia and Java from the literature, and no botanical information is available for other Malesian regions. *P. tetraphylla* (J.G. Forster) Hook. & Arn. is another pantropical representative that occurs in South-East Asia. Although it is used in local medicine in South America, there are no reports of its medicinal use in South-East Asia.

Ecology *P. pellucida* is mostly found in disturbed habitats up to 1000 m altitude. It is a common and widespread weed, frequent in gardens and cultivated areas that are damp and lightly shaded, particularly common on damp hard surfaces such as walls, roofs, steep gullies, and in flower pots. Under certain growing conditions impoverished types that were previously described as separate species can develop.

Propagation and planting *P. pellucida* produces seed in abundance. It is not cultivated in South-East Asia. In West Africa, however, it is cultivated from seed and reputed for its fast growth.

Harvesting *P. pellucida* is collected fresh whenever the need arises.

Genetic resources and breeding Since *P. pellucida* is a common pantropical weed the risk of genetic erosion is minimal.

Prospects *P. pellucida* is easy to grow, even in urban settings, and is a nutrituous and savoury vegetable. Its fungicidal properties deserve further research for low-budget applications. The significant antibacterial activity of the ethyl acetate extract suggests a potential as a broad-spectrum antibiotic.

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Other selected sources 97, 202, 572, 580, 1227, 1570, 1647, 1648.

R. Kiew

Phyllanthus L.

Sp. pl. 2: 981 (1753); Gen. pl. ed. 5: 422 (1754).
EUPHORBIACEAE

x = 6, 7, 8, 9, 13, 15, most commonly 13; *P. acidus*: $2n$ = 26, *P. amarus*: $2n$ = 26, 52, *P. emblica*: $2n$ = 98, 104, *P. maderaspatensis*: $2n$ = 26, 52, *P. pulcher*: $2n$ = 78, *P. reticulatus*: $2n$ = 26, *P. simplex*: $2n$ = 26, *P. urinaria*: $2n$ = 52

Major species *Phyllanthus acidus* (L.) Skeels, *P. amarus* Schum., *P. emblica* L., *P. reticulatus* Poiret.

Vernacular names Phyllanthus, seaside laurel (En). Phyllanthe, bois à enivrer, bois de gaulettes (Fr). Vietnam: ph[ef]n den, me r[uwf]ng.

Origin and geographic distribution *Phyllanthus* comprises over 700 species and has a pantropical distribution. It is primarily an Asiatic genus, with only about 100 species being native to Africa and some 200 to the New World. Most of the New World species are found in the West Indian region. Southern Brazil appears to be another important centre of speciation. The most important centres of diversity in the Old World are located in India, Indo-China, the Philippines and New Guinea. Within Malesia about 100 species occur.

Uses The medicinal applications of *Phyllanthus* have a long history. Several *Phyllanthus* species have been used in India for about 2000 years in the Ayurveda, Unani and Siddha systems of medicine, especially for the treatment of jaundice. Although the species may vary locally, *Phyllanthus* is used in virtually the whole of South-East Asia, the Pacific, East, West and Central Africa, the Caribbean and South America. Generally *Phyllanthus* has aphrodisiac, diuretic and purgative properties, and is used in the treatment of chest complaints, conjunctivitis, cough, diabetes, diarrhoea, oedema, fevers, hepatitis, nephritis, ophthalmic diseases, smallpox and venereal diseases. Some of the medicinal *Phyllanthus* species are also used for dye and tanning purposes (e.g. *P. emblica*, *P. reticulatus*), as edible fruits (*P. acidus*, *P. emblica*), and as ornamentals (*P. pulcher*). The wood of *Phyllanthus* (*P. acidus*, *P. emblica*, *P.*

reticulatus) can be used for utensils and other small objects, and as firewood.

Crushed young leaves of *P. gomphocarpus* Hook.f. are used in Indonesia to heal wounds. The roots of *P. elegans* Wallich are used in Indo-China as a febrifuge; the leaves are given to children with a coated tongue.

Production and international trade In India, *P. amarus*, *P. debilis* and *P. fraternus* Webster are generally collected from natural stands, often on well-drained, cultivated ground in the rainy season. *P. amarus* is sometimes also cultivated in small plots and sold on local markets. Fruits of *P. emblica* are gathered from wild and garden trees and used for local consumption or sold on the market. In India, preserves made from these fruits are manufactured and marketed on a large scale.

Properties The latex of many members of the *Euphorbiaceae* is known for its toxicity; it causes inflammations of the skin and mucous membranes, conjunctivitis and sometimes even blindness. The latex of *Phyllanthus* can also cause allergic reactions. Several *Phyllanthus* species are poisonous to livestock or fish and can be allelopathic to desirable forage plants. Various groups of medicinally interesting compounds are present in *Phyllanthus*, including triterpenoids, flavonoids, tannins, alkaloids and phenolic acids. Triterpenoids have been isolated from *P. acidus* (phyllanthol, β-amyrin), *P. discoides* Muell. Arg. (betulinic acid), *P. emblica* (lupeol, lupenone), *P. reticulatus* (friedelin, β-sitosterol, betulinic acid, glochidonol, friedelan-3-β-ol, 21α-hydroxyfriedelan-3-one, 21α-hydroxyfriedel-4(23)-en-3-one) and *P. urinaria* (β-amyrin, β-sitosterol, triacontanol). Flavonoids have been found in *P. amarus* (quercetin-3-O-glucoside, rutin), *P. emblica* (quercetin, kaempferol, kaempferol-3-O-glucoside (= astragalin)) and *P. urinaria* (quercetin, kaempferol, rutin). Tannins have been isolated from *P. amarus* (mainly geraniin, amariin and gallocatechin) and *P. emblica* (e.g. phyllembin, gallotannin as 1,2,3-trigalloylglucose and the ellagitannins terchebin, corilagin, chebulagic acid and chebulinic acid). Alkaloids, mainly of the quinolizidine type, have been reported for *P. amarus* (phyllantine, securinine, norsecurinine, isobubbialine, epibubbialine) and *P. discoides* (allosecurine, phyllantidine, phyllantine). The quinolizidine alkaloid phyllantine (= methoxy-securinine) must not be confused with phyllanthin and hypophyllanthin, which are lignans isolated from e.g. *P. amarus* and *P. urinaria*. Furthermore, a range of phenolic acids has been isolated from *P. acidus*, *P. emblica*, *P. maderaspatensis*, *P. reticulatus* and *P. simplex*.

P. amarus, *P. debilis* and *P. urinaria* have all been found to inhibit DNA polymerase of the hepatitis B virus and other hepatitis-DNA-viruses, such as the woodchuck hepatitis virus (WHV). Lesser known species of the same subgenus *Phyllanthus* also showed this effect, but species from other subgenera generally show much weaker inhibitory activity. However, intraspecific differences make it difficult to compare the activity of the different species. In some other studies, *P. urinaria* extracts showed inhibitive effects on duck hepatitis B virus (DHBV) polymerase, whereas *P. amarus* and *P. maderaspatensis* extracts were found to lack antiviral activity against DHBV.

P. amarus possesses in vitro and possibly in vivo activity against hepatitis B virus (HBV) and related viruses, together with in vitro activity against the enzyme reverse-transcriptase of retroviruses and possibly in vivo activity against retroviruses. The efficacy of *P. amarus* preparations in treating hepatitis B carriers is unclear: both success and failure have been reported.

P. amarus has also shown antibacterial and antifungal activity. Whole plant extracts of *P. amarus* reduce digestive tract motility, delay gastric emptying in rats, and cause relaxation of isolated rat fundus and ileum. This confirms the use of *P. amarus* in the treatment of diarrhoea and other gastro-intestinal disorders in Nigeria. Whole plant extracts of *P. amarus* also have diuretic, hypotensive and hypoglycaemic effects in humans. An alcohol extract of *P. amarus* has been found to induce declining fertility in male mice.

P. amarus contains the lignans phyllanthin and hypophyllanthin, which have shown endothelin antagonistic effects. *P. debilis* and *P. urinaria* also contain phyllanthin. Furthermore, phyllanthin and hypophyllanthin have been reported to have protective activity in rat hepatocytes against cytotoxicity induced by carbon tetrachloride and galactosamine, and it has been suggested that phyllanthin is responsible for antigenotoxic effects reported for *P. amarus* extracts. But phyllanthin has also been reported to be toxic to the nervous system and liver.

A range of hydrolysable tannins isolated from *P. amarus* has shown inhibitory activity on signal-regulated protein kinases. Aqueous extracts of *P. debilis* leaves have shown immunomodulatory activity, whereas leaf decoctions have a high potassium content, producing diuretic effects.

The triterpenoid triacontanol isolated from *P. uri-*

naria has hepatoprotective properties, e.g. against galactosamine-induced cytotoxicity in rat hepatocytes. This may, at least partly, confirm the hepatoprotective action shown by alcohol extracts of *P. urinaria* in rats. Furthermore, hydroalcoholic extracts of *P. urinaria* have shown analgesic effects against formalin-induced and capsaicin-induced pain in mice (antinociceptive activity), and methanol extracts have demonstrated hypoglycaemic activity in diabetic rats. *P. urinaria* plant extracts exhibited some antibiotic activity against *Staphylococcus*, *Escherichia coli*, *Salmonella typhi*, *Vibrio cholerae* and *Shigella dysenteriae* bacteria.

The fruit of *P. acidus* is very acidic, and, similar to lemon or grapefruit, contains 40 mg/100 g ascorbic acid (vitamin C). The root-bark of *P. acidus* contains saponins, gallic acid and tannins.

P. emblica fruits are also highly acidic and contain much vitamin C, with reported contents ranging from 470–1810 mg/100 g. The fruits also contain trigalloylglucose, ellagic acid, corilagin, terchebin, phyllemblin, phyllemblic acid and emblicol. They have strong antibacterial, antifungal and antioxidant properties. Aqueous extracts of *P. emblica* fruit have been found to antagonize the toxic effects of Cs^{+}, Zn^{2+} and metanil yellow similarly to the equivalent amount of vitamin C, but to be more effective against the effects of ethylparathion, Pb^{2+}, Al^{3+} and Ni^{2+} than the equivalent amount of vitamin C alone. These results imply that vitamin C is an important active compound of *P. emblica* fruits, but that they contain other active compounds as well. Gallic acid and vitamin C both have antioxidant, antibacterial and chelating properties, whereas tannins protect vitamin C from oxidation. The antioxidant activity of *P. emblica* fruits may also be due to the presence of hydrolysable tannins itself, such as emblicanin A and B, punigluconin and pedunculagin.

Phyllemblin has been reported to potentiate the action of adrenaline, to have a mild depressant action on the central nervous system and to have spasmolytic properties. The administration of fruit extracts to mice reduced the cytotoxic effects of the carcinogen 3,4-benzo(a)pyrene and aqueous fruit extracts provided protection against chromosome damage in *Allium sativum* L. root tips induced by X-radiation: these effects were attributed to the antioxidation system of vitamin C, gallic acid, reducing sugars and tannins. Powdered *P. emblica* fruits have been found to enhance natural killer cell activity and antibody-dependent cellular toxicity in mice with Dalton's lymphoma ascites tumour. The fruit juice reduced cholesterol levels in humans and in rabbits fed cholesterol.

Further research has shown that methanol extracts of the fruits have a potent inhibitory activity on Human Immunodefiency Virus (HIV) reverse transcriptase, which may be exploited in the prophylaxis and intervention of AIDS. The most active compound isolated from the methanol extracts was putranjivain A, whereas 1,6-di-O-galloyl-β-D-glucose and digallic acid showed weak inhibitory activity. An alcoholic extract of *P. emblica* fruits, and quercetin isolated from the extract have shown in vivo hepatoprotective activity in rats and mice. Seeds of *P. emblica* contain about 16% oil, with linoleic acid (44%), oleic acid (28.4%), linolenic acid (8.8%), stearic acid (2.2%), palmitic acid (3.0%) and myristic acid (1.0%).

Leaves of *P. emblica* contain ellagic acid, kaempferol, kaempferol-3-glycoside and amlaic acid, stems and leaves lupeol, β-sitosterol and ellagic acid, and the bark lupeol and (+)-leucodelphinidin. Various *P. emblica* leaf extracts have shown inhibitory activity on human polymorphonuclear leukocytes and platelets, which at least partly confirms the anti-inflammatory and antipyretic properties of *P. emblica* leaves. A large part of the medicinal uses of *P. emblica* is related to the astringent action of tannins. Though short-term effects may be beneficial, the frequent systemic use of tannins might be dangerous, because of their antinutrient effects.

Finally, extracts of *P. reticulatus*, especially aqueous extracts of the leaves, have shown in vitro activity against *Plasmodium falciparum*.

Description Monoecious or dioecious herbs, shrubs or trees of various habit; branching either unspecialized (the phyllotaxy spiral or distichous) or phyllanthoid, i.e. the spiralled leaves on the main axes reduced to cataphylls which subtend a deciduous branchlet with distichous leaves, the latter resembling a compound leaf; indumentum present or absent, simple or rarely dendritic. Leaves alternate, simple, entire, shortly petiolate; stipules present, those of cataphylls larger than those of foliage leaves. Inflorescence axillary, composed of a solitary flower or of a vestigial, bisexual or unisexual cyme, these cymes occasionally aggregated into thyrses. Flowers unisexual, small, apetalous; calyx 4–6-lobed, the lobes imbricate in bud; disk nearly always present. Male flowers with 2–6(–15) stamens, filaments free or connate, anthers free or connate (and forming a 'synandrium'), extrorse; pistillode absent. Female flowers usually without staminodes; ovary superior, sessile or stipitate, 3(–12)-locular with 2 ovules in each cell, styles 3 or rarely more, free or connate at base, bifid, multifid, or dilated into an entire or lacerate stigma. Fruit usually a dehiscent capsule, less commonly baccate or drupaceous. Seeds usually triquetrous, smooth or variously ornamented, testa usually thinly crustaceous; endosperm present. Seedling with epigeal germination; cotyledons emergent, leafy, persistent; hypocotyl elongated, often first curved in a loop above the soil; all leaves alternate, sometimes the first few scale-like, in species showing phyllanthoid branching a few normal leaves are generally produced, followed by cataphylls.

Growth and development *Phyllanthus* seedlings are of the *Macaranga* seedling type and develop according to Cook's architectural model, which is determined by continuous growth of a monopodial trunk with phyllomorphic branches. Two types of shoots are produced: indeterminate and determinate. The indeterminate shoots provide annual extension growth, but do not flower and do not abscise. The determinate shoots are often short, bear flowers, and abscise.

In Java, all medicinal *Phyllanthus* species flower throughout the year, except for *P. emblica*, which flowers in August. In India, the fruits of *P. emblica* remain dormant throughout the summer and begin to develop as the monsoon starts.

The seeds of the often explosively dehiscing fruits are ejected and thus dispersed over some distance. Under experimental conditions in Florida *P. amarus* reached maximum height at 5–7 months after sowing, and senescence began after 7 months. *P. acidus* trees start producing a substantial crop after 4 years. *P. emblica* seedlings start bearing after about 8 years, whereas budded trees take about 6 years.

Other botanical information *Phyllanthus* belongs to the subfamily *Phyllanthoideae* and is related to *Breynia*, *Glochidion*, *Phyllanthodendron* and *Sauropus* which all show phyllanthoid branching. The genera *Cicca* and *Emblica* are incorporated in *Phyllanthus*, although occasionally still treated as being distinct. *Phyllanthus* has been subdivided into 10 subgenera which are sometimes further divided into a number of sections.

The species *P. simplex* and *P. virgatus* P. Forst. are sometimes regarded as a single species, *P. virgatus* sensu lato, but the mainland populations (*P. simplex*) appear separable from those in the Pacific (*P. virgatus* sensu stricto) although there are records of intermediate specimens. Another taxonomic problem concerns *P. niruri* L. Asiatic specimens formerly assigned to this species actually belong to either *P. amarus*, *P. debilis* or *P. fraternus* Webster, whereas true *P. niruri* is restricted to the West Indies. Much of the research performed with '*P. niruri*' in Asia, mainly in India, thus needs botanical correction.

Ecology *P. amarus* (often reported as *P. niruri*) is a troublesome weed in pulses, soya bean, groundnut, cereals, sugar cane, cassava, taro, sesame, sunflower, and cotton. Less important weeds are *P. debilis*, *P. maderaspatensis*, *P. simplex* and *P. urinaria*, outside South-East Asia also *P. fraternus*. The species belonging to the subgenera *Phyllanthus* (e.g. *P. amarus*, *P. debilis*, *P. emblica*, *P.urinaria*) and *Isocladus* (e.g. *P. maderaspatensis*) show a marked preference for calcareous sites in humid tropical areas. In China, warm, well-drained sandy soils and fertilization with N and K are recommended for cultivated *P. urinaria*. *P. urinaria* is more drought-sensitive than *P. amarus* and *P. debilis* and is generally found in wetter sites. *P. amarus* grown in greenhouses at a temperature of 15°C showed much less inhibitory activity on the DNA polymerase of woodchuck hepatitis virus (WHV) than when grown at 25°C. *P. emblica* is a short-day plant, requiring photoperiods of 12–13.5 hours for flowering. It can be grown in both light and heavy soils, but it prefers well-drained, fertile loamy soils. Seeds of the herbaceous *P. debilis*, *P. simplex* and *P. urinaria* are dispersed by water and animals.

Propagation and planting Seed of *P. amarus* and *P. urinaria* requires light to germinate. *P. urinaria* seed showed adequate germination at temperatures of 25–35°C, but germination was poor at 20°C or 40°C. Germination of *P. urinaria* seed is poor under moisture stress conditions too (osmotic potential higher than 300 kPa). A 1000-seed weight of 150 mg has been reported for *P. amarus* seed harvested in Puerto Rico. There is some speculation that seed production in *P. amarus* may be parthenocarpic. *P. acidus* is generally grown from seed, but vegetative propagation such as budding, greenwood cuttings or air layering can also be used, whereas *P. emblica* may also be propagated through seed and vegetative methods (budding, grafting, cutting, root sprouting). Inarching is also possible, but gives only limited success. *P. emblica* has been successfully propagated in vitro. In India, *P. emblica* is often grown at spacings of 9–12 m × 9–12 m, *P. acidus* in Indonesia at 8 m × 8 m.

In vitro production of active compounds Callus can be induced from stem or phyllanthoid branch pieces of *P. amarus* and *P. urinaria*, but callus extracts showed less activity against viral DNA polymerase and reverse transcriptase than extracts from field-grown plants. Phyllemblin present in extracts of in vitro *P. emblica* tissue cultures showed antimicrobial activity against bacteria (*Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhosa*) and a fungus (*Candida albicans*).

Husbandry Most material used for medicinal purposes is collected from the wild. Though *P. amarus* is also cultivated in India, there is no information on any specific cultivation measures. Soil fertility and soil moisture experiments in the United States affected morphology and yield of *P. debilis* and *P. urinaria*, with plants being shorter, more branched and with a higher dry weight under favourable conditions. Differences in soil fertility and soil moisture generally did not affect these species' in vitro inhibitory activity on WHV viral DNA polymerase. In *P. amarus*, maximum dry weight is obtained in wet neutral soils, but differences in soil moisture, pH and Ca content did not affect the inhibitory activity of plant extracts. These findings imply that plant yields can be maximized through cultivation measures, without affecting the antiviral activity of plant material.
Where *P. urinaria* is not desired, it may be controlled by mulching. Young plantations of *P. emblica* need regular weeding. Established *P. emblica* trees do not need frequent irrigation, which makes them well suited for drier regions. However, the crop benefits from 2–3 irrigations at full bloom stage and fruit set. Irrigation is not beneficial during fruit dormancy. *P. emblica* does not need regular pruning, but pruning in the early years promotes the development of a proper shape and a strong frame.

Diseases and pests In India, *P. simplex* is infected by mildew (*Erysiphe cichoracearum*), which appears as small, circular, whitish powdery spots on leaves, petioles and stems.
Caterpillars of *Parallelia absentimacula* and *P. joviana* feed on *Phyllanthus acidus* in Indonesia. The main pest of *P. emblica* in India is the bark-eating caterpillar *Indarbela* sp., which tunnels into the trunk and branches. *P. urinaria* weed in Indian rice fields is infested with the rice root-knot nematode (*Meloidogyne graminicola*).

Yield Since most *Phyllanthus* products are collected from the wild, yield data are scarce. Under experimental conditions in Florida, 6–7 months old *P. amarus* reached an average dry weight of about 40 g/plant when harvested in July or August. Annual fruit yields of *P. emblica* vary considerably, depending on cultivar, plant age and management: from 15 kg per tree for wild trees to 25–200 kg per tree for some cultivars.

Handling after harvest Sun-drying of *P. emblica* fruits leads to loss of vitamin C, but this is not the case when fruits are vacuum-dried. Once dried, the vitamin C is very stable, even when stored for prolonged periods; this has been attributed to tannins and polyphenols retarding oxidation. Vitamin-rich syrups and concentrates have been prepared from *P. emblica* fruits in India.

Genetic resources and breeding There is rich genetic diversity in cultivated and wild relatives of *P. emblica* in India, but genetic erosion is severe because of deforestation and the use of only a few popular cultivars. Germplasm survey, collection and evaluation work has been done and accessions are maintained at Narendra Dava University of Agriculture and Technology in Faizabad (India). Other accessions are reported to be kept in Havana (Cuba), Uttar Pradesh (India), Udaipur (India), Bangkok (Thailand) and Miami (United States). No breeding has been done on other *Phyllanthus*, except for *P. emblica*.

Prospects *Phyllanthus* seems under-exploited. A considerable number of its species have been used against jaundice for a long time. More research is needed to ascertain its activity against the hepatitis virus and other viruses and to obtain the necessary information on possible side-effects. *Phyllanthus* has potential beneficial therapeutic action in the management of hepatitis B, nephrolithiasis and in painful disorders (as antinociceptive agent). However, well-controlled, double-blind clinical trials are lacking. The possible anti-AIDS activity deserves further research. Some *Phyllanthus* also produce edible fruits, others can be used for tanning and dyeing. The fruits of *P. emblica* are somewhat under-valued. Not only are they highly nutritious and contain much vitamin C, but they also have many medicinal properties. The ease of long-distance transportation and the stability of the vitamin C make *P. emblica* interesting for commercial exploitation.

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Selection of species

Phyllanthus acidus (L.) Skeels

U.S. Dept. Agric. Bur. Pl. Industry Bull. 148: 17 (1909).

Synonyms *Phyllanthus acidissimus* (Blanco) Muell. Arg. (1863), *Phyllanthus distichus* (L.) Muell. Arg. (1866), *Cicca acida* (L.) Merr. (1917).

Vernacular names Otaheite gooseberry, Malay gooseberry, country gooseberry (En). Cerisier de Tahiti (Fr). Indonesia: ceremai, cerme (general), caramele (southern Sulawesi). Malaysia: chermai, chermala, kemangur. Philippines: iba (Tagalog), bangkiling (Bisaya, Tagalog), karmay (Ilokano). Burma (Myanmar): thinbozihpyoo. Cambodia: kântûët, kântouot srôk. Laos: nhôm baanz, mak nhom, nhom ban[2]. Thailand: ma yom (general). Vietnam: ch[uf]m ru[ooj]t, t[aaf]m ru[ooj]t.

Distribution *P. acidus* is probably native to the coastal region of north-eastern Brazil, but since time immemorial it has been cultivated, mainly as a fruit tree, in tropical Asia from India to Malesia and Polynesia, and on all larger islands of the West Indies. Within Malesia it has not yet been reported from New Guinea.

Uses The latex is credited with emetic and purgative activity. In Indonesia, the bark is heated with coconut oil and spread on eruptions on feet and hands. In Java, an infusion of the root is taken to alleviate asthma. In Borneo, roots are used in the treatment of psoriasis of the feet. Although the roots are weakly poisonous, in Malaysia they used to be boiled and the vapour inhaled to relieve cough and headache. In the Philippines, leaf decoctions are applied to urticaria, and a decoction of the bark is used to treat bronchial catarrh. In Burma (Myanmar), the fruit is used as a laxative. In India, the fruits are taken as a liver tonic to enrich the blood. The juice of the root bark is reported to have been employed in criminal poisonings. The fruit flesh is added to many dishes in Indonesia as a flavouring. In the Philippines, the fruit juice is used to make cold drinks and the fruit to make vinegar. In Malaysia, ripe and unripe fruits are served as a relish, syrup or sweet preserve. The fruits are also combined with other fruits in making chutney or jam, because of their setting properties. Young leaves are cooked as a vegetable in Indonesia, Thailand and India. The wood is fairly hard, strong, tough and durable if seasoned. The bark has limited use in India as a tanning agent.

Observations A monoecious, small, glabrous tree up to 10 m tall with phyllanthoid branching, bark rough, grey, with prominent lenticels; cataphylls not persistent, blackish-brown, their stipules triangular-ovate; deciduous branchlets ascending, (20–)25–52 cm long, with 25–40 leaves; leaves broadly ovate to ovate-lanceolate, (4–)5–9 cm × (2–)2.5–4.5 cm, base obtuse to rounded, apex acute, petiole 2.5–4 mm long, stipules triangular-acuminate; flowers in dense, cushion-shaped cymules at the nodes of leafless branchlets on older wood, and usually also on proximal branchlets of current year's growth, pale green to reddish; male flowers 4-merous, filaments and anthers free, dehiscing vertically; female flowers on a stout pedicel, 4-merous, disk deeply lobed or split, styles connate, deeply bifid, staminodes present; fruit drupaceous, oblate, 1–1.5 cm × (1.2–)1.5–2(–2.5) cm when fresh, shallowly 6- or 8-lobed, greenish-yellow to creamy-white; seeds smooth. In north-eastern Brazil *P. acidus* has been found in coastal forest. In South-East Asia it is cultivated on humid sites, up to 1000 m altitude.

Selected sources 97, 190, 202, 287, 580, 641, 697, 900, 980, 1035, 1126, 1128, 1178, 1211, 1212, 1476, 1521, 1555.

Phyllanthus amarus Schum.

Kongel. Danske Vidensk. Selslk. Skr., Naturvidensk. Math. Afh. 4: 195 (1829).

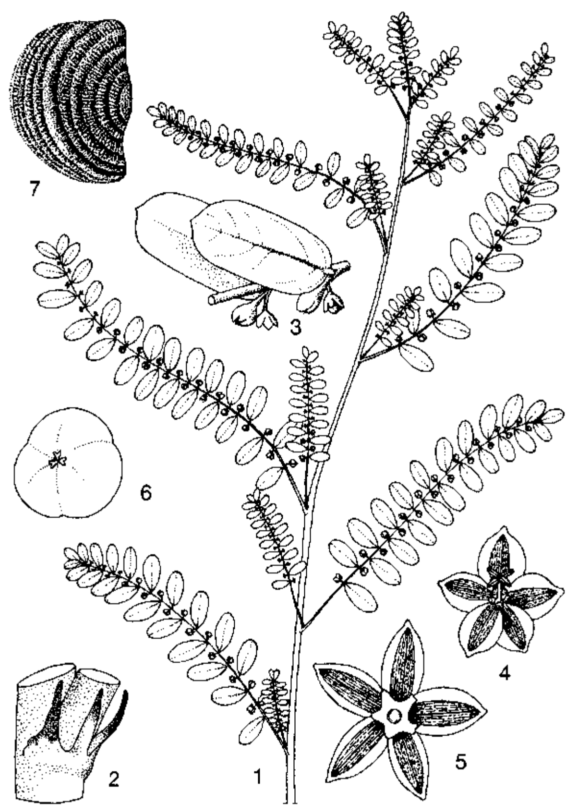
Synonyms *Phyllanthus swarzii* Kostel. (1836), *Phyllanthus nanus* Hook.f. (1887), *Phyllanthus niruri* auct. non L.

Vernacular names Herbe au chagrin (Fr). Indonesia: memeniran (Sundanese), meniran (Javanese), gosau ma dungi (Ternate). Malaysia: dukong anak, dukong-dukong anak, rami buah (Peninsular). Papua New Guinea: manjinimbi (Kanganaman, Sepik). Philippines: kurukalunggai (Bikol), sampasampalukan (Tagalog), san pedro (Bisaya). Cambodia: préâk phlè (Battambang). Thailand: luuk tai bai (central), ma khaam pom din (northern), yaa tai bai (general). Vietnam: c[aa]y ch[os] d[er], di[eej]p h[aj] ch[aa]u.

Distribution *P. amarus* is native to the Americas, but now a pantropical weed. It is found throughout Malesia, though not yet reported from Sulawesi.

Uses From Hainan to Indonesia a decoction or tea is drunk as a diuretic to treat kidney and liver trouble, colic and venereal diseases. It is credited with expectorant (children's coughs), febrifuge, emmenagogue and antidiarrhetic properties. The pounded plants are applied externally on contusions and skin complaints. A decoction of the whole plant is used as a stomach tonic. In Papua New Guinea, a cooled tisane of the whole plant is used to treat headache or migraine. In India, leaves and fruits of *P. amarus* are ground into a paste with buttermilk, garlic and peppers, and given orally for seven days to treat jaundice. According to Ayurvedic medicine *P. amarus* has astringent, deobstruent and antiseptic properties, and is furthermore used to treat dyspepsia, dysentery, dropsy, diseases of the urogenital system, gonorrhoea and diabetes. In the form of a poultice with rice water, *P. amarus* is used on oedematous swellings and ulcers. South-American uses include the treatment of malaria, kidney and bladder stones and urinary disorders in general, whereas the plant is also reported to induce abortion. Traditional healers in Tanga (north-eastern Tanzania) use an aqueous extract of aerial parts of *P. amarus* for the management of diabetes mellitus that is not insulin-dependent. In Nigeria, an aqueous extract of dried plant material is used against diarrhoea. Leaves are chewed against persistent coughs and used to soothe stomach-ache. In the West Indies, *P. amarus* is applied to treat childhood intestinal worms and on the Cook Islands (Rarotonga) to treat earache.

Observations A monoecious, annual, erect, glabrous herb up to 60 cm tall with phyllanthoid branching; cataphylls subulate, with triangular stipules often turning black; deciduous branchlets 4–12 cm long, with about 15–30 leaves; leaves subsessile, elliptical-oblong, 5–11 mm × 3–6 mm, obtuse to rounded at base, obtuse or rounded and often apiculate at apex, stipules ovate-lanceolate to lanceolate; proximal (1–)2 axils of deciduous branchlets with cymules of (1–)2 male flowers, all



Phyllanthus amarus Schum. – 1, plant habit; 2, cataphyll and stipules; 3, leaves and inflorescences; 4, male flower; 5, female flower; 6, fruit; 7, seed.

succeeding axils consisting of 1 male and 1 female flower; flowers pale green, often flushed with red, with 5(–6) calyx lobes with scarious margins; male flowers with 5 disk segments, stamens (2–)3, filaments completely connate, anthers free, dehiscing obliquely to horizontally; female flowers shortly pedicellate, disk deeply 5-lobed to laciniate, styles free, very shallowly bifid; fruit an oblate capsule, 1.8–2.5 mm in diameter, obtusely trigonous, smooth; seeds longitudinally ribbed on the back. *P. amarus* is the commonest species of the genus and occurs as a weed of open ground, waste places, grassy scrub and dry deciduous forest, usually on humid, sandy soils, up to 1000 m altitude.

Selected sources 97, 192, 202, 225, 580, 597, 838, 949, 982, 1035, 1126, 1128, 1135, 1178, 1193, 1380, 1555, 1556.

Phyllanthus debilis Klein ex Willd.

Sp. pl. 4: 582 (1805).

Synonyms *Phyllanthus niruri* L. var. *debilis* (Klein ex Willd.) Muell. Arg. (1863), *Phyllanthus niruri* L. var. *javanicus* Muell. Arg. (1863), *Phyllanthus niruri* auct. non L.

Vernacular names Lagoon spurge (En). Indonesia: meniran (Javanese), memeniran (Sundanese). Vietnam: di[eej]p h[aj] ch[aa]u y[ees]u.

Distribution *P. debilis* is probably native to southern India and Sri Lanka; introduced into Vietnam, Thailand, Peninsular Malaysia, Singapore, Indonesia (throughout), Papua New Guinea, the Pacific Islands, and the West Indies.

Uses The uses of *P. debilis* are similar to those of *P. amarus*, with which it may have often been confused.

Observations A monoecious, annual, erect, glabrous herb up to 100 cm tall with phyllanthoid branching; cataphylls narrowly lanceolate with triangular-lanceolate to triangular stipules; deciduous branchlets 4–10(–12) cm long, with 15–35 leaves; leaves subsessile, narrowly elliptical to narrowly elliptical-ovate, (5–)8–20 mm × 2.5–5 mm, cuneate at base, acute at apex, stipules lanceolate, acuminate; proximal 1–4 axils of deciduous branchlets with cymules of 2–4 male flowers, distal axils with solitary female flowers, sometimes accompanied by a few male ones; male flowers with 6 calyx lobes, disk with 6 segments, stamens 3, filaments completely connate, anthers free or partially connate, dehiscing horizontally; female flowers pedicellate, with 6 calyx lobes with wide scarious margin, disk entire to shallowly 6-lobed, styles free, appressed to the ovary, bifid to about the middle; fruit an oblate capsule about 2–2.5 mm in diameter, smooth; seeds radially and tangentially with longitudinal ribs and fine striae on the back. *P. debilis* is locally an abundant weed of ruderal places, gardens, grassland and upland rice fields, preferring fertile soils, up to 2000 m altitude.

Selected sources 33, 102, 192, 1135, 1386, 1555, 1556.

Phyllanthus emblica L.

Sp. pl. 2: 982 (1753).

Synonyms *Emblica grandis* Gaertner (1790), *Emblica officinalis* Gaertner (1790), *Emblica arborea* Raf. (1838).

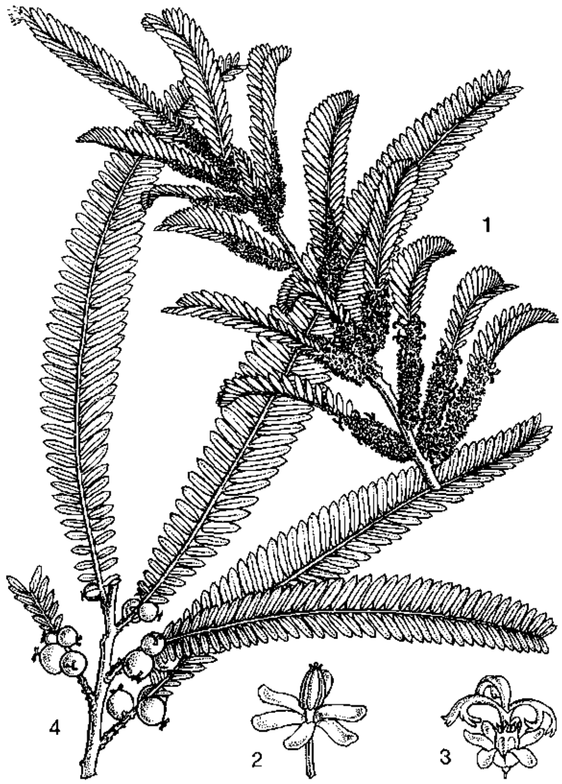
Vernacular names Aonla, emblic myrobalan, Indian gooseberry (En). Emblique officinale, groseillier de Ceylan, myrobalan emblic (Fr). Indonesia: malaka (general), kemloko (Javanese), ki malaka (Sundanese). Malaysia: laka, melaka (Peninsular). Philippines: nelli. Burma (Myanmar): ta-sha-pen. Cambodia: karn lam, kam lam ko, kântûët préi. Laos: khaam poomz, mak kham pom. Thailand: ma-khaam pom (general), kan-tot (south-eastern), kam thuat (south-western). Vietnam: me r[uwf]ng, chu me (northern), b[oo]ng ng[os]t (southern).

Distribution *P. emblica* is native to tropical South-East Asia, from India, Nepal and Pakistan to Burma (Myanmar), Indo-China, southern China, Thailand, Peninsular Malaysia, Sumatra, Borneo, Java, the Lesser Sunda Islands and the Moluccas. It is widely cultivated for its fruits throughout its natural area of distribution, in India since time immemorial, and also in the West Indies, Japan, the Mascarene Islands and Sri Lanka, where it is doubtfully native. For several centuries only its fruits were known; they were used medicinally. In 1901 seeds of *P. emblica* were distributed to early settlers in Florida and to public gardens and experimental stations in e.g. the West Indies, Hawaii and the Philippines. In 1982 seeds were sent to Australia.

Uses All plant parts are applied medicinally. A decoction of the dried fruits is used in Indonesia to treat bloody diarrhoea. Fruit pulp is smeared on the head to dispel headache and dizziness, caused by excessive heat and fever. In Burma (Myanmar) and Thailand, the fruit juice is used as a laxative and for the treatment of inflamed eyes. In Indo-China, fruits are used to treat diarrhoea, and fruit juice is administered to treat colic and other abdominal disorders. In India, the fruit is valued as an antiscorbutic, refrigerant, diuretic, laxative and antibiotic, and considered useful in the treatment of haemorrhages, diarrhoea, dysentery, anaemia, jaundice, dyspepsia, diabetes, fever, bronchitis and cough. It is used as an ingredient for several medicines of the indigenous Ayurvedic system. Leaf decoctions are used in Malaysia as a febrifuge, and in Thailand for skin diseases. Seeds are applied in India against asthma, bronchitis, and biliousness, whereas flowers are credited with refrigerant and aperient properties. The bark is used in India for the treatment of diarrhoea or as a stomachium for elephants. The root bark is used in Burma (Myanmar) as an astringent and in India, mixed with honey, to treat inflammation in the mouth. In Malaysia, Thailand and to a greater extent India the fruits are a delicacy, eaten raw or preserved. The Akha in northern Thailand use the fruit as a masticatory and to blacken the teeth. Dried fruits are sometimes used as a shampoo. Fruits, leaves and bark are used for tanning and dyeing. Leaves and fruits are used for animal fodder, whereas leaves can also be applied as green manure. Although the wood may warp and split, it is used for the construction of furniture and implements; it is very durable when submerged. Finally, the wood is suitable as firewood and produces charcoal of good quality.

Observations A monoecious, small to medium-sized tree up to 15(–25) m tall with phyllanthoid branching, bole often crooked and gnarled, up to 35 cm in diameter, bark thin, grey, smooth, flaking; cataphylls inconspicuous, scarious, their stipules triangular-ovate; deciduous branchlets (5–)10–25(-30) cm long, with (15–)30–100(–150) leaves; leaves subsessile, narrowly oblong, 12–20 mm × 2–5 mm, slightly oblique and subcordate at base, margin and tip almost inflexed, stipules triangular; proximal axils of deciduous branchlets with reduced leaves and cymules of male flowers followed by cymules of 1–2 female flowers surrounded by several male ones, distal part sterile or rarely reduced; flowers pale green, with 6 calyx-lobes; male flowers with 6 disk segments, stamens 3, filaments entirely connate, anthers free, minutely apiculate, dehiscing vertically; female flowers subsessile, with cup-shaped, 6-ribbed disk enclosing the ovary, styles shortly connate, mostly twice bifid; fruit drupaceous, tardily dehiscent, depressed globose, in wild plants 13–25 mm × 23–30 mm, in cultivated ones up to 42 mm in diameter, pale green becoming yellowish-white, smooth; seeds smooth. *P. emblica* is most common in dry, semi-deciduous forest, at elevations up to 1800 m.

Selected sources 64, 97, 105, 190, 202, 264, 284, 287, 580, 842, 900, 980, 1126, 1128, 1135, 1211, 1212, 1257, 1380, 1476, 1555.



Phyllanthus emblica L. – 1, flowering twig; 2, male flower; 3, female flower; 4, fruiting twig.

Phyllanthus maderaspatensis L.

Sp. pl. 2: 982 (1753).

Synonyms *Phyllanthus venosus* A. Rich. (1851), *Phyllanthus vaccinioides* Klotzsch (1861), *Phyllanthus gueinzii* Muell. Arg. (1863).

Distribution Tropical Africa to India and Sri Lanka, East Java and Australia.

Uses In India, a leaf infusion is used to treat headache, and seeds are credited with laxative, carminative and diuretic properties. Powder from dried plant material mixed with cow milk is given orally for eight days to treat jaundice.

Observations A monoecious, annual or perennial, erect to spreading, unbranched to much branched, glabrous herb up to 90(–120) cm tall with unspecialized branching; leaves arranged spirally, linear to oblanceolate, (5–)10–30(–60) mm × (1–)2–7(–17) mm, cuneate to broadly cuneate at base, acute to rounded at apex, on a petiole about 1 mm long, with ovate-lanceolate stipules; proximal axils of branches with solitary female flowers, distal ones with 1–4 male flowers and a single female one; male flowers with 6 calyx lobes, yellowish-green or whitish, disk segments 6, stamens 3, filaments partly united, anthers free, vertically dehiscing; female flowers pedicellate, with 6 calyx lobes, dark green, sometimes flushed with red or pink, margins white, disk with 6 free segments, styles free, shortly bifid; fruit an oblate capsule, about 3 mm in diameter, smooth; seeds with longitudinal rows of tubercles on the back. *P. maderaspatensis* is found in deciduous woodland, wooded savanna, beaches, dunes, also along streams and ponds, in cultivated and disturbed places, on a wide variety of soils, up to 1850 m altitude.

Selected sources 92, 97, 287, 1135, 1187, 1193.

Phyllanthus oxyphyllus Miq.

Fl. Ind. Bat., Suppl.: 179, 448 (1860).

Synonyms *Phyllanthus frondosus* Wallich ex Muell. Arg. (1863), *Phyllanthus hasskarlianus* Muell. Arg. (1863), *Phyllanthus kunstleri* Hook.f. (1887).

Vernacular names Piggyback tree (En). Malaysia: asin-asin, cherek hantu, meroyan puteri (Peninsular). Thailand: yaai chuung laan, yaai theep laan, yom hin (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and Sumatra.

Uses In Peninsular Malaysia, a decoction of the leaves may be applied to cure fever, and is given after childbirth as a protective medicine. It is also a diuretic and diaphoretic in treating gonorrhoea.

Observations An evergreen, glabrous shrub or small tree up to 3 m tall with phyllanthoid branching, bole crooked; deciduous branchlets 15–42 cm long; leaves subsessile, oblong to oblong-lanceolate, 2–7 cm × 1–2 cm, cuneate to slightly cordate at base, apex long tapering, stipules minute, narrowly triangular; cymules borne directly in the leaf axils; male flowers in contracted cymules, calyx lobes 5–6, stamens 3, filaments almost connate, anthers apiculate; female flowers subsessile, solitary or accompanied by male ones, calyx lobes 5–6, styles free or connate below, bifid; fruit a subglobose capsule, 3-lobed, about 7 mm in diameter, red. *P. oxyphyllus* is found in evergreen, primary or secondary rain forest, in lowland and mountains up to 1200 m altitude, sometimes on rocky places, rarely on limestone.

Selected sources 32, 34, 202, 284, 1126, 1227, 1564.

Phyllanthus pulcher Wallich ex Muell. Arg.

Linnaea 32: 49 (1863).

Synonyms *Diasperus pulcher* (Wallich ex Muell. Arg.) Kuntze (1891).

Vernacular names Malaysia: kelurut tanjong, naga buana, semelit patong. Thailand: kaang plaa (peninsular), trueng baa daan (south-western), waan thoraanee saan (Bangkok). Vietnam: me l[as] l[eej]ch.

Distribution *P. pulcher* is found from Burma (Myanmar) and Indo-China towards Thailand, Peninsular Malaysia, Sumatra, Borneo, Java and the Lesser Sunda Islands; cultivated in Sri Lanka, Tanzania and the West Indies; occasionally escaping.

Uses In Peninsular Malaysia, a decoction is drunk to relieve stomach-ache, or is used as an eyewash. Poultices are applied to the skin to treat boils, gumboils, swellings and itch, to the nose to treat ulceration, and to the abdomen to treat fever or, in children, kidney trouble. Leaves may be applied to the gums to treat toothache. *P. pulcher* is also cultivated for ornamental purposes.

Observations A monoecious, small shrub up to 1.5 m tall with phyllanthoid branching, younger branches with dendritic hairs; cataphylls persistent, with triangular-lanceolate stipules; deciduous branchlets 10–15(–18) cm long, with about 15–30 leaves; leaves oblong to elliptical or elliptical-ovate, 18–28 mm × 8–14 mm, strongly asymmetrical at base, apex abruptly pointed, very shortly petiolate, stipules persistent, triangular-lanceolate; proximal axils of deciduous branchlets with cymules of male flowers, distal ones with solitary female ones; male flowers with 4 calyx lobes, pale green with a dark red base and pale, fimbriate margin, disk segments 4, subpetaloid, stamens 2, filaments connate into a very short column, anthers fused, dehiscing horizontally, rudimentary pistil present; female flowers with 6 calyx lobes similar to those of the male flower but larger, disk cup-shaped and enclosing the base of the ovary, styles free, bifid nearly to the base; fruit a subglobose capsule, smooth, about 3 mm in diameter, pale brown, often not developed. *P. pulcher* may be locally common and is found as an invasive plant in old forest clearings, or as a weed in fruit gardens and along rivers, but also scattered in evergreen forest, up to 700 m altitude.

Selected sources 32, 97, 202, 1126, 1135, 1187, 1380, 1555, 1564.

Phyllanthus reticulatus Poiret

Lamk, Encycl. 5: 298 (1804).

Synonyms *Phyllanthus microcarpus* (Benth.) Muell. Arg. (1863), *Phyllanthus dalbergioides* Wallich ex J.J. Smith (1910), *Phyllanthus erythrocarpus* Ridley (1923).

Vernacular names Indonesia: congcong belut, trembilu (Javanese), wawulutan (Sundanese). Malaysia: kayu darah belut, tampal besi.
Philippines: malatinta (Tagalog), matang-buiud (Bikol), sungot-olang (Bisaya). Cambodia: prâ-péénh chhmôôl. Laos: am ai^2, kang^2 pa. Thailand: kaang plaa khruea (general), mat kham (northern), am aai (eastern). Vietnam: ph[ef]n den, c[aa]y n[oox].

Distribution *P. reticulatus* is widespread in the Old World tropics, from tropical Africa to Pakistan, India, Sri Lanka, Burma (Myanmar), Indo-China, southern China, Thailand and throughout the Malesian region towards northern Australia (Queensland); it has been introduced into the West Indies.

Uses In Peninsular Malaysia, stems and leaves of what is probably *P. reticulatus* are rubbed onto the chest to alleviate asthma, whereas a decoction of leaves is used to treat a sore throat. In the Philippines, a decoction of the leaves or bark is used for its diuretic, alterative, depurative, refrigerant and odontalgic properties, and the leaves can be applied to the abdomen as a remedy for pinworms. An infusion of the bark is a cure for dysentery and an infusion of the roots for asthma. In Indo-China, *P. reticulatus* is used to treat smallpox and syphilis. In southern Africa, dried and powdered leaves are dusted over wounds to aid the healing process. Ink is prepared from the ripe fruits in the Philippines, whereas in Indonesia a decoction of stems and leaves used to be used to dye cotton black. It is also used as a mordant. In India, the root is reported to produce a red dye. The wood is sometimes used to make utensils.

Observations A monoecious, glabrous to pubescent, bushy shrub or small tree up to 5(–18) m tall with disagreeable scent, with phyllanthoid branching, bark rough, brown or grey, cataphylls lanceolate, with triangular stipules; deciduous branchlets steeply ascending, (8.5–)10–20(–25) cm long, with (10–)13–20(–25) leaves; leaves elliptical to elliptical-ovate or elliptical-obovate, 10–50 mm × 5–27 mm, cuneate to rounded at base, apex obtuse to emarginate, shortly petiolate, stipules lanceolate; cymules usually axillary or sometimes on leafless shoots and resembling a raceme, usually bisexual and composed of 1(–2) female flowers and up to 8 male ones; flowers with 5–6 calyx lobes and 5(–6) disk segments; male flowers with 5–6 stamens, in two sets, one with longer filaments fused into a central column and one with shorter, free filaments, anthers free, dehiscing longitudinally; female flowers on a slender pedicel, styles bifid, free but connivent over the top of the ovary; fruit a berry, globose or oblate, 4–6 mm in diameter, smooth, blueish-black when ripe; seeds nearly smooth. *P. reticulatus* is a variable and weedy species of secondary vegetation, mixed evergreen forest, scrub and hedges, frequently along watercourses, up to 1000 m altitude, in India up to 2000 m.

Selected sources 97, 190, 202, 580, 842, 1035, 1126, 1128, 1135, 1178, 1187, 1380, 1476, 1525, 1555, 1564.

Phyllanthus simplex Retz.

Observ. bot. 5: 29 (1788).

Vernacular names Indonesia: sahakepo (Minahassa, Sulawesi). Philippines: kaya-an, kayutbulang (Bagobo). Laos: ket 'hoy, 'khi^2 doy^2. Thailand: khaang amphai (northern), luuk tai bai (central), phaeng kham hoi (eastern). Vietnam: v[aar]y [oos]c.

Distribution *P. simplex* is found from India and Sri Lanka to Indo-China, southern China, Thailand, and throughout the Malesian region.

Uses In the Philippines, leaf juice is used as an eyewash for inflamed eyes. In India, *P. simplex* is credited with antiseptic properties. Leaves are crushed and mixed with buttermilk to make a lotion against itching, and root preparations are externally applied to mammary abscesses.

Observations A monoecious, annual or perennial, erect to prostrate, glabrous herb up to 50 cm tall with unspecialized branching, branchlets compressed, narrowly wing-angled; leaves distichous on the main stem, narrowly to broadly oblong-lanceolate, 5–32 mm × 2–9 mm, obtuse to rounded at base, apex obtuse, margin often purplish, subsessile, stipules broadly ovate; male flowers in axillary glomerules of 2–4, with (5–)6 calyx lobes, disk segments 6, stamens 3, free, anthers dehiscing horizontally; female flowers solitary in leaf axils, long-pedicellate, with 6 calyx lobes, disk shallowly cupular, entire to subentire, styles free, bifid down to the base; fruit a depressed globose capsule, 2.5–3.5 mm in diameter, papillate-verruculose; seeds verruculose. *P. simplex* is a weed of roadsides, grassy places, arable land and upland rice fields, up to 750 m altitude.

Selected sources 97, 287, 580, 1126, 1128, 1135, 1178, 1188, 1380, 1386, 1525, 1556.

Phyllanthus urinaria L.

Sp. pl. 2: 982 (1753).

Synonyms *Phyllanthus lepidocarpus* Siebold & Zucc. (1843), *Phyllanthus leprocarpus* Wight (1852), *Phyllanthus verrucosus* Elmer (1915).

Vernacular names Leaf flower (Am). Kikilé, petit tamarind rouge, urinaire de Malabar (Fr). Indonesia: memeniran (Sundanese), meniran (Javanese), gosau ma dungi roriha (Ternate). Malaysia: amin buah, dukong anak, keman jolok (Peninsular). Philippines: laiolaioan (Bikol), ibaiba-an (Tagalog), takumtakum (Bisaya). Cambodia: prak phlè. Laos: khao ham, khao ham 'sano khok. Thailand: ma khaam pom din (northern), maak khai lang (north-eastern), yaa tai bai (central, peninsular). Vietnam: ch[os] d[er] r[aw]ng c[uw]a, di[eej]p h[aj] ch[aa]u.

Distribution *P. urinaria* is native to the Asian tropics, but was introduced into America and Africa and is nowadays an almost pantropical weed; throughout the Malesian region.

Uses *P. urinaria* has the same uses as *P. amarus* in South-East Asia, but *P. amarus* is generally preferred. In Malaysia, the juice is also used to clean a child's tongue and to stimulate a child's appetite. In Papua New Guinea, a decoction is used as a febrifuge. In Brunei, a leaf poultice is applied, with coconut milk, to smallpox. In Cambodia, it is used against malaria. In the Pacific, *P. urinaria* is known as an emmenagogue and abortifacient. In Guam, a decoction is employed to treat dysentery and in the Solomon islands the leaves are used to relieve pain in the chest. In India, *P. urinaria* is considered a very good diuretic.

Observations A monoecious, generally annual, usually erect herb up to 80 cm tall with phyllanthoid branching, cataphylls scarious, their stipules ovate-lanceolate and conspicuously auriculate; deciduous branchlets (3–)5–13 cm long with 10–42 leaves; leaves oblong or elliptical-oblong to elliptical-obovate, 4–20(–25) mm × (1–)3–6(–9) mm, obtuse to rounded and sometimes slightly unequal at base, apex rounded to obtuse and often apiculate, subsessile, stipules unequal, triangular-lanceolate; proximal 5–20 nodes of deciduous branchlets with solitary female flowers, succeeding nodes bearing monochasia of 5–7 male flowers; male flowers with 6 calyx lobes, disk segments 6, stamens 3, filaments connate, anthers free, dehiscing vertically; female flowers subsessile, calyx lobes 6, disk cup-shaped, margin sometimes crenulate, styles fused at base into a triangular plate; fruit a globular capsule, about 2 mm in diameter, usually rugose; seeds with sharp transverse ridges on the back and sides. *P. urinaria* is highly variable and two subspecies have been recognized. The rare subspecies *nudicarpus* Rossignol & Haicour has creeping branches that root on the nodes and smooth-skinned capsules; within Malesia it is found in the Philippines. *P. urinaria* is a common weed of waste places, clearings, gardens, along paths, but is also found in evergreen forest and bamboo forest. It grows on well-drained, fertile, sandy soils, sometimes on limestone, often in humid places or even in marshy ground, up to 1500 m altitude.

Selected sources 97, 202, 536, 580, 597, 965, 1035, 1126, 1128, 1135, 1204, 1255, 1380, 1386, 1476, 1525, 1555, 1560.

F.L. van Holthoon

Phytolacca L.

Sp. pl. 1: 441 (1753); Gen. pl. ed. 5: 200 (1754).

PHYTOLACCACEAE

$x = 9$; *P. acinosa*: $n = 9$, $2n = 36$, 72, *P. americana*: $n = 9$, $2n = 36$, *P. dodecandra*: $2n = 36$, *P. octandra*: $2n = 36$

Major species *Phytolacca acinosa* Roxb., *P. americana* L.

Vernacular names Pokeweed (En). Vietnam: th[uw][ow]ng l[uj]c.

Origin and geographic distribution *Phytolacca* consists of about 25 species, most of which are native to the tropical and subtropical regions of South and Central America, with a few species in Africa, Madagascar and Asia. No species occur naturally in South-East Asia, but a few have been introduced and these have sometimes naturalized.

Uses In traditional medicine in Vietnam the roots of *P. acinosa* are considered to be diuretic and antiphlogistic, and are used internally (as a decoction) against dropsy, ascites, oedemas and pleuritis. Externally they are used against pharyngitis, boils and swellings. Outside South-East Asia the uses of roots of *P. acinosa* and *P. americana* (e.g. in Chinese medicine) are, in addition to those already mentioned, antiparasitic, laxative and antirheumatic, and against apoplexy, tumours and bronchitis.

Berries of the African *P. dodecandra* are a potent molluscicide, and can be used to control bilharzia-transmitting snails. They are also used as a soap

substitute in Ethiopia. In Africa, parts of the plant are used for various medicinal purposes.
The young shoots and leaves of several *Phytolacca* species, when cooked, are used as a vegetable. After their toxic constituents have been removed, the red fruits of *P. americana* can be used to colour wine and foods. Some species, particularly *P. americana*, are common ornamentals in temperate climates. They are sometimes weeds.

Production and international trade To date, *Phytolacca* has not been important as a medicinal plant in South-East Asia except in countries in Indo-China, where it is sometimes cultivated as a medicinal plant in pots or home gardens. Plant parts or products are not traded commercially.
Small areas of *P. dodecandra* are grown in Ethiopia, Swaziland, Zambia and Zimbabwe. Experimental trials for its introduction in Indonesia are being started.

Properties *Phytolacca* leaves, fruits and roots contain numerous triterpenoids, e.g. phytolaccagenin, isophytolaccagenin, phytolaccagenic acid, isophytolaccinic acid, phytolaccanol, acetylaleuritolic acid, acinospesigenin, acinosolic acid, esculentic acid, esculentagenic acid, esculentagenin, jaligonic acid and spergulagenic acid.
On a dry weight basis the pericarp of *P. dodecandra* berries contains 25% bidesmosidic saponins with an oleanolic-acid aglycon; these saponins have molluscicidal properties. At concentrations well below 75 mg/kg, and after a certain period of exposure, fish and snails are killed. Other water animals such as insect larvae and tadpoles, are not affected at the concentrations that kill fish and snails. Tests showed that *P. dodecandra* berries have a potential use against *Schistosoma* larval stages in fresh water in schistosomiasis control programmes; they have cercariacidal and miracidiacidal properties.
Anti-inflammatory activity is attributed to the triterpenoid saponins, such as phytolaccoside and esculentoside, which are common e.g. in the roots. The inhibition of antibody production may partially explain the anti-inflammatory effect. Fungistatic properties have also been attributed to the saponins (e.g. yiamoloside from *P. octandra*). The bark and the roots of several species (e.g. *P. dodecandra*) are poisonous for people and animals. The toxicity may manifest in hallucinations. Lethal poisoning of horses caused by *Phytolacca* roots has been reported. Patients using Chinese drugs containing *Phytolacca* have also been poisoned. Aerial parts of *P. americana* have been found to have antigalactagogic effects in cattle. The roots of *P. acinosa* and *P. americana* have hypotensive properties; they contain the hypotensive agents histamine and gamma-aminobutyric acid. When ingested, leaves of *P. americana* typically produce self-limited but severe gastro-enteritis, characterized by intense vomiting and frothy diarrhoea.
Tests with mice suggest that *P. acinosa* polysaccharides augment the immunological functions in vivo and inhibit tumour growth; the antitumour effect may be mainly related to the augmenting effect on macrophages in the mice. Leaf and seed extracts of several species have shown antiviral activity in tests, e.g. against golden mosaic virus and tobacco mosaic virus in beans and tobacco, and against sugar cane mosaic virus and cucumber green mottle mosaic virus, and also against viruses in animal cells. The complete amino acid sequence of antiviral protein from *P. americana* seeds has been determined. The proteins are ribosome-inactivating. The lectins from the roots of *P. octandra* are mitogenic for unseparated human peripheral blood lymphocytes and stimulate plasma cell formation. Lectins from the roots of *P. americana* are called pokeweed mitogen (PWM). They are haemagglutinating (tested with human blood group A erythrocytes) and mitogenic (determined by ^{3}H-thymidine incorporation in lymphocyte cultures). Pokeweed mitogen plays an important role in fundamental leukocyte research.
The roots, leaves, and particularly, seeds of *P. acinosa* have abortifacient activity in mice. Extracts of *P. americana* have lysozyme activity. Fruits of *P. acinosa* and *P. americana* contain betalains such as humilixanthin. Lectins from *P. americana* have insecticidal properties. The neo-lignans americanol and isoamericanol from the seeds of the latter species showed neurotrophic properties in in vitro tests with rat cells. *P. americana* shows allelopathic activity: it may inhibit seed germination and seedling growth of crops like lettuce, sesame and cucumber.
The berries of *P. americana* contain the red betacyanin pigment phytolaccanin, which is identical to betanin from beetroot. The toxic saponins must be removed before this pigment is used as a food colourant. The colourant can be used in foods with a wide range of acidity, since it is not influenced by pH; however, its stability at room temperature is poor, so it is recommended for refrigerated and frozen foods.
The leaves of *P. acinosa* are reported to be a rich source of iron, phosphorus and calcium; fresh samples contain 84% water and 2.4% ash.

Adulterations and substitutes In Japan, roots of *Cynanchum caudatum* Maxim. are used as a substitute for *Phytolacca* roots; they are also diuretic. *Hibiscus sabdariffa* L., *Tamarindus indica* L. and *Tacca leontopetaloides* (L.) O. Kuntze show toxic activity against snails transferring the parasitic trematode *Schistosoma mansoni* (causing bilharzia), which is comparable to *Phytolacca dodecandra*.

Description Erect or scandent perennial herbs, sometimes shrubs and rarely trees, usually glabrous except for the often papillate or short-haired main axis of the inflorescence; stems up to 3 m long, but up to 10 m when scandent, often angular; roots often long and fleshy or tuberous. Leaves alternate, simple and entire, usually ovate-oblong to oblong-lanceolate, herbaceous, acute at both ends, petiolate; stipules absent. Inflorescence terminal or pseudolateral, racemose, often long, sometimes spiciform. Flowers usually bisexual, but sometimes functionally male or female, actinomorphic, pedicel often short; perianth 5-partite, herbaceous, greenish, whitish or pinkish during anthesis and dark red under the ripe fruit, tepals free, equal or slightly unequal, ovate or obovate to lanceolate, persistent, spreading during anthesis, later often reflexed; stamens (6–)7–22(–33), in 1 or 2 series, inserted on the outer margin of the disk, sometimes also partly on the underside of the disk, filaments usually free, filiform-subulate, anthers dorsifixed, bilobed at both ends; carpels (3–)5–10(–16), whorled, laterally connate into a superior depressed-globose ovary, or almost free (*P. acinosa* and *P. dodecandra*), ovules solitary and basal in each carpel, styles terminal on the inner angle of the carpels, subulate, short, erect or recurved. Fruit a depressed-globose berry, longitudinally 5–10-furrowed, or apocarp, juicy, orange or dark red to black, usually 5–10-seeded. Seeds strongly laterally compressed, oval to lenticular, inaequilateral at base, shining black; embryo large, peripheric, enclosing the endosperm.

Growth and development In Ethiopia *P. dodecandra* flowers and fruits throughout the year, but with a peak during the dry season. Plants in the shade often do not flower. Pollination is effected by insects such as ants, flies and spider wasps. *Phytolacca* fruits are often eaten by birds which disperse the seed. Sometimes monkeys also eat the fruits.

Other botanical information *Phytolacca* belongs to the subfamily *Phytolaccoideae*, together with the genera *Anisomeria* and *Ercilla*, which are both restricted to South America. *Phytolacca* species are often difficult to distinguish. Many of the morphological characters appear to be under weak genetic control. Moreover, many species hybridize readily, thus obscuring the characters by which they are recognized. Three highly molluscicidal and productive cultivars of *P. dodecandra* have been developed and are now in production in eastern and southern Africa.

Ecology In South-East Asia, *Phytolacca* speces are found in open forest and forest borders, roadsides, along watercourses and in waste places, up to 1700 m altitude in Java. They occur very locally in South-East Asia, but are common in some locations. *P. dodecandra* usually occurs in Africa at altitudes above 1000 m, with an annual rainfall of about 1400 mm and a distinct dry period.

Propagation and planting Mass multiplication is done by non-woody stem cuttings. It is advantageous to use a 50–75 mg/kg α-naphthalene acetic acid solution as root-promoting substance, and a slightly acid soil medium. After 6–8 weeks rooted cuttings can be planted in the field, usually at 1–3 m × 2–3 m. Propagation by seed is only appropriate for selection purposes. Soaking seed of *P. americana* in e.g. concentrated H_2SO_4 prior to sowing improves germination rate. Seed of *P. dodecandra* takes about 14 days to germinate.

In vitro production of active compounds Betacyanins have been produced in cell cultures of *P. americana* initiated from stem explants. The cells were maintained in Schenk-Hildebrandt medium. The suspension was subcultured every week in darkness at 25°C, and calluses were subcultured every 3 weeks. Whereas in fruits prebetanin (betanin 6'-O-sulphate) and its isoform predominate, in the cell culture feruloylated derivatives occur as the major components. Callus cultures of *P. americana* can be stored at 4°C for at least 3 months, but betalain production of cultures that have been stored is inferior. A dual culture consisting of callus of *P. americana* and the fungus *Botrytis fabae* showed marked fungicidal activity to *Cladosporium herbarum*. The main active constituent of this extract was identified as phytolaccoside B.

Husbandry Plantings of *P. dodecandra* must be shaded in the first weeks. Occasional watering and weeding are important until the crop has become established.

Diseases and pests *P. dodecandra* plantings may be attacked by leaf and stem borers (*Gitona* spp.), so far the only serious insect pests. Precautions have to be taken against soilborne insect larvae.

Harvesting The content of saponins of *P. dodecandra* berries varies seasonally: berries harvested during the dry season just before the onset of the rains have the highest content. Berries possess the highest molluscicidal potency when fully developed but still unripe. Complete fruiting racemes are collected and dried in the open under shade.

Yield About 1000 kg dry fruits of *P. dodecandra* can be obtained per ha per year, i.e. about 250 g of dry fruits per plant annually.

Handling after harvest Dry fruits of *P. dodecandra* can be stored for many years without losing molluscicidal activity. While grinding the berries care should be taken to avoid contact with the dust because it irritates the mucous membranes.

Genetic resources and breeding *Phytolacca* occurs in South-East Asia only in cultivation or as an escape. The species highlighted here have a wide distribution and are rather commonly cultivated and naturalized outside South-East Asia. With the exception of *P. dodecandra* and some ornamentals (particularly *P. americana*) there has been no serious selection and breeding.

The world germplasm collection of *P. dodecandra* covers all the highland areas in Africa between 20°N and 30°S. There is abundant morphological variation. In Ethiopia, the Institute of Pathobiology in Addis Ababa has a collection.

Prospects Although *Phytolacca* species are little known in South-East Asia, they might be promising for planting. The medicinal properties are interesting and comparatively well documented and, moreover, the plants also have molluscicidal, insecticidal and possibly fungicidal properties, and can be used as a vegetable and ornamental. Undoubtedly, several *Phytolacca* species are able to grow well in South-East Asia, particularly at higher elevations. However, more research is needed on planting requirements and uses, to realize the potential of these plant resources.

The use of *P. dodecandra* as a molluscicide might be limited, since the frequent applications required to ensure that treated waters remain clear of snails might also drastically reduce the fish population. However, as infected snails only occur at locations heavily frequented by people, berry suspensions can be applied locally. A few square metres of cultivated plants will enable people to treat their snail-infested watersides themselves, preferably during the dry season.

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Selection of species

Phytolacca acinosa Roxb.

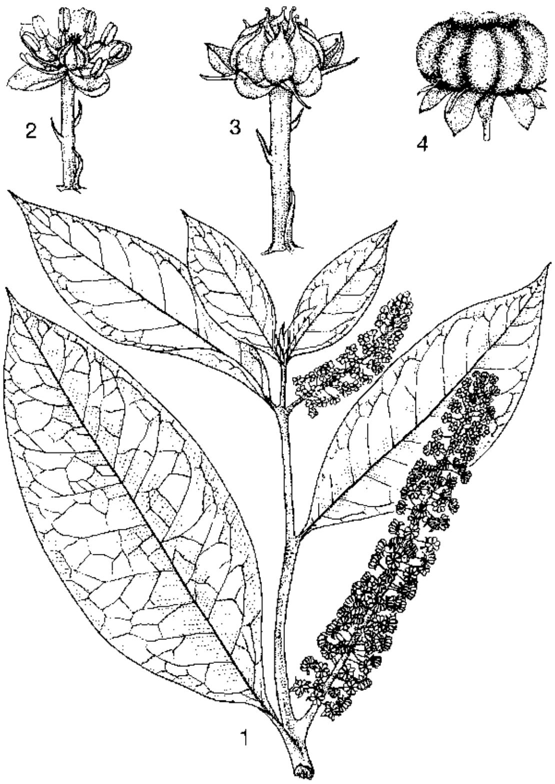
Hort. bengal.: 35 (1814).

Synonyms *Phytolacca esculenta* van Houtte (1848).

Vernacular names Indian poke (En). Vietnam: th[uw][ow]ng l[uj]c nh[or].

Distribution Pakistan, India, Nepal, Bhutan, China, Taiwan, Korea and Japan; introduced in Vietnam, occasionally cultivated elsewhere, e.g. in the Philippines.

Uses The roots are used in traditional medicine in Vietnam, both internally and externally; they



Phytolacca acinosa Roxb. – 1, flowering and fruiting stem; 2, flower; 3, young fruit; 4, mature fruit.

are commonly used in Chinese medicine. In Japan, the entire plant is used as a diuretic, while in India, it is used to alleviate body pain. Young leaves are cooked and eaten as a vegetable. *P. acinosa* is sometimes cultivated as an ornamental.

Observations A perennial herb up to 2(–3) m tall, often with purplish stems; leaves elliptical to ovate, up to 35 cm × 16 cm; flowers in racemes generally shorter than leaves, bisexual, stamens 7–15 (often 10), sometimes in 2 whorls, carpels 6–9 (often 8), free in fruit. The roots of *P. acinosa* taste bitter-sour and pungent.

Selected sources 190, 287, 452, 816, 900, 1035, 1057, 1356, 1545, 1627, 1631, 1632, 1660.

Phytolacca americana L.

Sp. pl. 1: 441 (1753).

Synonyms *Phytolacca decandra* L. (1763).

Vernacular names Pokeweed (En). Raisin d'Amérique, morelle à grappe (Fr). Laos: kub nyuj (Hmong). Vietnam: th[uw] [ow]ng l[uj]c.

Distribution Originating from North America, now cultivated worldwide and sometimes naturalized; in South-East Asia particularly in Indo-China.

Uses The roots in particular have numerous medicinal uses in Indo-China; they are also used in Chinese medicine. Young shoots are cooked and eaten as a vegetable. The red fruits can be used to colour wine and foods, but the toxic substances must be removed. *P. americana* is a common ornamental in temperate climates.

Observations A perennial branched herb up to 3 m tall, often with purplish stems, roots tuberous; leaves elliptical to ovate-lanceolate, up to 30(–40) cm × 12 cm; flowers in racemes generally longer than leaves, bisexual, stamens about 10, in 1 whorl, carpels about 10, united in fruit. *P. americana* occurs in Laos up to 2000 m altitude. In Indo-China it is a relic of former cultivation for the dye from the fruits.

Selected sources 80, 298, 390, 424, 425, 436, 450, 507, 538, 590, 703, 755, 797, 816, 900, 1035, 1057, 1298, 1356, 1660.

Phytolacca dodecandra L'Hér.

Stirp. nov. 6: 143, pl. 69 (1791).

Synonyms *Phytolacca abyssinica* Hoffm. (1796).

Vernacular names Endod, soap berry (En).

Distribution Central and southern Africa and Madagascar.

Uses The berries are used to control bilharzia-transmitting snails; they are also used as a soap substitute. Parts of the plant have various medicinal uses, e.g. laxative, anthelmintic and in the treatment of respiratory problems.

Observations A dioecious scandent shrub with branches up to 10 m long; leaves usually ovate, up to 15 cm × 10 cm; flowers in racemes generally longer than leaves, unisexual, stamens 8–15(–20), in 2 whorls, carpels (3–)5(–8), free in fruit.

Selected sources 157, 670, 841, 877, 1014, 1057, 1563.

Phytolacca octandra L.

Sp. pl. ed. 2, 1: 631 (1762).

Vernacular names Inkweed, dyeberry (En).

Distribution Probably native to tropical America, but now pantropical; in South-East Asia very locally naturalized in northern Sumatra and western Java.

Uses The roots have fungistatic and medicinal properties. Young sprouts and leaves can be used as a vegetable.

Observations A perennial branched herb up to 60(–200) cm tall; leaves oblong-lanceolate to ovate-lanceolate, up to 15(–22) cm × 6(–7.5) cm; flowers in spiciform racemes shorter to slightly longer than leaves, bisexual, stamens 8–15(–20), in 1 whorl, carpels 7–9(–10), united in fruit. In Malesia, *P. octandra* occurs at about 1700 m altitude.

Selected sources 96, 165, 166, 976, 1057, 1356.

Razali Yusuf

Plantago L.

Sp. pl. 1: 112 (1753); Gen. pl. ed. 5: 52 (1754).

PLANTAGINACEAE

$x = 4, 5$; *P. afra*: $2n = 12$, *P. asiatica*: $2n = 12, 24, 36$, *P. lanceolata*: $2n = 12 + 0\text{–}1B, 24$, *P. major*: $2n = 12, 24$, *P. ovata*: $2n = 8, 16$

Major species *Plantago major* L.

Vernacular names Plantain (En; a confusing name as in the tropics it is mainly used for the cooking banana).

Origin and geographic distribution *Plantago* consists of approximately 250 species and is cosmopolitan except the polar regions. It is essentially temperate in its natural distribution. Some species, particularly *P. major* and *P. lanceolata*, are extremely widespread, throughout temperate regions and also penetrating into tropical highland regions. *P. major* is the most widespread species in South-East Asia, and *P. lanceolata* is only very locally naturalized.

Uses The seed or seed coat of e.g. *P. afra* and *P. ovata* are widely used as laxative, but also to treat dysentery of amoebic and bacillary origin and diarrhoea. Products containing seed preparations are taken by many people worldwide to control bowel function: to treat habitual constipation, as supportive therapy in diarrhoea and with irritable bowel syndrome. Seed husks ('Psyllium husk') have become very popular in breakfast foods in the United States. They may also be a useful supplement in weight control diets by affecting fat intake and effecting a subjective feeling of fullness.

The seeds of *P. asiatica* and *P. major* are considered as expectorant, diuretic and antimicrobial in Chinese and Vietnamese medicine.

In China and Japan, the aerial parts of these plants (known as 'Plantago herba') are commonly used to treat coughs, bronchitis and asthma. *Plantago* leaves are used traditionally topically as an emollient and itch-relieving treatment against dermatological complaints and eye irritation. A poultice of 10% of dried and pulverized leaves of *P. major* is used to treat eczema, but juice from pressed fresh leaves, extracts in 96% alcohol and maceration products are also used. In modern phytotherapy aerial parts or leaves of *P. major* ('Plantago major herba') and *P. lanceolata* ('Plantago lanceolatae herba/folium') are used to alleviate irritation in catarrh of the upper respiratory tract. Macerates, fluid extracts, syrups and expressed juice from the fresh plant are all used for treating inflammation of the mouth and throat, and externally for inflamed skin.

The seed mucilage is also used in cosmetics (e.g. in lotions and hair wave sets) and as a basic stabilizer in the ice-cream industry. It is also used in the preparation of chocolate; it is an excellent thickener. The seeds can be used as a source of a low-cost gelling agent for tissue culture. The quality is reasonably comparable with that of agar, and the costs are only about 10% of those for agar.

Leaves are edible and sometimes eaten as vegetable. In some areas, *P. lanceolata* is considered a good fodder; it is reported to be a good source of calcium, potassium, sodium, cobalt, phosphorus and chlorine.

Production and international trade India is an important exporter of seed husks (mainly of *P. ovata* and to a lesser extent of *P. afra*), especially to the United States, where annual imports were worth about US$ 3.5 million in the late 1980s. It has been estimated laxatives containing *Plantago* are daily used by about 4 million Americans.

Properties The amount of mucilage in the seeds can be substantial (up to 30% in *P. ovata*). Being located only in the epidermis of the testa, it mainly consists (up to 85%) of a water-soluble polysaccharide fraction (arabinoxylan) in which D-xylose is the main constituent. The backbone is a xylan polymer with 1–3 and 1–4 linkages and no apparent regularity in their distribution, with the xylose monomers substituted on C-2 or C-3 by L-arabinose, D-xylose and α-D-galacturonyl-L-rhamnose. The quality of the mucilage is evaluated by measuring its swelling index, which should exceed 9. *P. lanceolata* and *P. major* provide a similar mucilage which is rich in D-galactose and L-arabinose and contains nearly 40% uronic acids. On hydrolysis the mucilage of *P. afra* yields D-xylose (about 70%), L-arabinose (about 10%), α-D-galacturonyl-(1–4)-L-xylose and D-galactose; the swelling index must be at least 10. The seeds also contain 5–10% lipids with unsaturated fatty acids, sterols, 15–18% proteins, traces of cyclopentanopyridine-type alkaloids and the iridoid aucubin. An isomer of ricinoleic acid, β-hydroxyolefinic acid 9-hydroxy-cis-11-octadecenoic acid, has been found as a minor constituent (1.5%) of the seed oil of *P. major*.

The seeds owe their laxative properties to the very hydrophilic polysaccharides. The action is purely mechanical and linked to the mucilage taken together with abundant fluid; the polysaccharide macromolecules absorb much water and form a gel that increases stool bulk, stimulates peristalsis and facilitates bowel movements. The effect has been confirmed by several clinical studies. In double-blind, placebo-controlled studies with patients suffering from chronic constipation, administration of *Plantago* seeds (or preparations containing seed testa) showed good results, increasing the frequency and decreasing the consistency of stools. No adverse effects were observed and, notably, no flatulence occurred, as often seen in patients taking bran. On the other hand, the mucilage can also be used as supportive therapy in diarrhoea: by absorbing water, the transit period of the bowel contents is extended. The mucilage has also frequently been reported to lower blood sugar and cholesterol, similar to the activity following the administration of galactomannans or pectins, although in general these effects are only very slight and often not demonstrated in clinical studies. In some tests, however, it was demonstrated that *P. afra* mucilage is useful as an adjunct to dietary therapy in patients with type II diabetes. A test in which patients were treated with a commercially available preparation of *P. ovata* showed positive effects on internal bleeding haemorrhoids. *P. ovata* seeds might be as effective as mesalamine to maintain remission in ulcerative colitis.

P. major seeds, administered orally, showed a significant haemostatic activity in the treatment of menorrhagia in a preliminary clinical study in India. When tested under standardized conditions in a placebo-controlled double-blind crossover model in Vietnam, no influence of the drug was recorded on the urine output and sodium excretion.

The reticuloendothelial system-potentiating and alkaline phosphatase-inducing activities of the mucilage from *P. asiatica* have been found to be markedly enhanced when the mucilage was de-O-acetylated. The deacetylated product showed considerable anti-complementary activity as well as considerable hypoglycaemic activity on administration to mice.

Administration of the seeds has no serious side-effects; only a few exceptional cases of allergic reactions have been documented. However, the husks are known to elicit respiratory allergic reactions after inhalation or ingestion by sensitized individuals. Immunological, biochemical and microscopic findings suggest that other contaminating seed components are primarily responsible for the allergenicity of commercial-grade *Plantago* husk powder rather than the husk itself. The preparations are contra-indicated if there is pyloric stenosis and abnormal narrowing of the gastro-intestinal tract, and must be used with care, to avoid product stagnation in the oesophagus in the case of bedridden patients with megacolon by alteration of colon motility, and in patients with diabetes that is difficult to control.

Leaves of *P. major* contain iridoids and phenols: flavonoids, phenolic acids and phenylpropanoic esters of glycosides (verbascoside, plantamajoside). The iridoid glucoside majoroside has also been isolated from *P. major*, along with aucubin and catalpol. *P. lanceolata* leaves also contain iridoids (1.9–2.4%) such as aucubin, catalpol and asperuloside, flavonoids and phenolic acids. Aucubin glycoside can be detected by thin-layer chromatography of a methanol extract. It can also be quantified by high pressure liquid chromatography. The proposed levels for the French pharmacopoeia are 0.5% for *P. major* and 1.0% for *P. lanceolata*. The content of aucubin in *P. asiatica* is reported in Vietnam to decrease gradually from the roots to the flowers and leaves. The drying temperature affects the content of aucubin; plant material dried at 80°C is reported to contain higher concentrations of aucubin than plant material dried at 40°C. Analysis of dried samples sold on markets in Vietnam showed that aucubin was absent, but that the allantoin content was often high (up to 80%) which makes the drug effective for the treatment of burns and stomach ulcers. The iridoids have a potential role in anti-inflammatory activity. Aucubigenin liberated from aucubin by glycosidases present possesses antibacterial activity. 3,4-Dihydroxyphenethyl alcohol-6-O-caffeoyl-β-D-glucoside, the phenylethanoid glycoside plantasioside, acteoside (verbascoside), plantaginin, plantamajoside and the phenylpropanoid glycoside hellicoside have been isolated from aerial parts of *P. asiatica*. Acteoside showed high inhibition of lens aldose reductase. Plantamajoside and hellicoside showed high inhibition of cyclic AMP phosphodiesterase and 5-lipoxygenase, which might have some correlation with the therapeutic effect of the herb as anti-inflammatory and anti-asthmatic. Acteoside and plantamajoside, which have also been found in *P. lanceolata*, showed inhibitory effects on arachidonic acid-induced ear oedema in mice. A hot-water extract of the whole plant of *P. major* exhibits diuretic activity and dissolves kidney stones. A chromatographic fraction of dried leaves was found to promote wound healing. Aqueous extracts of *P. lanceolata* showed immunomodulatory effects; in tests they stimulated the production of anti-SRBC (IgG) antibodies in mice and stimulated the release of angiogenic factors by mouse spleen cells and human mononuclear blood cells, and in vitro a *P. lanceolata* polysaccharide fraction showed an increase in phagocytosis of granulocytes. Liquid *P. lanceolata* preparations are said to have hepatoprotective (chloroform, α-amanitin) activity, and might also offer protection against adverse effects of cytostatic agents (e.g. 5-fluorouracil). In vitro experiments showed a mortality of 76% of the zooflagellate *Giardia duodenalis* when treated with a *P. major* extract.

In the United States, interplanting peach trees with *P. lanceolata* reduced nematode numbers (*Criconemella xenoplax*), but not to acceptable levels to justify commercial control. In tests with germinating lettuce seeds, aqueous extracts of *P. lanceolata* and *P. major* showed allelopathic activity.

Pollen, particularly that of *P. lanceolata*, may cause allergic reactions in sensitive persons.

Adulterations and substitutes The seed of flax (*Linum usitatissimum* L.) also contains mucilage which can be used as 'bulk laxative' just like that of *Plantago* seeds. All parts of some *Malvaceae* such as the European *Althaea officinalis* L. and *Malva sylvestris* L. contain mucilage which is used orally in the adjunctive therapy of the painful component of spasmodic colitis and for symptomatic treatment of cough, and topically as emollient and to treat itch. In India, *Plantago* seeds are frequently mixed with those of *Salvia aegyptiaca* L., which also yield copious mucilage.

Iridoid glycosides are fairly common in dicotyledonous Angiosperms. They are, for instance, present in *Scrophulariaceae* such as *Verbascum* species, which are used in phytotherapy for similar purposes as *Plantago*. Aucubin is also present in the genera *Aucuba* (*Cornaceae*) and *Garrya* (*Garryaceae*).

Description Annual or perennial herbs up to 50(–80) cm tall, stemless or with branched stem. Leaves in basal rosettes or opposite, with distinct, parallel veins, usually distinctly petiolate when in rosettes and without distinct petiole when inserted on stems; stipules absent. Inflorescence a pedunculate, bracteate spike. Flowers actinomorphic, usually bisexual, 4-merous; sepals connate at base or free, equal or nearly so, imbricate, scarious, persistent; corolla gamopetalous, usually with patent or deflexed imbricate lobes, scarious, persistent; stamens inserted on corolla tube, alternating with corolla lobes, exserted, anthers conspicuous; ovary superior, 2–4-locular, style 1 with a stout pilose stigma, protruding. Fruit a circumscissile capsule, few- to many-seeded. Seeds with endosperm and straight embryo; testa thin, often mucilaginous when wet. Seedling with epigeal germination; cotyledon sessile or shortly petiolate, sheathed at base; hypocotyl elongate, epicotyl absent; first leaves alternate or opposite (in species developing stems).

Growth and development In tropical climates *Plantago* may flower all year round, and a life cycle may be accomplished in 6 weeks. The flowers remain functionally female much longer than functionally male. The stigma is already protruding and receptive when other flower parts are still in bud, whereas it can still be functional after the stamens have withered. *P. lanceolata* is gynodioecious: specimens can be found with either bisexual flowers or only female ones. In *P. lanceolata* cross-pollination is the rule, whereas in *P. major* self-pollination is common. The flowers are wind-pollinated.

The seeds are already ripe 2–3 weeks after fertilization. Seeds readily adhere to animals or people thus facilitating their dispersal. They can also be transported by water. Perennial *Plantago* species may live for up to 15 years; in cultivation in Turkmenistan they may last up to 8 years.

Other botanical information *P. major* and *P. asiatica* are probably often confused as they are difficult to distinguish. However, they are reported to be clearly distinguishable in Japan by anatomical characters of seeds and leaves. Some authors consider both species to be conspecific.

P. afra is closely related to *P. arenaria* Waldst. & Kit. (synonym: *P. indica* L.), which in southern Europe is a source of mucilage with medicinal value too. Some cultivars of *P. afra* and *P. ovata* were developed in India in the late 1980s.

P. ovata and *P. afra* seem to be occasionally confused in the literature on cultivated *Plantago* in India, although they can easily be distinguished by leaves in rosettes (*P. ovata*) or on distinct, much-branched stems (*P. afra*).

Ecology *P. lanceolata* and *P. major* occur in areas disturbed by man. Because of their morphology they are well adapted to withstand the trampling of livestock and humans. Once established in fields, they can become a noxious weed in e.g. coffee, onions, cotton and, in particular, in cereals like rice.

In general, cool and dry weather is favourable to crops of *P. afra* and *P. ovata*; they require dry weather from flowering until seed maturity (about 2.5 weeks). *P. major* is more tolerant of compacted soils than *P. lanceolata*, so the former appears frequently in almost pure stands on the edges of paths, whereas the latter often occurs in grasslands. *P. major* is more tolerant of waterlogging, whereas *P. lanceolata* is more drought tolerant. *P. afra* and *P. ovata* tolerate dry, sandy soils extremely well. They are grown in India on medium to poor sandy soils; however, they grow best on rich, well-drained loamy soils.

Propagation and planting *P. major* reproduces mainly by seed. A seed production of up to 14 000 seeds per plant has been reported for this species. *Plantago* may be multiplied by seed or vegetative means. For large-scale seed production of *P. ovata*, propagation is by seed. The seed is broadcast or drilled in rows 30 cm apart, so 6–13 kg/ha of seed is needed. *P. lanceolata* may also be propagated by new buds arising on the thick underground stem. The 1000-seed weight of *P. afra* is 1.1–1.2 g. Plant spacing in experimental plantings of *P. afra* in Thailand was 25 cm × 10–30 cm. Interplanting of *P. ovata* with poplar (*Populus* spp.) has shown good results in India. Seeds may exhibit dormancy, which can be broken by several months of dry storage at room temperature or by a few weeks at 5°C. Seed 1–5 years old shows better germination rates than fresh seed. Seed has remained viable in the soil for over 60 years.

Husbandry In India, *P. ovata* as a crop is irrigated. Weeding is carried out when the crop is about 6 weeks old.

Diseases and pests *P. lanceolata* may serve as a host for *Pseudomonas viridiflava* and *P. syrinage* which can cause a serious bacterial disease in tomato. In India, *P. major* has been reported a host for *Meloidogyne hapla* which causes root galls in Irish potato. *Meloidogyne* species have also been identified from *P. lanceolata*. Larvae of the fruit weevil *Naupactus xanthographus*, a pest of several fruit trees, have been observed on *P. major*. *P. ovata* has been reported to be a host of the coriander aphid (*Hyadaphis coriandri*) which can be a pest of coriander, fennel, dill and celery in India.

Harvesting In Thailand, harvesting *P. afra* seeds 17 days after the first inflorescence was mature gave the highest seed yield. This means that the crop can already be harvested about 10 weeks after sowing. In western India, *P. ovata* is harvested after 3–4 months. Plants are cut about 15 cm above the ground early in the morning to prevent seed shedding.

Care should be taken when collecting *P. major* from the wild for medicinal purposes, since plants may contain high concentrations of heavy metals like lead and cadmium as they often grow along the roads.

Yield The seed yield of *P. afra* in experimental plantings in Thailand was estimated at about 1150 kg/ha. The seed yield of *P. ovata* in India is 500–1100 kg/ha. The yield of husks is approximately 25% of the seed weight.

Handling after harvest Plants harvested for seed are threshed, winnowed and sieved until the seed is clean. The husk is removed by mechanical milling and subsequent winnowing and sieving.

Genetic resources and breeding The *Plantago* species treated here are common in anthropogenic habitats, and there is no reason to consider them as liable to genetic erosion. Except for *P. major* and *P. lanceolata*, the *Plantago* species highlighted here are not yet found in Malesia. This implies that the genetic variability of *Plantago* is limited in the region.

Prospects The uses of *Plantago* orally to treat digestive and bronchial disorders and topically to treat skin disorders are very widespread. Modern research seems to confirm the activity of the drug, although information is far from complete. This, plus the ease of cultivation, seems to justify advocating planting *Plantago* for medicinal purposes. However, more research is needed to achieve a proper standardization of the drug, and to establish the potential in the Malesian region of *Plantago* species that are currently cultivated in neighbouring countries like Thailand. Leaves of *P. asiatica* and *P. lanceolata* have been recorded as a promising vegetable in regions with malnutrition.

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Selection of species

Plantago afra L.

Sp. pl. ed. 2: 168 (1762).

Synonyms *Plantago psyllium* auct. non L. (1753).

Vernacular names Psyllium, black psyllium (En).

Distribution Southern Europe, northern Africa, western Asia to Afghanistan and Pakistan; cultivated in India and locally introduced in South-East Asia as medicinal plant, e.g. in Thailand.

Uses The mucilage obtained from the seeds is used as laxative.

Observations A small annual herb up to 50(–80) cm tall, with well developed erect to slightly ascending stems, upper part of stems with glandular hairs; leaves opposite, linear-lanceolate to linear, 3–8 cm × 0.1–0.3(–0.4) cm, entire or distantly dentate, sparsely covered with short glandular hairs; spike 0.5–1.5 cm long, dense, bracts ovate-lanceolate to lanceolate, 3–8 mm long; fruit about 2 mm long, 2-seeded; seeds narrowly oblong or narrowly ellipsoidal, 2–3 mm long, smooth and reddish-brown. *P. afra* occurs in dry, open and usually sandy locations.

Selected sources 193, 237, 287, 525, 549, 1012, 1249, 1566.

Plantago asiatica L.

Sp. pl. 1: 113 (1753).

Synonyms *Plantago major* L. var. *asiatica* (L.) Decne.

Vernacular names Cambodia: slap chravea. Vietnam: m[ax] d[eef], xa ti[eef]n.

Distribution India, Indo-China, China, Taiwan, Korea, Japan and Siberia.

Uses In Indo-China, the seeds are used as diuretic, whereas the whole plant is used to treat coughs and bronchitis. The leaves are applied as a poultice to treat boils and furuncles. The leaves are sometimes consumed as a vegetable.

Observations A small perennial herb up to 20 cm tall; leaves in a rosette, broadly ovate to ovate or elliptical-ovate, 5–15 cm × 3–8 cm, entire or obscurely dentate, glabrous or nearly so; spike 2–10 cm long, variably densely flowered, bracts ovate, about 1.5 mm long; fruit 3–4 mm long, 4–6(–12)-seeded; seeds ellipsoidal and plano-convex, (1–)1.5–2 mm long, blackish-brown. *P. asiatica* is closely related to *P. major* and often considered to be conspecific. It may differ in its thinner and slightly broader leaves and on average fewer and larger seeds; however, there is much overlap with the variable *P. major*. It is common in grasslands, along roads and in waste places, especially on poorly drained soils.

Selected sources 287, 826, 851, 1035, 1042, 1208, 1439, 1464.

Plantago lanceolata L.

Sp. pl. 1: 113 (1753).

Vernacular names Buckhorn plantain, ribwort (En). Plantain lancéolé, herbe-à-cinq-côtes, bonne femme (Fr). Philippines: lanting-haba (Tagalog). Thailand: phak kaat nam, mo noi (Bangkok), yaa enyuet (northern).

Distribution Originally from Europe and western Asia, *P. lanceolata* is now cosmopolitan, including some tropical highland regions.

Uses The leaves are applied to wounds, skin inflammations and sores. In India, the seeds are used with sugar as a purgative and haemostatic. The plant is also used in traditional medicine in India to treat headache.

Observations A small perennial herb up to 30(–60) cm tall, with a short thick rootstock;

leaves in several rosettes, narrowly lanceolate to linear-lanceolate or narrowly elliptical, (2–)10–25(–40) cm × (0.5–)1–3(–5) cm, entire or remotely and shallowly denticulate, subglabrous or appressed pubescent to villous; spike 0.5–5(–8) cm long, very dense, bracts ovate, about 3 mm long; fruit 3–4 mm long, 2-seeded; seeds boat-shaped, about 2 mm long, smooth, brown. *P. lanceolata* is extremely variable, but much of the variation reflects differences in habitat (e.g. hairy plants in more dry habitats). It is very local in eastern Java (Ijen plateau, in fields and roadsides at about 1500 m altitude) and the Philippines (Luzon, in gardens at about 2200 m altitude).

Selected sources 97, 193, 287, 549, 614, 1012, 1178, 1403, 1565, 1566.

Plantago major L.

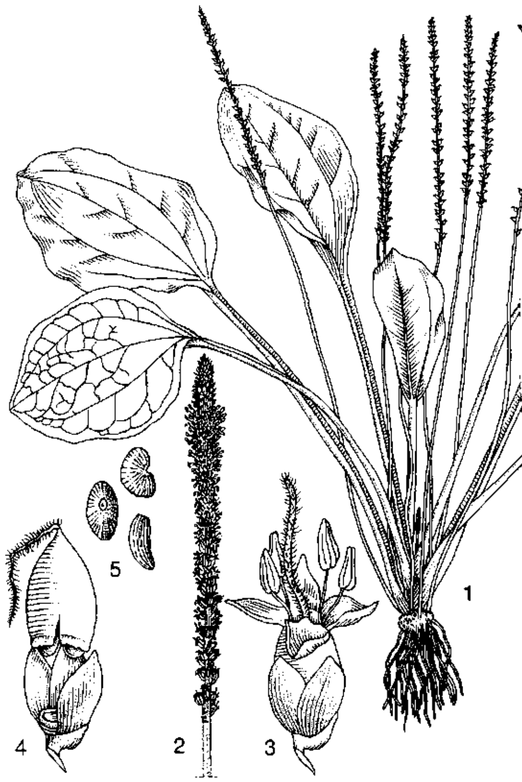
Sp. pl. 1: 112 (1753).

Vernacular names Great plantain, waybread, nipple grass (En). Grand plantain, plantain majeur (Fr). Indonesia: daun sendok, daun urat (general), ki urat (Sundanese). Malaysia: ekor anjing (general). Philippines: lanting, lantin, lanting haba (Tagalog), llantin (Spanish).

Distribution *P. major* is cosmopolitan; in the tropics it is most common in mountainous regions.

Uses The seeds have a great reputation as a remedy for dysentery and diarrhoea. They are considered pectoral, demulcent, quieting, antirheumatic and tonic, and to conduce fertility. In Indonesia, an extract of the whole plant is used as diuretic in cases of renal calculi, often in a mixture with 5 parts of *Clerodendrum*, and also to treat diabetes and skin diseases. Leaves are used to heal wounds and to treat pimples. A decoction of the plant is used in Japan to treat asthma and cough, and of the leaves in the Philippines as emollient. In Thailand, the whole plant or leaves of *P. major* are used as diuretic and antipyretic. The seeds are used as laxative, anti-inflammatory and carminative. The uses of the leaves as diuretic, astringent, and to treat wounds, insect stings and skin diseases are widespread all over the world. Other applications are against malaria (fresh leaf juice or decoction of whole plant), earache (leaves), dysentery (decoction of leaves), burns, contusions and ulcers of the mouth (decoction of leaves), gonorrhoea (decoction of leaves) and as eyewash (decoction of leaves) and mouthwash against inflammation of gums (decoction of leaves).

Observations A small perennial herb up to 30(–70) cm tall, with numerous fibrous and whitish roots; leaves in one or few rosettes, ovate to elliptical, (1.5–)5–30(–40) cm × (0.5–)3–10(–15) cm, entire or irregularly dentate, glabrous or nearly so; spike 5–20(–35) cm long, densely to rather laxly flowered, bracts ovate, 1–2 mm long; fruit 2–4 mm long, (4–)6–34-seeded; seeds ellipsoidal or ellipsoidal-trigonous, 1–1.5 mm long, dark brown to dull black. *P. major* is a variable species in which several subspecies and varieties have been described. However, the different types are often connected by a series of intermediates. It is common in open grasslands and along roads, particularly on more fertile and compact soils, from sea-level (but usually above 700 m) up to 3300 m altitude.



Plantago major L. – 1, fruiting plant; 2, inflorescence; 3, flower; 4, dehisced fruit; 5, seeds.

Selected sources 30, 97, 190, 193, 202, 287, 317, 332, 350, 545, 549, 580, 614, 851, 1012, 1151, 1178, 1287, 1439, 1566, 1571.

Plantago ovata Forssk.

Fl. aegypt.-arab.: 31 (1775).

Vernacular names Flea seed, blond psyllium (En).

Distribution South-eastern Spain, northern Africa, western Asia to Uzbekistan, Afghanistan and Pakistan; much cultivated in India and locally introduced in South-East Asia as medicinal plant, e.g. in Thailand.

Uses The mucilage obtained from the seeds is widely used as laxative. It can also be used as a gelling agent for tissue culture.

Observations A small annual or sometimes perennial herb up to 15(–20) cm tall; leaves in one or few rosettes, linear-lanceolate to linear, 2–12 cm × 0.1–0.8 cm, entire or distantly denticulate, sparsely to densely villous-lanate; spike 0.5–3.5 cm long, dense, bracts suborbicular to ovate, about 3 mm long; fruit about 3 mm long, 2-seeded; seeds boat-shaped, 2–2.5 mm long, smooth and yellowish-brown to pale greyish-pink. *P. ovata* occurs in dry regions, and is cultivated on poor to moderately fertile sandy soils.

Selected sources 147, 193, 287, 411, 525, 549, 1012, 1125, 1566.

Lilis Pangemanan

Plectranthus L'Hér.

Stirp. nov.: 84, pl. 41, 42 (1788).

LABIATAE

x = 12, 14, 15, 16, 17; *P. amboinicus*: $2n$ = 28, 32, 34, 68, 112, *P. barbatus*: $2n$ = 28, 30, 32, 34, *P. scutellarioides*: $2n$ = 16, 24, 30, 36, 40, 48, 54, 72

Major species *Plectranthus amboinicus* (Lour.) Spreng., *P. barbatus* Andrews, *P. scutellarioides* (L.) R.Br.

Origin and geographic distribution *Plectranthus* comprises approximately 200 species and is distributed in the tropical and subtropical regions of the Old World. The greatest diversity in species is found in Africa. Several species have been introduced and cultivated outside their natural areas of distribution long ago (also in tropical America) and have naturalized, and it is sometimes very difficult or even impossible to deduce their origin. About 15 species occur in the Malesian region.

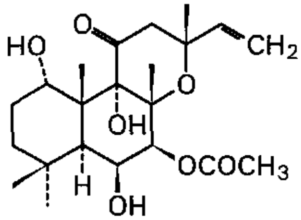
Uses The most common medicinal uses of *Plectranthus* in South-East Asia are externally for healing wounds, sores, swellings, burns, insect stings, aphtha and haemorrhoids, and internally to treat asthma, bronchitis, cough, dyspepsia, diarrhoea, and as an analgesic. In the African and South American tropics, the uses in local medicine are similar. In the Ayurvedic healing system in India, *Plectranthus* leaves are used to treat asthma, chronic cough, strangury, calculus, gonorrhoea, piles, fever, epilepsy, heart diseases, abdominal colic, dyspepsia, respiratory problems and disorders of the nervous system such as insomnia and convulsions.

In Vanuatu, *P. amboinicus* and *P. scutellarioides* have been suggested to be useful to protect *Cordia alliodora* (Ruiz & Pavon) Oken plantations from *Phellinus noxius* attack. Planting *P. scutellarioides* around taro (*Colocasia esculenta* (L.) Schott) plantations in Samoa controlled the pests *Spodoptera litura* (cluster caterpillar) and *Tarophagus proserpina* (planthopper). The leaves of several *Plectranthus* species and the tuberous roots of *P. barbatus* are used as a spice or condiment. Forms with variegated and often purplish leaves (e.g. of *P. scutellarioides*) are cultivated as ornamental.

Properties Steam distillation, hexane extraction and supercritical CO_2 extraction of *P. amboinicus* leaves resulted in respectively 0.5%, 6.5% and 1.5% volatile compounds. Approximately 30 components were identified, with carvacrol (50–90%) as the main constituent. In another experiment, stems and leaves yielded 0.07% of a yellow essential oil after hydrodistillation, in which over 30 different compounds have been identified, with monoterpene hydrocarbons forming the major part (53%). The major components were 3-carene (16%), γ-terpinene (12%), camphor (12%) and carvacrol (13%). The antiseptic activity of *P. amboinicus* has been attributed to the presence of phenolic compounds such as carvacrol in the essential oil. The essential oil has antibiotic activity against numerous gram-positive and gram-negative bacteria. Biochemical studies of the leaf extract revealed the presence of hexacosanol, β-sitosterol, oleanolic acid, betulin and other triterpenoids, whereas the flavones salvigenin, 6-methoxygenkwanin, quercetin, chrysoeriol, luteolin and apigenin, the flavanone eriodyctiol and the flavanonol taxifolin were isolated from leaves of South American origin.

In vitro tests in Burma (Myanmar) with isolated trachea, intestine and uterus segments of guinea-pigs and rats showed that *P. amboinicus* extracts inhibited the contractions of the smooth muscles induced by carbachol, histamine and 5-hydroxytyptamine. At its minimum inhibitory concentration as antimicrobial the extract showed toxicity in the brine shrimp bioassay.

Several abietane diterpenes have been isolated from the leaves of *P. barbatus* grown in Brazil, but the leaves of Kenyan plants afforded highly unsat-



forskolin

urated rearranged abietanes, and the roots of Indian plants furnished polyhydroxylated labdane diterpenes. The steroid stigmasterol has also been isolated. *P. barbatus* contains several diterpenes whose basic skeleton is 11-oxo-nanoyl oxide (8,13-epoxy-labd-14-en-11-one), with forskolin as the chief constituent. Forskolin was first isolated as the active component from the ayurvedic plant *P. barbatus* (synonym *Coleus forskohlii*) by 2 separate research groups almost simultaneously. This led to some confusion in the literature on the name of this compound (forskolin or coleonol) and its absolute structure (does the 7-acetoxy group of the molecule have the β-configuration or α-configuration?). Later, the identity of the two molecules was demonstrated unambiguously to correspond to the structure given to forskolin. The compound has not been found in *P. amboinicus* and *P. scutellarioides*.

Forskolin has numerous pharmacological actions. The compound has a positive inotropic action on the myocardium, and it exerts an antihypertensive activity by decreasing peripheral vascular resistance. From animal tests it has been concluded that forskolin affects blood flow and platelet parameters favourably in cases of occlusive arterial disease and reconstructive arterial surgery. Preliminary studies in humans have shown that forskolin does indeed increase the contractility of the myocardium, without increasing oxygen consumption, and that it is a vasodilator. It also possesses bronchodilating properties, causes a substantial and lasting decrease in intra-ocular pressure, and has an immunostimulant effect. Forskolin has been demonstrated to strongly inhibit the aggregation of human platelets induced by melanoma cells, showing a potential as an agent to prevent cancer metastasis. An in vitro study involving pre-injection of mice with forskolin at a dose of 82 μg/mouse, followed by tail-vein injection of cultured B16-F10 cells, reduced tumour colonization in the lungs by more than 70%. Giving forskolin orally to alloxan diabetic rats caused 37% increase in blood glucose level compared with alloxan diabetic controls, whereas feeding it for 7 days to normal rats raised blood glucose, serum insulin, glucagon and free fatty acid levels, with a corresponding increase in glucose-6-phosphatase activity and depletion of liver glycogen. Forskolin has also shown effects on the thyroid gland (increased secretion, iodine incorporation), the adrenal glands (increased steroid genesis) and the pituitary gland (increased ACTH release).

Much research has been done on the mechanism of action. Forskolin has been found to act by activating membrane-bound adenylate cyclase to cause an increase in cellular cyclic AMP (cAMP) levels. The exact site of action is a direct activation of the catalytic unit of the enzyme. The increase of cAMP e.g. in heart muscle is known to increase its contractility (due to opening of the slow Ca^{2+} channels, thus leading to a rise in intracellular calcium). In addition, increase of cAMP in the smooth muscle causes relaxation. This mechanism is probably responsible for the cardiovascular and vascular effects of forskolin. Furthermore, cAMP acts as a second messenger in many receptor-mediated signal transduction systems, e.g. that of the β-adrenergic receptor. Several hormone receptors also regulate their actions via adenylate cyclase reactions, which accounts for many of the effects of forskolin on the hormonal system.

The compound barbatusol has been isolated from Brazilian *P. barbatus* plants. Given intravenously at 3 mg/kg it induced potent lowering of blood pressure associated with discrete bradycardia in rats. The cardioactive dichloromethane crude stem extract of *P. barbatus* yields 20-deoxocarnosol (a phenolic diterpene with an abietane skeleton) and cariocal. The alcoholic extract of *P. barbatus* has been found to inhibit passive cutaneous anaphylaxis in mouse and rat. The extract showed highly significant antisecretory activity against *Escherichia coli* enterotoxin-induced secretory responses in rabbit and guinea-pig ileal loop models. Tests with mice in Brazil showed that water extracts of *P. barbatus* produced mild stimulation of the central nervous system, increased intestinal movements and reduced gastric secretion, indicating an antidyspeptic activity and protective activity against gastric ulcers induced by stress. A leaf extract was found active in the in vivo test against Ehrlich's ascites tumour in mice. The diterpenoids barbatusin, cyclobutatusin and 3β-hydroxy-3-deoxybarbatusin have been isolated and identified; barbatusin was the major com-

pound. Tumour-inhibitory tests against Lewis lung carcinoma and lymphocytic leukaemia P388 in mice indicated significant inhibitory activity for barbatusin at doses of 200 mg/kg and 400 mg/kg, respectively.
The caffeic acid ester rosmarinic acid has been isolated from *P. scutellarioides*. This compound, which is one of the most abundant caffeic acid esters occurring in plants, is of pharmaceutical interest because of its anti-inflammatory, antiviral, antibacterial and antioxidant properties. A mixture of 6 n-saturated hydrocarbons was isolated from *P. scutellarioides* leaves. The sterol mixture isolated was shown to consist of 4 sterols, with β-sitosterol and stigmasterol as major components. In tests with mice in the Philippines, the leaf juice of *P. scutellarioides* completely inhibited the formation of all types of tumours initiated by dimethylbenzanthracene and promoted by croton oil; 67% of the mice in the control group developed skin tumours, 50% liver tumours and 33% colon tumours. The crude extract showed antibacterial activity and inhibited the growth of Ehrlich ascites tumour cells.
A crude water extract of *P. scutellarioides* showed in vitro fungicidal activity against *Cercospora cruenta*, the pathogen of leafspot of mung bean, and against *Helminthosporium* spp. A crude leaf extract of *P. barbatus* was found to have repellent action on the larvae of the cigarette beetle (*Lasioderma serricorne*), whereas the oil and powder of *P. amboinicus* significantly protected stored maize, sorghum and mung bean seeds from the attacks of the insect pests *Sitophilus zeamais*, *Rhizopertha dominica* and *Callosobruchus chinensis* but reduced germination of mung bean seeds. The oil from *P. amboinicus* has also been found to be topically toxic to red flour beetle, common cutworm, corn weevil, lesser grain borer, black armyworm and housefly, and caused 100% mortality in young *Pomacea* snails at 10–20 ppm in tests in the Philippines.

Adulterations and substitutes The phenolic acid rosmarinic acid is also found in many other *Labiatae* (e.g. in *Orthosiphon aristatus* (Blume) Miq., *Rosmarinus* spp. and *Salvia* spp.) and in *Boraginaceae*. Diterpenes are commonly found in *Labiatae*, but they have limited therapeutic applications in pure form. However, some of them have therapeutic potential, just like forskolin from *P. barbatus*, whereas several diterpene-containing drugs are ingredients of phytotherapeutic products or allopathic proprietary drugs. Examples are compounds or drugs from *Ballota*, *Marrubium*, *Rabdosia*, *Salvia*, *Sideritis* and *Teucrium* species.

Description Herbs or undershrubs, aromatic, sometimes with tuberous roots. Leaves opposite, simple, margin serrate, crenate or dentate, petiolate, exstipulate. Inflorescence a lax or dense cyme or verticillaster, arranged collectively in a terminal or axillary spurious spike, raceme or panicle, 6-many-flowered. Flowers bisexual, zygomorphic; calyx tubular or campanulate, straight or declinate, with 5-toothed limb, usually 2-lipped with larger and broader upper lip, but teeth sometimes subequal, often accrescent; corolla with long or short tube, decurved or straight, sometimes with a spur or angle on the upper side, limb 2-lipped with short 3–4-fid, recurved upper lip and entire or notched, boat-shaped lower lip, whitish, bluish or purplish; stamens 4, declinate, filaments free or connate at base into a sheath around the style or adnate to the corolla tube but free from each other, anther cells usually confluent; disk prominent, produced anteriorly, about as long as the ovary; ovary superior, style briefly 2-fid. Fruit splitting into 4 orbicular, or occasionally oblong or ovoid nutlets, these smooth, granulate or punctate, 1-seeded.

Growth and development *Plectranthus* usually flowers throughout the year. *P. amboinicus* rarely flowers in Malesia. The flowers are insect-pollinated.

Other botanical information *Coleus* is often considered as distinct from *Plectranthus* sensu stricto, mainly on the basis of the fused bases of the filaments. However, this is a variable and unreliable character, and in most modern treatments *Coleus* is considered as a synonym of *Plectranthus*. *Solenostemon* is sometimes also kept apart because of the distinctly 2-lipped calyx; however, *Solenostemon* is connected by intermediate structures to *Plectranthus* s.s. (with calyx segments about equal). Here, one large genus, *Plectranthus* sensu lato, including *Coleus* and *Solenostemon* has been assumed, although there is still disagreement about generic delimitation in the complex.

Ecology *Plectranthus* species are usually found in open locations, on waste places, roadsides, river banks and thickets, and along cropped fields, but *P. scutellarioides* also occurs in shaded locations and forest vegetation. *P. barbatus* can more readily withstand extended periods of drought than the other species.

Propagation and planting *Plectranthus* is usually propagated by stem cuttings, which root readily. Usually, cuttings of 15–20 cm long are taken from the end of young stems and planted at a spacing of 40 cm × 40 cm. Soaking *P. scutellarioides* cuttings in placobutrazol (up to 25 mg/l) for 1.5–3 days increased the number of roots formed, but strongly inhibited shoot growth for a period of up to 10 weeks.

In vitro production of active compounds Cell suspension cultures of *P. scutellarioides* have been established, producing high amounts of rosmarinic acid. In the growth phase, the cell suspension cultures are maintained in bioreactors in modified B5-medium with 2% sucrose, and later the cell mass is diluted into a production medium consisting of a 4–5% sucrose solution, where the cells start to accumulate rosmarinic acid, but grow only slowly. Rosmarinic acid starts to accumulate at the end of the growth phase and continues for only 5 days of the culture period. The accumulation of up to 21% of the cell dry weight as rosmarinic acid makes cell suspension cultures of *P. scutellarioides* among the highest-producing plant cell cultures with respect to secondary product formation.

The synthetic purine derivative 1-(6-purinyl)-2,5-dimethylpyrrole has a stimulatory effect on the callus, which is pale green and fluffy and considered suitable for establishing cell suspension cultures; the stimulatory effect is better than that of kinetin. A biosynthetic pathway for rosmarinic acid has been deduced from studies of the enzymes detectable in the cell suspension cultures. Eight enzymatic activities are involved in the transformation of the precursors phenylalanine and tyrosine to the end product rosmarinic acid. Continuous permeabilization of preconditioned cells with dimethyl sulphoxide showed an effective strategy for the enhanced release of rosmarinic acid while preserving cell viability. Product release peaked at 0.5% dimethyl sulphoxide.

Sucrose has a greater stimulative effect on growth and rosmarinic acid accumulation of the culture than glucose and fructose. The rosmarinic acid content in normal growth medium with 2% sucrose is similar to the level in the whole plant (about 2.5% of the cell dry weight). Rosmarinic acid contents of about 20% of the cell dry weight have been found in suspension cultures grown in medium with 4% sucrose. Low phosphate concentrations in the medium result in an increased rosmarinic acid accumulation. Callus and suspension cultures have been cryopreserved and successfully stored for periods up to 15 months, with the best results obtained when using cells from the early growth period.

Husbandry Most *Plectranthus* species are easy to cultivate. Seedlings of *P. barbatus* grow well when transplanted in sandy soils.

Diseases and pests In India, *P. amboinicus* is recorded as a host of the root-knot nematode *Meloidogyne incognita*, whereas *P. barbatus* is highly susceptible to *Meloidogyne incognita* and *M. javanica*.

Yield In the United States sixty *P. barbatus* plants grown from seed yielded 430 g of dried tuberous roots after 9 months, whereas another sixty plants grown from stem cuttings yielded 730 g of dried tuberous roots. About 2 g of forskolin was isolated from 430 g dried tuberous roots.

Genetic resources and breeding Most *Plectranthus* species are widespread and common in habitats that are not at risk. All the species described here (except for *P. congestus*) are also commonly planted. This means they are not readily liable to genetic erosion. No selection and breeding is known of, but future work might focus on obtaining large amounts of compounds with interesting medicinal properties. Chemical studies of plant material from different regions showed considerable differences in compounds isolated, providing a basis for selection.

Several other *Plectranthus* species seem to be local endemics which could easily become endangered, e.g. *P. kunstleri* Prain in Peninsular Malaysia, *P. petraeus* Back. ex Adelb. and *P. steenisii* H. Keng in Java, and *P. apoensis* (Elmer) H. Keng, *P. merrillii* H. Keng and *P. sparsiflorus* (Elmer) H. Keng in the Philippines.

Prospects *Plectranthus* is extremely interesting medicinally. The efficacy of many of the traditional applications is supported by modern research. Forskolin is thus an example of a new pharmacologically active natural product with a unique mode of action. It is useful not only as a tool in pharmacology but also for the development of, for example, anti-hypertensive or cardioactive drugs based on a novel mechanism of action. The antitumour, antimicrobial and anti-allergenic effects of *Plectranthus* compounds also deserve further attention. The wide distribution and ease of cultivation make some species ideal for commercial exploitation. Although *P. barbatus* is neither indigenous to nor currently planted in South-East Asia, it seems worthwhile to establish experimental plantings for this promising species in the drier regions.

The presence of β-sitosterol and stigmasterol is interesting too. The former is employed in hypercholesterolaemia, and both compounds can be used as starting material for commercial semisynthesis of steroid hormones, such as corticosterone and antifertility hormones. Generally easy to propagate, *Plectranthus* might be developed as a commercial source of sterols of medicinal and economic importance.

A thorough taxonomical study covering the whole genus complex on a worldwide scale is desirable.

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Selection of species

Plectranthus amboinicus (Lour.) Spreng.

Syst. veg. 2: 690 (1825).

Synonyms *Coleus amboinicus* Lour. (1790), *Coleus aromaticus* Benth. (1830), *Coleus carnosa* Hassk. (1842).

Vernacular names Country borage, Indian borage (En). Indonesia: daun jinten (general), ajeran (Sundanese), daun kucing (Javanese). Malaysia: bangun-bangun, membangun (Peninsular). Philippines: oregano (Sp), suganda (Tagalog), latai (Subanun). Cambodia: sak dam ray. Thailand: niam hu suea (central), hom duan luang, hom duan hu suea (northern). Vietnam: rau t[aaf]n, rau t[aaf]n d[aaf]y l[as], h[us]ng chanh.

Distribution Almost pantropical nowadays, assumed to be of Indonesian origin, but possibly originally from Africa; also much planted throughout Malesia.

Uses *P. amboinicus* is considered as wound-healing in Indonesia, and is used to treat sores, fever (externally and internally), asthma and cough (juice or decoction of the leaves), headache (externally) and aphtha (chewing). In Malaysia, a decoction of the leaves is given after childbirth, and the juice to treat cough. Macerated fresh leaves are applied externally to burns and stings of centipedes and scorpions in the Philippines, and also to treat headache, and an infusion of the leaves as a carminative, and to treat dyspepsia and asthma. In Thailand, it is used to treat wounds and to alleviate cough. In Papua New Guinea, cuts, sores and scabies are treated with the sap squeezed from heated leaves. In pharmacy in Indonesia the leaves are known as 'Folia Colei'; they are commonly used to treat thrush and aphtha. In Brazil, *P. amboinicus* is used to treat leishmanial ulcers. In Indo-China, it is used to treat asthma, bronchitis and insect stings, and as a pectoral and vulnerary. In India, it is applied to treat complaints of the genito-urinary system and colics. In Réunion, the leaf juice is used for curing wounds, and an infusion is said to possess anti-influenza properties. The leaves are used in Indonesia and the Philippines as a spice to give fragrance to dishes, and they are also rubbed on the hair and clothes for their scent. In Vietnam, the leaves are often used as a condiment in a popular sour soup, and also in meat dishes and stews, and in India they are eaten raw with bread and butter.

Observations A perennial or semi-shrubby, variably succulent herb up to 100(–120) cm tall, non-tuberous; leaves broadly ovate, suborbicular or reniform, (3–)5–7(–10) cm × (2.5–)4–6(–8.5) cm, thick and fleshy; flowers in dense verticillasters disposed in terminal spike-like inflorescences, calyx subequally 5-toothed, corolla 8–12 mm long, pinkish-lilac to blue; nutlets flattened-globose, about 0.7 mm long, smooth, pale brown. *P. amboinicus* occurs on roadsides, waste places and on river banks up to 1500 m altitude.

Selected sources 202, 292, 332, 350, 580, 720, 981, 1035, 1126, 1139, 1178, 1518.

Plectranthus barbatus Andrews

Bot. repos. 9: pl. 594 (1810).

Synonyms *Coleus barbatus* (Andrews) Benth. (1831), *Coleus forskohlii* (Willd.) Briq. (1897) non Vahl (1790).

Distribution Nepal, Bhutan, India and Sri Lanka; introduced into Madagascar, East Africa and western Asia, and also planted in the Neotropics.

Uses In traditional medicine in Brazil, *P. barbatus* is commonly used as an analgesic and to cure liver and stomach diseases. In India it is considered to have anti-allergenic activity. The tuberous roots are eaten as a condiment in India, where they are prepared as a pickle.

Observations A perennial semi-succulent herb up to 75 cm tall, with generally decumbent stem rooting at lower nodes and thick tuberous roots; leaves ovate-oblong, 3–9 cm × 2–5 cm, thick; flowers in lax verticillasters disposed in terminal raceme-like inflorescences, calyx 2-lipped, corolla 13–17 mm long, deep purplish-blue; nutlets globose, about 1.2 mm long, granulate, blackish-brown. *P. barbatus* occurs in open, semi-arid areas, on waste places and often on shallow, moist soil among rocks on slopes, up to 1500 m altitude.

Selected sources 58, 193, 292, 524, 529, 718, 719, 1277, 1492, 1573, 1646.

Plectranthus congestus R.Br.

Prodr.: 506 (1810).

Vernacular names Papua New Guinea: ragi, magwu (Nyamikum, Sepik).

Distribution Timor, eastern New Guinea and northern Australia.

Uses The sap from crushed leaves has been reported to be applied to sores and scabies in Papua New Guinea.

Observations An annual herb, up to 150 cm tall; leaves ovate to elliptical, 2–6 cm × 1.5–4 cm, membranaceous; flowers in dense verticillasters forming false spikes and disposed in terminal panicles, calyx 2-lipped, corolla about 6 mm long, pale blue or lilac; nutlets flattened-globose, about 0.8 mm long, gland-dotted. *P. congestus* occurs in open places, thickets, savanna and on coastal rocks, up to 1500 m altitude.

Selected sources 597, 720.

Plectranthus scutellarioides (L.) R.Br.

Prodr.: 506 (1810).

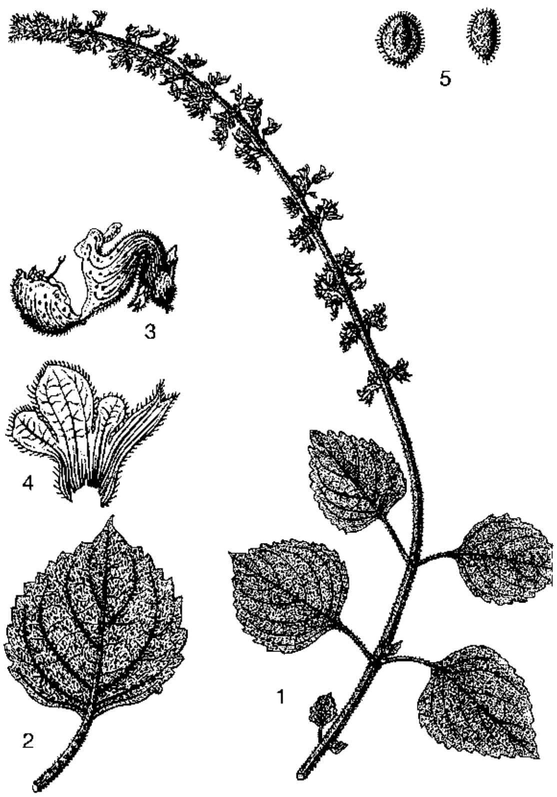
Synonyms *Coleus atropurpureus* Benth. (1830), *Coleus scutellarioides* (L.) Benth. (1830), *Coleus blumei* Benth. (1832), *Solenostemon scutellarioides* (L.) Codd (1975).

Vernacular names Painted nettle (En). Indonesia: jawer kotok (Sundanese), kentangan (Javanese), adang-adang (Palembang, Sumatra). Malaysia: daun ati-ati, ati-ati merah, ati-ati besar (Peninsular). papua New Guinea: jangata (Morawaka, Eastern Highlands), jeune (Agenehembo, Northern Province), okavu (Kami, Eastern Highlands). Philippines: badiara, malaina, mayana (general). Thailand: ruese phasom laeo (central), waan lueat haeng (Chiang Mai). Vietnam: ti[as] t[oo] t[aa]y.

Distribution India, Burma (Myanmar), Indo-China, southern China, Taiwan, Thailand, throughout Malesia, the Solomon Islands, northern Australia and Polynesia; often cultivated, also outside this region.

Uses The roots of *P. scutellarioides* are used internally in the Moluccas to treat diarrhoea and colic, and the leaves as anthelmintic and to treat urinary complaints, whereas sap is squeezed into the eye in the case of eye injury, and rubbed on swellings. Elsewhere in Indonesia the sap or a decoction is used as an abortivum and emmenagogue, and to treat haemorrhoids, inflamed eyes and boils. In Malaysia, a decoction of the leaves is used to stimulate digestion, as a sedative, to treat dyspepsia and congestion of the liver, and externally against swellings, smallpox and ophthalmia. Fresh leaves are applied in the Philippines externally or in cataplasm to bruises and contusions, and to treat headache. In Papua New Guinea, young leaves are baked and squeezed whilst hot onto fresh cuts and sores. *P. scutellarioides* is commonly cultivated for its ornamental purplish foliage.

Observations An erect or ascending, branched perennial herb up to 150 cm tall, non-tuberous; leaves generally ovate, 1–15 cm × 1–10 cm, membranaceous; flowers in lax verticillasters or in irregularly branched cymes disposed in simple or branched thyrses, calyx 2-lipped, corolla about



Plectranthus scutellarioides (L.) R. Br. – 1, flowering stem; 2, leaf; 3, flower; 4, opened calyx; 5, nutlets.

8–13(–18) mm long, blue or violet with whitish tube; nutlets broadly ovoid or globose, 1–1.2 mm long, shining, brown. *P. scutellarioides* occurs in all kinds of habitats, from rain forest to cropped fields and thickets, and from the lowland to 2900 m altitude.

Selected sources 140, 202, 292, 332, 471, 472, 477, 580, 628, 720, 1114, 1126, 1129, 1178, 1310.

Mulyati Rahayu

Plumbago L.

Sp. pl. 1: 151 (1753); Gen. pl. ed. 5: 75 (1754).

PLUMBAGINACEAE

x = unknown; *P. indica*: $2n$ = 14, *P. zeylanica*: $2n$ = 28

Major species *Plumbago indica* L., *P. zeylanica* L.

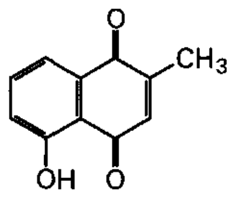
Vernacular names Leadwort (En). Vietnam: du[oo]i c[oo]ng.

Origin and geographic distribution *Plumbago* consists of about 24 species from tropical and warm temperate regions. For the Malesian region 4 species are reported, 2 of which are indigenous to the region.

Uses *P. indica* and *P. zeylanica* are widely considered a vesicant and abortifacient, and are further used in the treatment of rheumatism and skin problems. Although both are generally reported to have similar applications, *P. zeylanica* is said to be milder and less dangerous than *P. indica*. Some *Plumbago* species are widely cultivated ornamentals in tropical and subtropical regions. In the Malesian region, *P. aphylla* Bojer ex. Boiss. originating from Madagascar and *P. auriculata* Lamk (synonym: *P. capensis* Thunb.) from southern Africa are planted as ornamentals.

Properties Dried roots of *Plumbago* are often the basis of the drugs used in traditional medicine and are found as such in the market. They are traded in pieces of usually less than 1.3 cm thick, with a shrivelled, yellowish to reddish-brown bark. The activity of preparations of *P. indica* and *P. zeylanica* can be largely attributed to the presence of plumbagin (2-methyl-5-hydroxy-1,4-naphthoquinone), which is mainly extracted from the roots and is only found in *Plumbaginaceae*. The *Plumbago* species from which plumbagin has been isolated not only include *P. indica* and *P. zeylanica*, but also *P. auriculata*, *P. caerulea* Humb., Bonpl. & Kunth, *P. europaea* L., *P. pearsonii* L. Bolus, *P. pulchella* Boiss. and *P. scandens* L. Analysis of dried and powdered *P. zeylanica* roots from Sri Lanka revealed the presence of naphthoquinone derivatives such as plumbagin (0.036%), isoshinanolone (0.035%), droserone (0.0013%) and 1,2(3)-tetrahydro-3,3'-biplumbagin (0.005%), and the steroid sitosterol (0.08%).

Plumbagin has been reported to have anti-implantation and abortifacient activity in rats, without having teratogenic effects, whereas it produces testicular lesions and testis weight reduction in dogs. It has shown antigonadotropic activity in rats, causing a decrease in weight of ovaries, and blocking the effect of applied gonadotrophin. It has also shown antiprogestational activity in rats.



plumbagin

Furthermore, in lower concentrations, plumbagin has an antimitotic activity comparable to that of colchicine. In larger doses, plumbagin also has nucleotoxic and cytotoxic effects. It has also been found that *P. indica* extracts have inhibitory activity on indirect mutagens and are not mutagenic themselves.

In small doses, plumbagin stimulates the central nervous system of frogs, mice and rabbits, whereas larger doses lead to convulsions and paralysis. In rabbits, it caused a decreased respiration and blood pressure, but no diuresis. In frogs, it paralysed muscular tissue and caused dilation of perfused blood vessels. Furthermore, it seems that plumbagin is a strong irritant and/or hepatotoxic.

Plumbagin has shown antibacterial activity against both gram-positive (e.g. *Staphylococcus, Streptococcus, Pneumococcus* spp.) and gram-negative (e.g. *Salmonella*) bacteria, whereas it is also active against certain fungi (*Trichophyton, Epidermophyton* and *Microsporum* spp.) and protozoa (*Leishmania*). It has been found to prevent *Escherichia coli* and *Staphylococcus aureus* developing resistance to antibiotics and it eliminated multidrug-resistant plasmids from *E. coli* strains, resulting in loss of resistance to the antibiotics tested. In low concentrations, it augments the bacterial activity of mouse macrophages against *Staphylococcus aureus*, whereas at higher concentrations it has shown inhibitory effects. Furthermore, plumbagin shows antitumour activity in mice, especially in combination with gamma radiation.

Plumbagin also has insecticidal activity. It has shown strong insect antifeedant activity against larvae of army worms (*Spodoptera exempta, S. littoralis*), toxicity to nymphs of red cotton bug or cotton stainer (*Dysdercus koeningii*) and mosquito larvae (*Culex quinquefasciatus*), whereas it retarded growth, delayed metamorphosis and reduced fertility in housefly (*Musca domestica*). It also produced morphogenetic effects in *Dysdercus koeningii* and various other insects. These effects are probably due to its interference with the neuro-endocrine system and the system which regulates metamorphosis.

Besides plumbagin, phytochemical analysis has revealed the presence of other naphthoquinones and their derivatives in the roots of *P. zeylanica* including 3-chloroplumbagin and 2-methylnaphtazarin, the plumbagin dimers 3,3'-biplumbagin, 3,6'-biplumbagin (= chitranone), 6,6'-biplumbagin (= elliptinone), maritinone, methylene-3,3'-diplumbagin, zeylanone and isozeylanone, and the plumbagin trimer plumbazeylanone. Further compounds include: nonyl-nonanoate and nonyl-8-methyl-dodec-7-enoate (long-chain aliphatic esters), benzyl-2,5-dihydroxy-6-methoxybenzoate and 2,2-dimethyl-5-hydroxy-6-acetyl-chromene (aromatic derivatives), steroids (e.g. stigmasterol, stigmasterol acetate, sitosterone) and triterpenes (lupeol, lupeol acetate, lupanone, friedelinol). The leaves of *P. zeylanica* are reported to contain leucodelphinidin and quercetin-3-rhamnoside, and the petals azaleatin-3-rhamnoside. Compounds isolated from the aerial part of *P. indica* include 6-hydroxyplumbagin, plumbaginol (a flavonol), leucodelphinidin and steroids (e.g. β-sitosterol, stigmasterol, campesterol). The petals are reported to contain delphinidin, cyanidin and pelargonidin-3-rhamnosides, kaempferol-3-rhamnoside, galloylglucose and digalloylglucose.

Adulterations and substitutes *P. indica* and *P. zeylanica* are sometimes used as a substitute for *Rauvolfia serpentina* (L.) Benth. ex Kurz. Different naphthoquinone derivatives have been prepared from plumbagin, with halogenated plumbagin showing stronger ichthyotoxicity than plumbagin itself.

Description Shrubs or perennial herbs, rarely annual, often straggling or subscandent. Leaves alternate, simple, entire, older ones often pale lepidote underneath as a result of carbonate exudations, or reduced in flowering stems, petiole often semi-amplexicaulous auriculate; stipules absent. Inflorescence composed of 1-flowered spikelets grouped in a terminal raceme or spike, often united in a leafy panicle. Flowers subtended by 2–3 bracts, 5-merous; calyx tubular, 5-ribbed, often with sessile or stalked glands outside, teeth erect, not enlarged in fruit; corolla funnel-shaped, lobes spreading, blue, red, white or violet; stamens 5, free, filaments broadened at the base; ovary superior, 1-locular, style 1, stigma lobes 5. Fruit a 1-seeded capsule, included in the calyx and corolla, often splitting from the base with 5 valves. Seed long, narrowly ovoid, slightly flattened, tapering towards apex, dark brown or black, surface colliculate, hilum small, oval, in a longitudinal depression.

Growth and development In South-East Asia, both *P. indica* and *P. zeylanica* flower throughout the year, which explains their success as ornamentals. No fruit of *P. indica* has ever been found. The fruits of *P. zeylanica* are easily dispersed because of the sticky glands on the persistent calyx.

Other botanical information *Plumbago* is placed together with *Ceratostigma* in the subfamily *Plumbaginoideae*, characterized by inflorescences consisting of spikes, racemes or heads, as opposed to the other subfamily *Staticoideae* (inflorescence a thyrse with cincinnate partial inflorescences) comprising e.g. *Armeria* and *Limonium* which are both mainly saltmarsh and maritime genera. *P. europaea* from the Mediterranean region and West Asia used to be used in traditional medicine to treat eye diseases. One of the side-effects of this rather poisonous plant is a discoloration of the skin resembling the colour of lead, from which the Latin name *Plumbago* and the popular name leadwort are derived.

Ecology In general, *Plumbago* prefers semi-arid conditions. *P. indica* is reported to be a short-day plant. It prefers rich, moist and well-drained soils, with a pH between 5.5 and 6.0, whereas a pH below 5.0 or above 7.0 may lead to stunted growth. In Indian experiments with *P. zeylanica*, the largest and heaviest roots were obtained from plants grown in loamy soils.

Propagation and planting Shrubby *Plumbago* species are usually propagated through cuttings. *P. indica* is propagated through offsets and root cuttings. In vitro micropropagation from stem segments, nodes and leaves is also possible. However, in vitro plants may not transplant successfully into a soil medium.

In vitro production of active compounds *P. zeylanica* cell strains derived from stem explants and grown in vitro have been found to have a different potential of plumbagin synthesis.

Handling after harvest Leaf poultices of *P. zeylanica* can be dried and stored for several months without losing their vesicant properties. However, dried roots of *P. indica* and *P. zeylanica* contain less plumbagin and show less activity than fresh ones.

Genetic resources and breeding In view of their wide distribution, neither *P. indica* nor *P. zeylanica* appear to be endangered. No breeding programmes are known to exist.

Prospects Although plumbagin may have medicinal potential, e.g. for its antimicrobial and antitumour activity, the use of plumbagin or plumbagin-containing plant material as medicine for humans is not devoid of danger. Plumbagin may have potential as a compound in synthetic insecticides.

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Selection of species

Plumbago indica L.

Stickm. Herb. Amb.: 24 (1754).

Synonyms *Plumbago rosea* L. (1762).

Vernacular names Rosy-flowered leadwort, officinal leadwort (En). Indonesia: akar binasa (Malay, Moluccas), ceraka merah (Malay), mehulatu (Ambon). Malaysia: cheraka merah, setaka. Philippines: laurel (Bikol, Tagalog), pampasapit (Tagalog). Burma (Myanmar): chuvondacovaillie, kanchopni, kenkhyokeni. Thailand: chettamun phloeng daeng (central), pit piu daeng (northern), fai tai din (peninsular). Vietnam: du[oo]i c[oo]ng, x[is]ch hoa x[af], du[oo]i c[oo]ng hoa d[or].

Distribution Tropical Africa, tropical Asia and the Pacific region. Common throughout South-East Asia but not reported for New Guinea and Borneo; reports for Peninsular Malaysia are contradictory. Widely cultivated in other tropical and subtropical regions.

Uses In Indonesia, a poultice of the roots is used as a remedy for rheumatism, paralysis, tumours, toothache (as a counter-irritant) and swollen glands. The root-bark is used as a vesicant. To this end, the fresh root is cut into very thin slices, which are tied on the skin. Similarly these slices may also be applied to the forehead against headache. The leaves are also used in the treatment of rheumatism and headache. Locally, *P. indica* is used as an abortifacient, either internally by topical application for its vesicant properties, or by chewing the roots for some time. In veterinary medicine, it is given as a vermifuge to horses only. In Malaysia, leaves and roots are externally applied in the treatment of rheumatism, glandular swellings and leprosy. In the Philippines, the bark is used as vesicant and the roots are employed in poultices to treat headache. The bark is also said to be an antidyspeptic. In Thailand, the dried root is credited with emmenagogue, stomachic and carminative activities, and it is reported to be used in the treatment of haemorrhoids, as an abortifacient and as a means to purify the blood and stimulate digestion. *P. indica* is widely cultivated for its ornamental value.

Plumbago indica L. – 1, plant habit; 2, roots; 3, flower.

Observations A shrub up to 1.5 m tall, branched from the base, stems drooping, sometimes rooting; leaves oblong, 5–15 cm × 2–8 cm, petiole not auriculate; inflorescence a rather sparsely flowered spike, not corymbose, rachis glabrous, 10–30 cm long; flowers with calyx about 1 cm long, covered in glands, red, corolla tube 2.5–4 cm long, lobes 2–3 cm in diameter, distinctly mucronate, red; fruit unknown. *P. indica* is found in the vicinity of (former) anthropogenic localities, locally semi-spontaneous, often persistent in abandoned cultivation, also in teak forest, up to 1000 m elevation.

Selected sources 92, 97, 190, 193, 202, 252, 287, 350, 354, 355, 556, 572, 580, 754, 793, 900, 1035, 1044, 1068, 1122, 1128, 1159, 1178, 1254, 1284, 1285, 1287, 1476, 1507.

Plumbago zeylanica L.

Sp. pl. 1: 151 (1753).

Vernacular names Ceylon leadwort, white-flowered leadwort (En). Indonesia: daun encok (general), bama (Javanese, Balinese)), ki encok (Sundanese). Malaysia: jarak, cheraka. Philippines: bangbang (Ilokano), sangdikit (Tagalog), talankan (Ilokano). Laos: pit pi' khao. Thailand: chettamun phloeng khaao (central), pit piu khaao (northern). Vietnam: du[oo]i c[oo]ng tr[aws]ng, b[aj]ch hoa x[af], du[oo]i c[oo]ng hoa tr[aws]ng.

Distribution Tropical Africa, tropical Asia and the Pacific region. Common throughout South-East Asia, although not reported for Borneo and the Moluccas.

Uses In Indonesia, crushed leaves are applied as a poultice to treat rheumatism and headache (never longer than a few minutes behind the ears). The crushed leaves may also be used as a substitute for cantharides ('Spanish fly'); though more painful they have the advantage of not irritating the uro-genital organs. In Bali, *P. zeylanica* is used to treat ringworm. Roots of *P. zeylanica* are also used internally, for their vesicant properties, as an abortifacient. In Malaysia, a decoction of the plant is reported to be taken during the first three days after childbirth, probably for its tonic properties. Furthermore, chewing the leaves or a decoction is used as an emmenagogue, but may well act as an abortifacient in early pregnancy. In the Philippines, an infusion of the roots is used against itch. The pounded roots are applied externally as a vesicant, and root decoctions are used to treat scabies, whereas the roots are also said to be ecbolic. In Indo-China, the roots and leaves are considered rubefacient and vesicant, and they are used as a poultice against rheumatism. Leaf and root infusions are applied as a wash to treat itch and skin diseases. In Java, *P. zeylanica* is planted in living fences.

Observations A creeping herb or scandent shrub up to 2.5 m tall, laxly branched; leaves ovate, ovate-lanceolate, elliptical or oblong, 2.5–13 cm × 1–6 cm, base cuneate, apex acute or mucronate, glabrous, often with white waxy dots below, petiole 2–12 mm long, base amplexicaul, sometimes auriculate; inflorescence a 6–30 cm long raceme, rachis with sessile glands; flowers with a green glabrous calyx, covered in stalked glands, corolla tube 1.7–2.6 cm long, lobes 0.6–1 cm × 0.3–0.5 cm, white, scented, anthers purple, ovary and style glabrous. Seed 6 mm × 2 mm, dark brown. In general prefering a dry season climate, *P. zeylanica* is almost exclusively found in rather open anthropogenic habitats, e.g. savanna, forest edges and fallow fields, up to 1000 m altitude.

Selected sources 2, 92, 97, 190, 193, 202, 287, 350, 381, 516, 518, 519, 520, 521, 572, 580, 715, 754, 785, 786, 807, 900, 921, 1035, 1122, 1126, 1128, 1154, 1178, 1200, 1210, 1280, 1281, 1293, 1353, 1476, 1507, 1581.

Wongsatit Chuakul, Noppamas Soonthornchareonnon & Promjit Saralamp

Premna L.

Mant. pl. 2: 154, 252 (1771).

VERBENACEAE

x = unknown

Major species *Premna herbacea* Roxb., *P. odorata* Blanco, *P. serratifolia* L., *P. tomentosa* Willd.

Origin and geographic distribution The number of species in *Premna* varies from 50–200, depending on literature sources. They are widely distributed in the African, Asian and Australian tropics and subtropics. The main distribution area extends from India, Indo-China, China and Japan, through Thailand and the Malesian region to northern Australia. *P. serratifolia* has the largest area of distribution, extending from eastern Africa to the whole of southern and eastern Asia (including Malesia) and northern Australia.

Uses Infusions or extracts of the leaves and roots of *Premna* spp. are widely used in South-East Asian traditional medicine as a diuretic to treat dropsy, as a carminative and stomachic, to treat diarrhoea, bronchial affections, rheumatism and headache, and as a febrifuge and tonic (e.g. after childbirth). In the Philippines, a decoction of the leaves of *P. odorata* is used for loosening phlegm and as a cough remedy.

The timber is sometimes used if trees have reached larger dimensions (particularly *P. tomentosa*). Some *Premna* spp. are used in hedges, occasionally also as ornamentals. Ripe fruits and cooked leaves are occasionally eaten.

Production and international trade Plant parts of *Premna* are only collected for local use and are not traded on a larger scale.

Properties Premnazole (an isoxazol alkaloid) has been isolated from the leaves of *P. serratifolia*. This compound has anti-inflammatory activity. In rats, it has reduced granuloma formation with an activity comparable to phenyl butazone and has lowered the weight of adrenal glands and their ascorbic acid content. In the same experiment, the enzyme activities of acid phosphatase, glutamate pyruvate transaminase (GPT, ALAT) and glutamate oxaloacetate transaminase (GOT, ASAT) were reduced in serum and liver, whereas the protein content was lowered in serum. The terpenoid compound β-sitosterol and the flavonoid luteolin have also been isolated from the leaves of *P. serratifolia*. The major alkaloid in the stem bark of *P. serratifolia* was found to be aphelandrine (a spermine alkaloid) which occurs together with two other alkaloid compounds. Several sesquiterpenoids and diterpenoids have been isolated from the root bark, e.g. caryophyllen-3-one, premnenol.

Phytochemical investigations of the leaves of *P. odorata* (methanol extract) have revealed the presence of six iridoid-glycoside-caffeoyl esters, two of them having a monoacyl-rhamnopyranosyl-catapol structure and four being diacyl-rhamnopyranosyl-catapols (named premnosides A–D). Premnaodoroside A–C (acyclic monoterpenediol-iridoidglucoside diesters verbascoside, decaffeoyl verbascoside and isoverbascoside) were also isolated from the same extract.

The leaves of *P. tomentosa* have been shown to contain limonene, caryophyllene and other di- and sesquiterpenoids. The flavone 6,8-di-C-glycoside has been isolated from the heartwood. Root nodules of *P. herbacea* have been reported to contain a diterpenoid quinone, methide. The heartwood yields the flavonoid vicenin 3.

Several African *Premna* species (e.g. *P. schimperi* Engl., *P. oligotricha* Baker) contain diterpenes, which showed antibacterial and cytotoxic effects in vitro.

An extract of *P. serratifolia* showed antifeedant and anti-ovipositional effects on *Callosobruchus chinensis*, which is a pest of stored crop products. However, the action persisted for no longer than one week. The water extract of the stem bark exhibits myocardial depressant, skeleton and smooth muscle stimulant, uterine stimulant and hypoglycaemic activity.

Description Perennial herbs or undershrubs, shrubs (sometimes lianescent) to small or medium-sized trees up to 20 m tall; bole up to 30(–50) cm in diameter, often with fissured flaky bark. Leaves decussately opposite, simple, entire or serrate, crenate or dentate in upper half, with reticulate tertiary venation, with foetid smell when crushed, petiolate or sessile, exstipulate. Inflorescence terminal, cymose, compound and often much branched, pedunculate; bracts small. Flowers small, bisexual, zygomorphic, usually white, greenish-white or yellowish, pedicellate or subsessile; calyx tubular or somewhat campanulate, variously toothed or truncate, often almost 2-lipped with one lip entire or 2-toothed, the other entire or 3-toothed, persistent; corolla tubular below with usually densely villous tube in upper half, almost 2-lipped above, usually with entire upper lip and 3-lobed lower lip; stamens 4, didynamous, inserted at about the middle of the corolla tube, filaments filiform, anthers dorsifixed; ovary superior, 4-locular, style filiform, with 2 short stigmatic lobes. Fruit a small globose or obovoid succulent drupe with a hard 4-celled kernel, green but usually turning dark purple or black at maturity, 1–4-seeded. Seeds without endosperm. Seedling with epigeal germination; cotyledons thin-coriaceous, hairy; hypocotyl elongate, hairy, epicotyl present.

Growth and development Many *Premna* species flower all year round. Fruits mature a few months after flowering.

Other botanical information *Premna* is closely related to *Gmelina*, but it can easily be distinguished by its short and cylindrical corolla tube; in *Gmelina* the corolla tube is long and ampliate above. *Vitex* is another closely related genus.

Pygmaeopremna is often kept separate from *Premna*, but the only reliable differential character is the dwarf habit, which does not seem to justify a distinct generic status.

Some *Premna* spp. have minor or obscure medicinal uses. In Peninsular Malaysia, leaves of *P. divaricata* Wallich ex Schauer have been used to treat headache and colds. *P. parasitica* Blume has been used in Indonesia after childbirth and as fish poison and in Peninsular Malaysia as febrifuge. *P. cordifolia* Roxb. has been used to treat shortness of breath and as febrifuge. The leaves of *P. nauseosa* Blanco have been used in the Philippines to treat stomach-ache.

Ecology *Premna* species usually occur in the lowland up to 1000 m altitude, in secondary forest, open forest, brushwood and hedges. *P. serratifolia* often grows near the sea. *P. herbacea*, which is a subshrub, often occurs in grasslands exposed to periodic fires.

Propagation and planting *Premna* is rarely planted and, if so, it is probably propagated by seed.

Harvesting The plant parts of *Premna* like leaves and roots needed to make medicinal preparations are collected from the wild.

Handling after harvest The collected leaves and roots are washed and dried in the sun. An infusion or extract is made when needed.

Genetic resources and breeding The *Premna* spp. treated here are usually common in secondary forest, scrub vegetation and sometimes even in grassland, and are not easily liable to genetic erosion. *P. odorata* is endemic to the Philippines, but occurs there abundantly and is not threatened; *P. cumingiana* and *P. peekelii* also have limited areas of distribution but do not seem to be immediately endangered. However, several species in South-East Asia appear to be narrow endemics and might easily be endangered.

Prospects Very little pharmacological research has been done, and little is known about active compounds of *Premna* species. There is so little information available that no statements about prospects in modern medicine are warranted. However, the few studies done indicate that the therapeutic properties attributed to several *Premna* species may have a scientific basis.

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Selection of species

Premna cumingiana Schauer

DC., Prodr. 11: 634 (1847).

Synonyms *Premna cardiophylla* Schauer (1847).

Vernacular names Philippines: magilik (Tagalog), manaba (Bikol, Bukidnon), banaba (Ibanag).

Distribution The Philippines and Sulawesi.

Uses An infusion of the leaves is reported to be used in the Philippines as a diuretic to treat dropsy.

Observations A small tree up to at least 8 m tall; leaves broadly ovate to subrotundate, 10.5–30(–42) cm × 8–20(–25) cm, densely tomentose with branched or stellate hairs, particularly beneath, petiolate; flowers with white corolla; fruit subglobose, about 5 mm long. *P. cumingiana* occurs mainly in secondary forest up to 1000 m altitude.

Selected sources 1178.

Premna herbacea Roxb.

Fl. Ind. (Carey ed.) 3: 80 (1832).

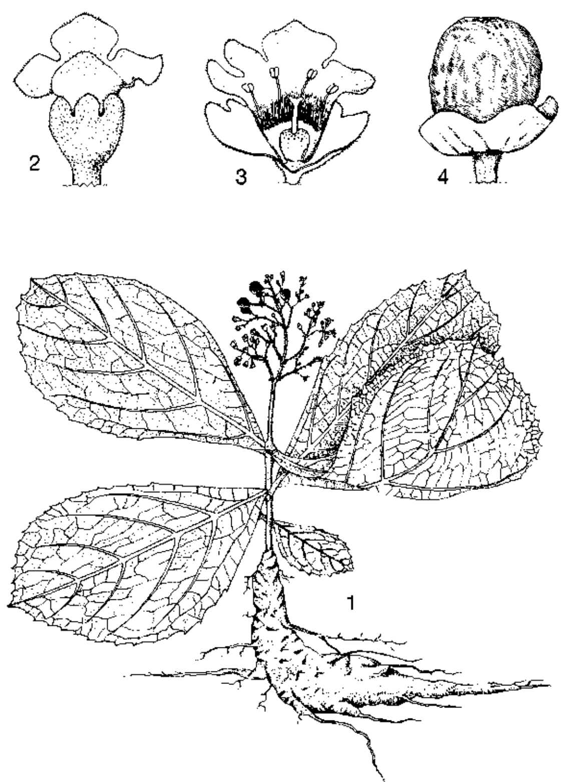
Synonyms *Pygmaeopremna humilis* Merr. (1910), *Pygmaeopremna herbacea* (Roxb.) Moldenke (1941).

Vernacular names Thailand: khaang hua lek (Chiang Mai), phaen din yen (Chiang Rai), som kang (Prachin Buri). Vietnam: c[as]ch c[or].

Distribution From Pakistan, Nepal and India, through Burma (Myanmar), Indo-China, southern China, Thailand, the Malesian region (the Philippines, the Lesser Sunda Islands (Sumba), Sulawesi, New Guinea) to Australia; cultivated as a medicinal plant in India and Sri Lanka.

Uses The juice from roots and rhizomes is used in India to treat dropsy, cough, asthma, fever, rheumatism and cholera. Ripe fruits are occasionally eaten in northern India.

Observations A low-growing perennial herb or a dwarf undershrub up to 15(–30) cm tall, most of the stem underground with creeping woody rhizome, the aboveground part slender and simple or with single dichotomous branching; leaves obo-



Premna herbacea Roxb. – 1, plant habit; 2, flower; 3, opened flower; 4, fruit.

vate, (2.5–)5–12(–15) cm × (2–)3–7(–10) cm, dentate or crenate-undulate in the upper half, subglabrous, sessile or subsessile, lowest pair lying flat on the ground; flowers with pedicel 1.5–2 mm long, corolla white or greenish-white; fruit obovoid-globose, 5–8(–10) mm long, green turning black. *P. herbacea* is particularly characteristic of open grasslands exposed to periodic fire.

Selected sources 972, 991.

Premna odorata Blanco

Fl. Filip.: 488 (1837).

Synonyms *Premna curranii* H.J. Lam (1919), *Premna benthamiana* Domin (1929), *Premna inaequilateralis* E. Beer & H.J. Lam (1936).

Vernacular names Philippines: alagao (general), agdau (Pangasinan), anobran (Iloko).

Distribution From Nepal, India, Burma (Myanmar), Indo-China, China, Taiwan and Japan, through Thailand and probably the whole of Malesia, to Australia; sometimes planted (e.g. in the Philippines, Java, India and Florida).

Uses The leaves are used as diuretic; a decoction with sugar and a little 'calamansi' (×*Citrofortunella microcarpa* (Bunge) Wijnands) juice is taken to treat cough, and an infusion is considered carminative and useful to treat beri-beri. A decoction of leaves or flowers is considered to be a febrifuge and is also used against abdominal pains and dysentery. Masticating the roots is prescribed against cardiac troubles.

Observations A shrub or small tree up to 10(–12) m tall, with bole up to 25(–30) cm in diameter, bark finely flaky fissured; leaves ovate to ovate-rotundate, sometimes ovate-lanceolate, (5–)6.5–16(–20) cm × 4–10(–13.5) cm, mostly entire, sometimes serrate-denticulate in upper half, pubescent all over, especially beneath, petiolate; flowers with pedicel 0.5–1.5 mm long, corolla greenish-white or pinkish-white; fruit obovoid, 3–5 mm long, green turning black. *P. odorata* has been much confused with *P. pubescens* Blume, which is a liana or climbing shrub. *P. odorata* is common in thickets and secondary forest at low altitudes.

Selected sources 327, 332, 991, 1091, 1092, 1093, 1178.

Premna peekelii H.J. Lam

Verben. Malay. Archip.: 115 (1919).

Vernacular names Papua New Guinea: kua (New Britain).

Distribution New Britain.

Uses In Papua New Guinea, young leaves are rubbed on the cheek of patients with mumps.

Observations A small tree up to 6 m tall; leaves broadly ovate to rotundate, 9–22 cm × 6–16 cm, entire or crenate-toothed, densely tomentose beneath, petiolate; fruit globose, 4–6 mm long. *P. peekelii* is common in forest and scrub vegetation.

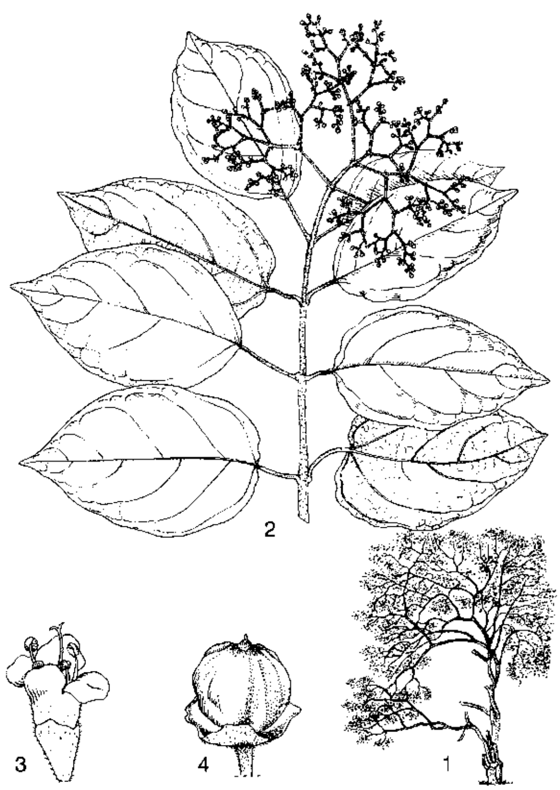
Selected sources 597.

Premna serratifolia L.

Mant. pl. 2: 253 (1771).

Synonyms *Premna integrifolia* L. (1771), *Premna corymbosa* Rottl. & Willd. (1803), *Premna obtusifolia* R.Br. (1810), *Premna foetida* Reinw. ex Blume (1826).

Vernacular names Indonesia: ki pahang (Sundanese), singkil alas (Javanese), daun kambing (Moluccas). Malaysia: buas-buas, pokok buru hantu (Peninsular). Papua New Guinea: kalokalo (Sipupu, Milne Bay), ninggrp (Yenchimangua, Sepik), lavakaliu (New Ireland). Thailand: cha lueat (Trat), man kai (Lampang), akkhe thawaan thale (peninsular). Vietnam: c[aa]y c[as]ch, v[oj]ng c[as]ch.



Premna serratifolia L. – 1, tree habit; 2, flowering twig; 3, flower; 4, fruit.

Distribution Madagascar, Mauritius, East Africa, and from India, Bangladesh, Indo-China, China, Taiwan and Japan, through Thailand and the whole Malesian area (at least reported from Peninsular Malaysia, Java, the Moluccas, New Guinea and the Philippines) to northern Australia, Polynesia and Melanesia.

Uses The leaves and roots are used in traditional medicine in Indo-China as a diuretic, stomachic and febrifuge. The leaves are employed as a galactagogue in India and Indonesia, and also to treat rheumatic arthritis, colic and flatulence in India. A decoction of roots and leaves is used as a febrifuge in Peninsular Malaysia. Extracts of the leaves are used to treat cough, headache and fever in Papua New Guinea. A tea made from the boiled bark is used in Guam to treat neuralgia. The wood is used for implements and paddles, the bark as binding material. Cooked leaves are eaten as vegetable. The plant is used locally in hedges.

Observations A shrub or small tree up to 10 m tall, bole up to 30 cm in diameter, much-branched and sometimes spiny, bark fissured-flaky, brownish-grey; leaves broadly ovate, obovate to suborbicular, sometimes oblong, (2–)8–15(–21) cm × (1–)5–10(–16) cm, mostly entire, sometimes serrate, crenate or dentate, glabrous, petiolate; flowers with pedicel 0.5–1 mm long, corolla greenish-white; fruit obovoid-globose, 3–6 mm long, green turning black. *P. serratifolia* is extremely variable, particularly the leaves and calyces. It grows in brushwood and hedges, often near the sea.

Selected sources 97, 126, 202, 316, 359, 580, 597, 972, 991, 1035.

Premna tomentosa Willd.

Sp. pl. 3(1): 314 (1800).

Synonyms *Premna pyramidata* Wallich (1827), *Premna flavida* Miq. (1861).

Vernacular names Indonesia: bulang (Javanese, Sundanese), leban capo, bebulang handak (Sumatra). Malaysia: bebuas, sarang burong, tembaroh (Peninsular). Papua New Guinea: garogira (Papa, Central Province). Thailand: kapiat (Prachuap Khiri Khan), sak khe kai (northern), saam paang (Chanthaburi).

Distribution Nepal, India, Sri Lanka, Burma (Myanmar), Indo-China, Thailand and the Malesian region (at least Peninsular Malaysia, Sumatra, Java and Timor).

Uses A decoction of the roots and leaves has been used in Malaysia as a tonic in mixtures after childbirth. The bark was used in Indonesia to treat diarrhoea. In Papua New Guinea, the leaves are crushed and applied to sores. The leaves are reputed to have diuretic properties, and they are used externally to treat dropsy. In Thailand, the dried entire plant is used to soothe skin irritation caused by caterpillars. The leaves have been used in veterinary medicine against maggots in wounds. The timber is used for house building and furniture, and also for carving and turnery.

Observations A shrub or small to medium-sized tree up to 20 m tall, with bole up to 30(–50) cm in diameter, often crooked and fluted at base, bark fissured or striate and shaggy, grey or yellowish to pale brown or pale rusty; indumentum consisting of branched or stellate hairs; leaves ovate or ovate-orbicular to ovate-oblong, (3–)10–35 cm × (2.5–)6–22 cm, entire, densely tomentose beneath, petiolate; flowers with pedicel 0.5–1 mm long, corolla white, greenish-white or yellowish; fruit obovoid-globose, 3–6 mm long, green turning black. *P. tomentosa* closely resembles *P. odorata*, but differs in the branched or stellate hairs. It occurs frequently in open forest and deciduous forest, in Java up to 800 m altitude.

Selected sources 97, 202, 580, 972.

L.B. Cardenas

Pueraria montana (Lour.) Merr.

Trans. Amer. Philos. Soc. n.s. 24(2): 210 (1935).

LEGUMINOSAE

$2n = 22, 24$

Synonyms Var. *lobata*: *Pueraria thunbergiana* (Sieb. & Zucc.) Benth. (1867), *Pueraria lobata* (Willd.) Ohwi (1947).

Vernacular names Kudzu, Japanese arrowroot (En). Koudzou (Fr). Indonesia: bitok, tobi (Madurese), tebi (Kangean). Philippines: baai (Igorot), tahaunon (Manubo). Laos: chüa tau kung, khauz pièd (northern). Thailand: tamyakhrua, phakpeetpe. Vietnam: s[aws]n d[aa]y, c[as]t c[aw]n.

Origin and geographic distribution *Pueraria* consists of 16 species of Asian origin. *P. montana* has a large area of distribution, ranging from eastern India, Burma (Myanmar), Indo-China, China, Korea and Japan, through Thailand and the Malesian region, to the Pacific islands and northern Australia. It was successfully introduced into South America and the southern United States, but did not become established in Africa. The commonest variety in the Malesian region is var. *lobata* (Willd.) v.d. Maesen & Almeida; it has been reported in Peninsular Malaysia, the Philippines, the Lesser Sunda Islands, the Moluccas and Papua New Guinea.

Uses In Chinese medicine the tuber of kudzu is known as 'Radix Puerariae', and it is one of the most important crude drugs. Tea from the tubers is used in China and Indo-China against colds, fever, influenza, diarrhoea, dysentery and hangovers. The flower buds are used as a diaphoretic and febrifuge. In China, its clinical use for various diseases in internal medicine, surgery, pediatrics and dermatology has been reported. The most important efficacy is for arrhythmia. The starch from the tuber is used medicinally in Japan in soup or tea to restore intestinal and digestive disorders. The extract is effective in lessening alcohol intoxication.

Kudzu tuber is esteemed for its fine starch, used especially in China, Japan and Papua New Guinea for sauces, soups, jelled salads, noodles, porridges, jelly puddings, confectionary and beverages. Elsewhere in South-East Asia the tubers are used in times of famine. The stem fibres are used for binding (ropes), weaving (clothes, fishing lines, baskets) and for paper production. The young leaves, shoots and flowers may be consumed as a vegetable. Kudzu is excellent for fodder and silage, if mixed with grass. It is effective for erosion control, provided its growth is controlled well. Its aggressive growth may lead to entire forests being covered and trees dying, as has been experienced in the United States. Kudzu is a good shade plant and also popular as an ornamental climber with fragrant flowers.

Production and international trade Japan produces over 300 t/year of kudzu tubers.

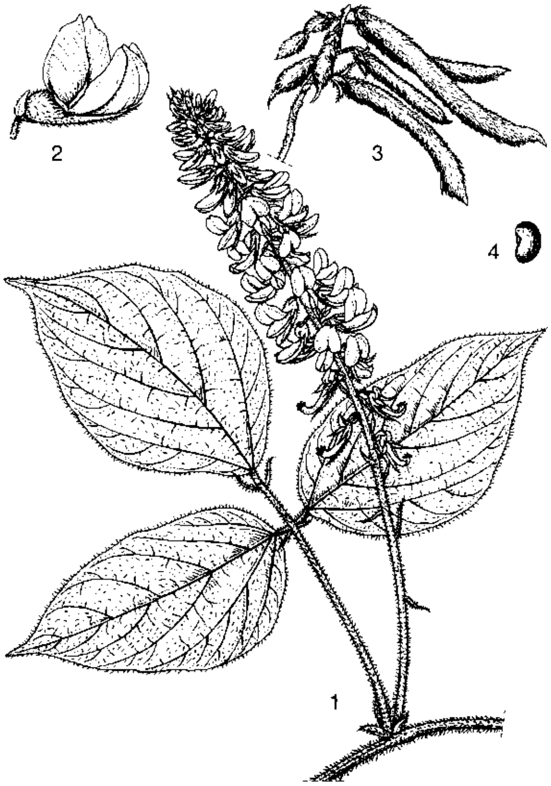
Properties *P. montana* var. *lobata* has a high flavonoid content. In a methanol extract of the tuber 7 isoflavones were identified and quantified: puerarin (160 mg/g extract), daidzin (22 mg/g), genistin (3.7 mg/g), daidzein (2.6 mg/g), daidzein-4',7-diglucoside (1.2 mg/g), genistein (0.2 mg/g) and formononetin (0.2 mg/g).

In tests with rats the plant showed antipyretic and anti-myocardial ischemia effects. The isoflavonoid glycosides have antioxidant, anti- hepatotoxic activity and also hypotensive effect, with excellent clinical results in the treatment of hypertension. Chinese pharmacologists have reported that the isoflavonoids stimulate cerebral and coronary blood circulation. Daidzein has been found to show a papaverine-like musculotropic action. The spasmolytic activity of daidzein has been proved using excised small intestine of mice. Puerarin acts as a β-adrenoreceptor antagonist in isolated arteries and veins. The extract showed antidipsotropic activity (suppression of ethanol intake) in golden hamsters, for which daidzin is the major active principle. This activity of the extract is greater than that of pure daidzin, and it seems that additional constituents in the methanol extract assist uptake of daidzin. The bioavailability of daidzin in the crude extract is about 10 times greater than that of the pure compound. In tests with rats, daidzin was efficacious in lowering blood alcohol levels and shortened sleeping time induced by alcohol ingestion. Daidzein and puerarin have also been effective in suppressing voluntary alcohol consumption by rats, but induced increased water intake. The compounds did not affect the activities of liver alcohol dehydrogenase and aldehyde dehydrogenase, from which it appears that the reversal of alcohol preference produced by these compounds may be mediated via the central nervous system. Antifebrile activity of the extract has been demonstrated in Vietnam. An aqueous extract of flowers and tubers showed wormicidal effect on *Clonorchis sinensis*.

Acute toxicity of each fraction of the tuber is very weak. High-performance liquid chromatography methods have been established for the determination of puerarin for the quality control of Chinese medicinal preparations.

Per 100 g, cooked leaves contain approximately water 89 g, protein 0.4 g, fat 0.1 g, carbohydrates 9.7 g, fibre 7.7 g and ash 0.8 g. Kudzu is nearly as nutritious as alfalfa (*Medicago sativa* L.) and is palatable to all types of livestock. The green forage contains 14.5–20% crude protein, 2–3.5% fat, 27–36% crude fibre and 7–8.5% ash on dry weight basis.

Description A perennial, woody climber, with stems up to 30 m long and up to 10 cm in diameter, initially grey to brown pubescent, later glabrescent, and with very large oblong tubers up to 2 m long and up to 45 cm in diameter. Leaves alternate, pinnately 3-foliolate; petiole 8–13(–21) cm long, rachis 1.5–7 cm long, both grey to golden-brown hairy, stipules peltate, up to 1.5(–2.5) cm long; leaflets ovate to orbicular, 8–26 cm × 5–22 cm, lateral leaflets oblique and often somewhat smaller than terminal leaflet, entire to 3-lobed, thinly appressed pubescent, petiolules 4–10 mm, stipels linear to lanceolate, up to 2(–3) cm long. Inflorescence a usually unbranched elongated pseudoraceme up to 35 cm long, with 3 flowers per node, bracts up to 10 mm long, early caducous, bracteoles up to 5 mm long, fairly persistent. Flowers bisexual, short-pedicelled; calyx campan-



Pueraria montana (Lour.) Merr. – 1, part of flowering stem; 2, flower; 3, part of infructescence; 4, seed.

ulate with 5 unequal teeth, tube 3–5 mm long, teeth 4–9 mm long; corolla papilionaceous, petals up to 2.5 cm long, purplish to blue or pink, often with a yellow or green spot on vexillum; stamens 10, monadelphous or with one free stamen; ovary superior, elongated, 1-celled. Fruit a flattened oblong pod, 4–13 cm × 0.5–1.5 cm, straight to falcate, with golden-brown hairs, 5–15-seeded. Seeds flattened ovoid, 4–5 mm × 4 mm × 2 mm, red-brown with black mosaic. Seedling with epigeal germination; first 2 leaves simple and opposite.

Growth and development Kudzu may grow 35 m or more in a single season. Bees have been reported to act as pollinators, and kudzu is said to be cross-pollinated. Outside its native area of distribution seed set is often poor.

Other botanical information Three varieties are distinguished within *P. montana*, of which var. *lobata* (Willd.) v.d. Maesen & Almeida is particularly common in the Malesian region. This variety is often considered as a distinct species: *P. lobata* (Willd.) Ohwi. The other two varieties, var. *montana* and var. *chinensis* (Ohwi) v.d. Maesen & Almeida (synonym: *P. lobata* (Willd.) Ohwi var. *thomsonii* (Benth.) v.d. Maesen), are mainly restricted to mainland Asia, although both have been reported from the Philippines. The main distinguishing characteristics are flower size, leaflet form and fruit size.

Extracts from *P. tuberosa* (Roxb. ex Willd.) DC., which does not occur in South-East Asia, showed anti-implantation activity in female rats. Its tubers are used in local medicine in Nepal, Pakistan and India, e.g. against renal complaints, as a febrifuge, as a cataplasm to cure swellings of joints and as a galactagogue; they are also used as a fish poison. In Thailand, the tubers of *P. candollei* Grah. ex. Benth. var. *mirifica* (Airy Shaw & Suvat.) Niyomdham (synonym: *P. mirifica* Airy Shaw & Suvat.) are used as a tonic and aphrodisiac, to treat mammary gland expansion and for their oestrogenic effect. Many flavonoids (daidzein, daidzin, genistein, genistin, kwakhurin, mirificin, miroestrol) as well as coumarins (columestrol, mirificoumestan and mirificoumestan hydrate) have been isolated. Pharmacological studies have shown oestrogenic, anti-implantation, abortifacient, antifertility, antispermatogenic and hypercalcaemic effects. Studies on the effects on birds found accelerated growth but inhibited egg-laying. The fertility in both male and female mice was effectively controlled by an aqueous extract of leaves, whereas the extract could effectively interrupt pregnancy.

Ecology *P. montana* occurs in thickets, forests, roadsides, pastures and hedges, and is common in the lowlands but is found up to 2000 m altitude. It grows on a wide range of soils, but does not grow well on poor sandy soils and poorly drained heavy clays. It is intolerant of waterlogging, and grows best on well-drained fertile loams. Kudzu is drought resistant because of its deep roots.

Propagation and planting Kudzu is propagated by seed, except in regions outside its native area where propagation is mainly by planting young stem cuttings almost horizontally. The very hard seed coat should be scarified with acid or by mechanical means before planting; a germination rate of 70% is considered excellent. Seeds are planted in a nursery in rows 1 m apart and 0.5–1.5 cm deep, and should be inoculated with the cowpea type of rhizobia. Seedlings are transplanted into the field after about 4 months when they have developed 4–6 leaves. Seed may be sown directly into the field, in rows 2 m apart; 1 kg of seed per ha is needed.

In vitro production of active compounds The biosynthesis of isoflavonoids in elicitor-treated cell suspension cultures of kudzu has been studied at the enzyme level. The main secondary metabolites produced by cell cultures are daidzin and puerarin. Addition of yeast extract to the cell culture stimulates the accumulation of isoflavones and daidzein-dimers.

Husbandry At planting, kudzu is fertilized. Plantings should be kept free of weeds during the first year.

Diseases and pests Fungal diseases in kudzu include leaf-spot (caused by *Alternaria* spp.), anthracnose (caused by *Colletotrichum* sp.), stem rot (caused by *Fusarium* sp.), and damping-off (caused by *Pellicularia solani*), whereas bacteria (*Pseudomonas* spp.) may cause blight. Nematodes (mainly *Meloidogyne* spp.) have been reported to attack the roots. Velvetbean caterpillars (*Anticarsia gemmatilis*) eat the leaves.

Harvesting Tubers of kudzu can be harvested about 1 year after planting the cuttings. If left longer in the soil they can become very large. For fodder production, the first harvest is possible in the second year, but full production is reached from the third year onwards.

Yield Tubers of kudzu may weigh up to 180 kg when old. A forage yield of 5 t/ha can be expected from good stands on fertile soil.

Handling after harvest A good method of preparing a decoction from kudzu is reported from China: the tuber is cut into slices of 4–7 mm, water is added at 12–15 times the weight of the tuber, and the mixture is decocted for 30 minutes.

Genetic resources and breeding Thanks to its large area of distribution, kudzu is not at risk of genetic erosion. Few cultivars have been developed, and breeding activities have mainly focused on its value as a forage. In Puerto Rico, crosses have been made between *P. montana* and *P. phaseoloides* (Roxb.) Benth. in order to combine the more vigorous growth of the former with the better adaptation to tropical conditions of the latter.

Prospects In China, the wide application of *P. montana* var. *lobata* has been recommended because the flavonoid fraction increases the blood flow to the brain and heart, decreases oxygen consumption by the myocardium and exerts spasmolytic activity. Moreover, clinical trials have shown the applicability of isoflavonoids in the treatment of hypertension, angina pectoris, myocardial infarction and migraines. Furthermore, kudzu is a valuable forage, yields useful fibre from the stems and starch from the roots, and can be used for erosion control and soil improvement. Its occasional behaviour as a weed which is difficult to eradicate acts as a brake on its wide application for planting as a multipurpose crop.

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Other selected sources 202, 580.

Praptiwi

Quisqualis L.

Sp. pl., ed. 2, 1: 556 (1762).
COMBRETACEAE
x = unknown; *Q. conferta*: $2n = 26$, *Q. indica*: $2n = 22, 24, 26$

Major species *Quisqualis indica* L.

Vernacular names Indonesia: udani. Malaysia: akar dani, selimpas (Peninsular). Philippines: niyog-niyogan. Thailand: lep mue naang. Vietnam: qu[ar] giun.

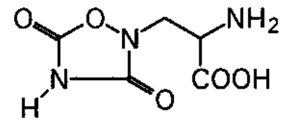
Origin and geographic distribution *Quisqualis* has about 14 species, 6 in tropical and South Africa, and 8 in tropical Asia of which *Q. indica* is now commonly cultivated throughout the tropics. In Malesia there are 4 species.

Uses The bitter half-ripe fruits and seeds of *Q. indica* are widely known as being anthelmintic and are extensively used as such, usually in decoction, particularly to treat ascarids. In large doses they cause nausea, vomiting, hiccough and even unconsciousness. The seed of the dried ripe fruit is used preferably to reduce the incidence of vomiting, but roots (*Q. conferta*, *Q. indica*) and decoctions of the leaves (*Q. conferta*) are also used as a vermifuge. Although the seeds are often applied to stop diarrhoea, an oil extracted from the seed has purgative properties. Leaf juice or seeds, macerated in oil, are applied externally to treat boils, ulcers and parasitic skin infections. Various preparations of the plant are applied both externally and internally for pain relief. In the Philippines, *Quisqualis* is used as a remedy for coughs, and the fruits and seeds are applied to alleviate nephritis. In Vietnam, the root is used in decoction to treat rheumatism. In Papua New Guinea, plants are eaten daily by men and women as a method of birth control.

Q. indica is widely cultivated as an ornamental climber, planted in hedges. In Indonesia, very young shoots are eaten raw or steamed. In West Africa, the long, flexible stems are used for basketry, fish weir and fish traps.

Production and international trade The dried fruits of *Q. indica* can be found in small drug stores and Chinese pharmacies throughout Malesia. Most of the fruits on sale in Malaysia and Thailand are imported from China.

Properties The seeds of *Q. indica* contain L-quisqualic acid (= β-(3,5-dioxo-1,2,4-oxodiazolidin-2-yl)-L-alanine or (S)-α-amino-3,5-dioxo-1,2,4-oxodiazolidine-2-propanoic acid), which exhibits marked anthelmintic activities. This active principle somewhat resembles the actions of the an-



quisqualic acid

thelmintic α-santonin (e.g. from *Artemisia maritima* L.); in China, *Quisqualis* seeds are used as a substitute for α-santonin as drug. In screening tests, parts of the fruit, e.g. the gum isolated from it, have failed to exhibit anthelmintic activity.

Furthermore, quisqualic acid has shown excitatory effects on cultured neurons, and in a variety of animal models (e.g. snails, chicks, mice and rats). It causes various types of limbic seizures and neuronal necrosis. Thus, in neuropharmacology this compound is known as one of the excitatory amino acids (EAAs) and, besides the study of the neurological effects mentioned, is used to identify a specific set of EAA receptors, in the case of quisqualic acid known as quisqualate receptors.

Pharmacological investigation of the chloroform fraction of a hot aqueous water extract of *Q. indica* showed that this fraction inhibits cyclic AMP phosphodiesterase by about 80%.

Q. indica extracts showed a mild repellent effect to the oviposition of oriental fruit fly (*Darcus dorsalis*). The aqueous extract of *Q. indica* showed antifungal properties against *Drechslera oryzae* through inhibition of germ tube elongation. The extract of the seeds of *Q. indica* had anticoccidial effect against *Eimeria tenella* in chicken.

Description Woody climbers or occasionally scrambling shrubs. Leaves opposite or subopposite, simple, margin entire, with domatia on the lower surface; base of petiole persisting as spines after leaf-fall. Flowers in elongated, usually unbranched, terminal or axillary, bracteate spikes, bisexual, actinomorphic or slightly zygomorphic, 5-merous; receptacle (calyx tube) hairy to nearly glabrous, divided into a lower part surrounding the ovary and a tubular upper part terminating in the calyx lobes, upper receptacle caducous, calyx lobes triangular; petals inserted on the receptacle tube and much larger than the calyx lobes; stamens 10, in 2 rows, inserted inside and near the mouth of the upper receptacle, not or scarcely exserted; disk narrowly tubular or absent; ovary inferior, 1-locular with 2–4 ovules, style adnate to the upper receptacle for at least half the length of the latter. Fruit a dry pseudocarp, 5-winged or -ridged, dehiscent or indehiscent, 1-seeded. Seed without endosperm.

Growth and development The lianescent stem of *Q. indica* twines to the left. Plants maintain themselves by root suckers and stooling. The flowers, which open at dusk, are initially white but gradually turn red during the next day. In the meantime the orientation of the flower changes from obliquely upwards or horizontal to pendulous. At night the white flowers are visited by hawk moths, during the day the pink and red flowers are visited by a wide range of pollinators such as solitary bees, honey bees, flies and sunbirds. Each flower lasts 3 days; the largest amount of nectar is present at the morning of the first day. In Vietnam, ripe fruits of *Q. indica* are available in August and September. Fruiting plants are rare in many localities. The fruits of *Quisqualis* are buoyant in both fresh water and seawater, and are thus dispersed.

Other botanical information *Quisqualis* is closely related to *Combretum* and the most recent view is that both should be united. *Quisqualis* was considered distinct from *Combretum* by having a dehiscent fruit and by the long tubular upper receptacle. These characters proved to be unreliable for the separation of the two genera. Another proposed delimitation based on the insertion of the style in the upper receptacle (adnate to the wall in *Quisqualis*, free in *Combretum*) and the length of the stamens (exserted in *Combretum*, not exserted in *Quisqualis*) also proved untenable. The junction of the two genera seems obvious, but has not yet been put into practice in literature. The name *Combretum* has priority over *Quisqualis*.

Ecology *Q. conferta* occurs in margins of primary forest at low altitudes. *Q. indica* is occasionally found in the same habitat, but more often in more disturbed habitats such as secondary forest, thickets, along streams, and even as a weed along roadsides, on waste places, in rice fields and along railway tracks. It occurs from sea-level up to 300 m altitude, preferably in full sunlight, on a wide range of soils, but preferably on well-drained soils.

Propagation and planting *Q. indica* can be propagated by leafless stem cuttings with at least 3 nodes; after 1 month an adequate root system has developed. Cuttings in coarse sand show about 55% rooting success. Good results have also been obtained using the tips of twigs placed in a mist bed after their leaves have been cut in half. *Q. indica* is also propagated by air layering and root division. Propagation from seed is easy, but fruits and seeds are seldom formed. In the Philippines, *Quisqualis* is planted at a spacing of 2–3 m × 4 m with 1.5 m high trellises along the rows.

Diseases and pests A leaf spot disease probably caused by a fungus has been very destructive in the Philippines in both the wet and dry seasons; older lesions are mostly circular and dark with distinct chlorotic halos. *Cercospora* leaf spot also causes irregular dark brown spots on the upper leaf surface, in which a clear whitish centre develops. In the Philippines, mites, several lepidopterous insects and also scarabaeid beetles have severely infested *Q. indica*. The bag-worm moth *Eumeta crameri* has become a serious pest on ornamental plants in Dacca, Bangladesh. In India, larvae of the moth *Othreis homaena* caused heavy defoliation of *Q. indica*. The nematode *Xiphinema americanum* was found infecting *Q. indica* and was associated with swollen root-tips.

Harvesting Mature fruits are ready for picking when they have turned golden-yellow.

Handling after harvest Fruits can be collected half-ripe, when they are still bitter, pulped in water and the liquid can be taken internally as a drug. Mature fruits are air-dried for a month in shallow containers with screened bottoms and stirred constantly to attain a moisture content of less than 10%. Immature fruits should be checked and any containing small holes, which are caused by oviposition of *Ephestia* sp., must be discarded as these will contaminate all fruits within 6 months after storage. Dried fruits can be stored for up to 1 year, but the effect of storage on the quisqualic acid content is not yet known.

Genetic resources and breeding No information is available on germplasm collections and breeding programmes.

Prospects The prospects for *Q. indica* seeds as an anthelmintic are limited, due to the toxic side-effects of quisqualic acid. The cultivation of *Q. indica* for its anthelmintic properties is being encouraged in the Philippines. However, it is not yet widely planted, possibly due to its toxic side-effects. Moreover, reports from Thailand state that fruiting is not common. Quisqualic acid is of interest for neuropharmacological applications, but there will be no need for large-scale production.

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Selection of species

Quisqualis conferta (Jack) Exell

Journ. Bot. 69: 122 (1931).

Synonyms *Quisqualis densiflora* Wallich ex Miq. (1855), *Quisqualis prostrata* Craib (1926), *Quisqualis thorelli* Exell (1931).

Vernacular names Malaysia: akar dani, selimpas, sumang (Peninsular). Thailand: lep mue naang (Chumphon). Vietnam: l[af]ng nhi[eef]u hoa, d[aa]y giun nh[or].

Distribution Indo-China, Thailand, Peninsular Malaysia and possibly in Sumatra.

Uses A decoction of the leaves or juice from the pounded roots is used as a vermifuge.

Observations A prostrate shrub or woody climber, young branches appressed pubescent or tomentulose; leaves 5–16 cm × 2–6 cm; upper receptacle 18–25 mm long, calyx lobes with recurved filiform tips, 2–3 mm long, petals 3–4 mm long; fruit 2–2.5 cm × 1–1.8 cm. *Q. conferta* is found in margins of primary forest at low altitude.

Selected sources 202, 403, 831, 1126, 1128, 1380.

Quisqualis indica L.

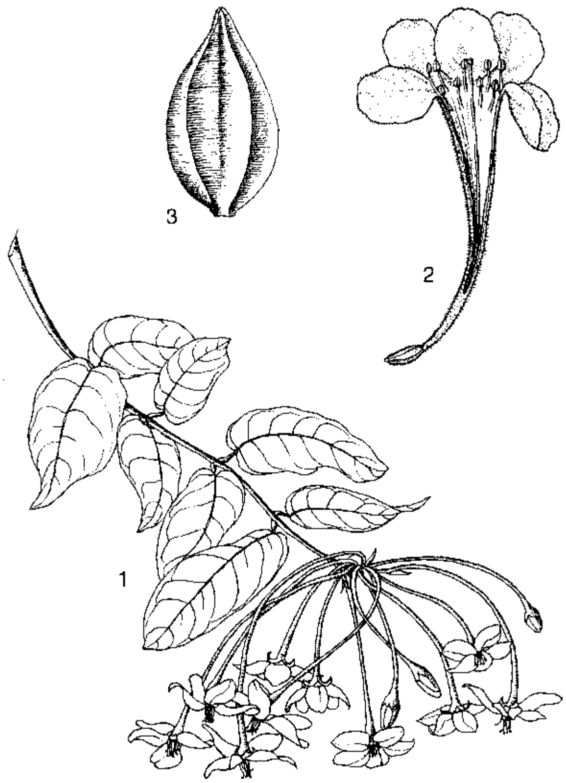
Sp. pl. ed. 2, 1: 556 (1762).

Synonyms *Quisqualis glabra* Burm.f. (1768), *Quisqualis pubescens* Burm.f. (1768), *Quisqualis spinosa* Blanco (1845).

Vernacular names Burma creeper, Chinese honeysuckle, Rangoon creeper (En). Indonesia: udani (Sumatra), bidani (Sundanese), cekluk (Javanese). Malaysia: akar dani, selimpas, udani (Peninsular). Philippines: niyog-niyogan (general, Tagalog), balitadham (Bisaya), tartaraok (Ilokano). Cambodia: dong preah phnom, vor romiet nhi. Laos: dok ung, khua hung, 'sa mang'. Thailand: cha mang (northern), thai-mong (Karen-Mae Hong Son), lep mue naang (central, peninsular). Vietnam: d[aa]y giun, qu[ar] giun, s[uwr] qu[aa]n.

Distribution Probably native to the Asian tropics and occurring throughout the Malesian region. Nowadays widely cultivated, mainly as an ornamental hedge plant, throughout the tropics. There is still doubt whether it is indigenous to east tropical Africa or was introduced there long ago.

Uses The fruits and seeds of *Q. indica* are well-known throughout Malesia as an anthelmintic, particularly to treat ascarids. In large doses they cause nausea, vomiting, hiccough and even unconsciousness. In Indonesia, a decoction of the root, seed or fruit is used as a vermifuge. In the Philippines, *Q. indica* is used as a bechic or pectoral, the fruits and seeds to alleviate nephritis, and the seeds as anthelmintic. In Peninsular Malaysia, a decoction of the seeds is given to children to stop diarrhoea, the juice of the leaves is considered a remedy for boils and ulcers and the leaves are applied to the head to relieve ache caused by jungle fever. In Papua New Guinea, plants are eaten daily by men and women as a method of birth control. In Vietnam, the root is used to treat rheumatism and a concentrated decoction of the fruit is used as a gargle effective against toothache. In China, seeds macerated in oil are applied to parasitic skin diseases, boils or sores on children's faces, and when roasted are given to treat diarrhoea and fever. In Mongolia, the seeds and fruit are reported to sustain the spleen and cause obstructions to disappear.



Quisqualis indica L. – *1, flowering twig; 2, opened flower; 3, fruit.*

Observations A woody climber, young branchlets tomentose to sparsely pubescent; leaves 5–18.5 cm × 2.5–9 cm; upper receptacle 5–8 cm long, calyx lobes deltoid to triangular, 1–2 mm long, petals 10–20 mm long; fruit 2.5–4 cm × 0.7–1.3 cm. *Q. indica* occurs in forest margins of undisturbed forest to very disturbed places, at low altitudes. *Q. indica* is highly variable; in Indo-China 3 varieties have been recognized on the basis of the bract size and fruit shape: var. *indica*, var. *pierrei* (Gagnep.) O. Lecompte (synonym: *Q. pierrei* Gagnep.), and var. *villosa* (Roxb. ex DC.) Kurz. Elsewhere still other varieties have been distinguished.

Selected sources 55, 61, 75, 186, 190, 202, 245, 287, 321, 332, 350, 358, 363, 368, 391, 403, 405, 454, 464, 467, 469, 531, 580, 597, 694, 728, 734, 802, 831, 913, 922, 1003, 1035, 1126, 1128, 1176, 1178, 1287, 1303, 1333, 1359, 1508, 1567, 1586, 1598, 1639.

N.O. Aguilar

Rauvolfia L.

Sp. pl. 1: 208 (1753); Gen. pl. ed. 5: 98 (1754).
APOCYNACEAE
$x = 11$; *R. serpentina*: $2n = 22, 44$, *R. sumatrana*: $n = 88$, *R. verticillata*: $2n = 22$

Major species *Rauvolfia serpentina* (L.) Benth. ex Kurz, *R. verticillata* (Lour.) Baillon.

Vernacular names Snakewood (En). Indonesia: lameh. Philippines: sibakong. Vietnam: c[aa]y ba g[aj]c.

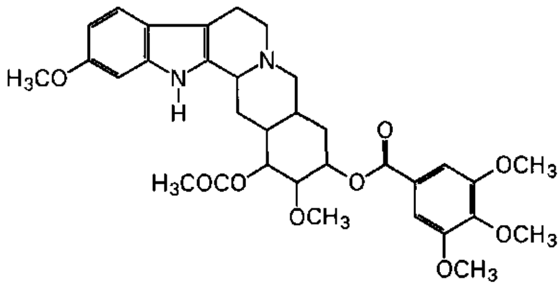
Origin and geographic distribution The number of species in *Rauvolfia* varies from 60–125, depending on literature sources. The genus is pantropical. Ten species occur in Africa and Madagascar, about 20 in tropical America, and the remainder in Asia, Australia and the Pacific. Nine species have been distinguished in the Malesian region, but as a result of new taxonomic studies this number might be reduced to 5.

Uses *Rauvolfia* has been used in Ayurvedic medicine in India since ancient times to treat snake bites, mental diseases and epilepsy, and is still important. In Vietnam it is considered to be one of the most useful and effective medicinal plants. Its main use is as an anti-hypertensive agent and as tranquilizer. An extract of the root rind is considered as a highly effective remedy against high blood-pressure and to relieve the central nervous system. Besides this, it is also used to treat dysentery, diarrhoea, liver diseases, psychoses, insanity, epilepsy and snake bites and/or scorpion stings, and to stimulate uterine contraction and to promote the expulsion of the foetus. In a mixture with other plants it is sometimes used to treat cholera and fever. The leaf juice is applied locally against opacity of the cornea and to treat wounds and itch. The drug is also considered as an anthelmintic and tonic.
Rauvolfia species are used for the extraction of alkaloids, principally reserpine, but also ajmaline and ajmalicine. Reserpine is marketed for the treatment of (mild to moderate) arterial hypertension. Combination with a diuretic is classical in order to control the water and Na^+ retention that is a side effect of reserpine. The drug has been much used since the 1960s, however, because of its narrow therapeutic index (i.e. the difference between therapeutic and toxic doses is very small) and its major side effect (depression), reserpine is currently of secondary interest. More manageable compounds have become available for therapy. In psychiatric therapy, reserpine has also been replaced by synthetic products (e.g.

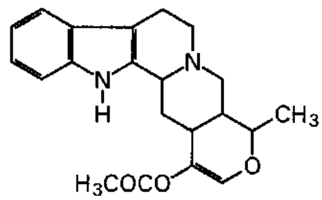
phenothiazines and butyrofenon derivatives).
Ajmalicine is an ingredient of propietary products used to treat the psychological and behavioral problems of senility, sensory problems, cerebrovascular accidents, cranial traumas and their neurological sequelae. Another alkaloid, ajmaline is used as a remedy for heart arrhythmias in distinct cases (class 1A agent).
The lightweight wood of some *Rauvolfia* spp. which can reach the size of a tree is sometimes used for small objects such as knife handles.

Production and international trade *Rauvolfia* roots and their preparations are used and traded in many countries and are important on the international market. Thailand appears to be the main exporter, with amounts of about 100 t/year in the second half of the 1970s, whereas Nepal exported some 30 t/year in the same period. India was a large supplier of *R. serpentina* roots before 1969 (on average 40 t/year), but then the export was banned by the government to help develop an extraction industry. In 1982, the price of powdered *R. serpentina* roots was US$ 9/kg and of reserpine US$ 0.4/g.

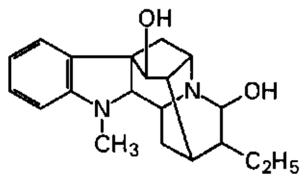
Properties Commercial samples of *R. serpentina* drugs consist of tortuous pieces of root of up to 15 cm long and 2 cm in diameter; they are yellowish and of low density. Although at present the botanical name is *Rauvolfia*, the crude drug is called *Rauwolfia* (Rauwolfia Radix). The total alkaloid content is 0.5–3%, and over 50 different alkaloids have been demonstrated, most of them indole-type, derived from tryptophan. The alkaloids can further be classified into 4 main groups (typical analysis in parentheses): (1) yohimbane-type derivatives, e.g. reserpine (0.14%), reserpinine (rescinnamine, 0.015%), isorauhimbine (3-epirauwolscine, 0.08%), (–)-corynanthine (rauhimbine, 0.03%), deserpidine, yohimbine and corynantheine; (2) heteroyohimbane derivatives, e.g. serpentinine (serpentidine, 0.13%), serpentine (0.08%), raubasine (ajmalicine, 0.02%), reserpiline and alstonine; (3) sarpagane derivatives, e.g. sarpagine (raupine, 0.02%); and (4) dihydro-indole (ajmalane) derivatives, e.g. ajmaline (0.1%). Standardized *Rauwolfia* powder has a total content of 0.15–0.20% alkaloids of the reserpin-rescinnamine group, calculated as reserpine, and analysed according to the USP XXII. Furthermore, several spectrophotometric and extraction-photometric methods have been developed for determining *Rauvolfia* alkaloids, e.g. reserpine, serpentine and ajmaline. These methods are comparatively simple and accurate.



reserpine



raubasine (ajmalicine)



ajmaline

Of the *Rauvolfia* alkaloids, 5 are used in medicine: reserpine, rescinnamine, deserpidine, raubasine (ajmalicine) and ajmaline. There are several patented methods available for the extraction of the main component reserpine.
Reserpine is a sympatholytic agent acting indirectly on the peripheral (noradrenergic) and central (noradrenergic and serotonergic) nerve terminals. By inhibiting the Mg^{2+} and ATP dependent transport of e.g. noradrenaline (norepinephrine) it amplifies the breakdown of this substance by monoamino oxidases and catecholamine transferases. The resulting depletion of catecholamines on the peripheral level induces a lasting drop in blood pressure and heart rate. Sedative and neuroleptic activity is caused by central neurotransmitter depletion. Contra-indications for using reserpine are depression, combination with monoamino-oxidase inhibitors or laevodopa, peptic ulcer, and hypersensitivity to the alkaloid. Side effects of the medication include drowsiness, nasal congestion, salivary and gastric hypersecretion, paradoxical anxiety, depression and retention of

water and Na^+ (the latter may be overcome by co-administration of a diuretic). Overdose may cause respiratory depression, bradycardia, hypotension, confusion, tremors, myosis, convulsions and gastro-intestinal distress. Oral administration of *R. serpentina* extract has caused blood and urine glucose to decrease in cats and diabetic patients. Reserpine has been shown to enhance the hypoglycaemic effect of insulin and the hyperglycaemic effect of adrenalin, and has inhibited the physiological hyperglycaemic response in diabetic patients. Reserpine did not show genotoxicity and was unable to induce reverse mutation and recombinational mitotic events (crossing-over and gene conversion) in yeast strains.

Rescinnamine (reserpinine) is a reserpine analogue containing a trimethoxycinnamic rather than a trimethoxybenzoic-acid residue. Deserpidine (11-demethoxyreserpine) lacks a methoxy function at position 11 of the reserpine molecule. Both alkaloids have the same effects as reserpine, and can be used to treat the same conditions, although their side effects are reported to be less pronounced.

Raubasine (ajmalicine) is an α-adrenergic blocking spasmolytic which, at high doses, reverses the effects of adrenalin (epinephrine), and moderates the activity of the vasomotor centres, especially in the brain stem. It causes a transient increase of the blood flow to the brain, and is slightly anxiolytic.

Ajmaline is an anti-arrhythmic (class 1A group), which substantially decreases the rate of depolarization of atrial and ventricular cells. Its toxicity has limited its uses to some specialized cases.

The alkaloids reserpine, spegatrine and verticillatine have been reported in *R. verticillata*. Spegatrine has been shown to be an α-adrenergic blocker, whereas verticillatine exhibited ganglionic blocking activity. Clinical application of verticillatine showed significant therapeutic effect in treating severe cases of hypertension, with few side effects.

R. serpentina powder at a concentration of 0.25% has been found to be very effective in protecting grain against *Rhizopertha dominica*. The roots also exhibit plant growth inhibition and uterine stimulant, antihyperglycaemic, and dopamine receptor blocking activity. The leaf extract showed fungitoxicity; it reduced growth of *Sclerotium rolfsii* significantly. An extract of *R. serpentina* markedly decreased the number of local lesions and systemic infection caused by brinjal necrotic mosaic virus on aubergines.

Adulterations and substitutes *Apocynaceae* other than *Rauvolfia*, for example *Catharanthus roseus* (L.) G. Don, have similar or related alkaloids with similar applications.

Description Shrubs or small to medium-sized trees up to 30 m tall, often candelabra-shaped, with latex in branchlets but not in bark; bark smooth, rough, fissured or scaly. Leaves verticillate in whorls of 3–4(–5), rarely opposite, simple and entire, short-petioled with axillary glands on the petiole, exstipulate. Inflorescence a terminal, peduncled cyme, sometimes seemingly axillary. Flowers actinomorphic, bisexual, small, 5-merous; calyx deeply divided, with overlapping lobes; corolla salver-shaped, with cylindrical or campanulate tube, sometimes ventricose in or above the middle, with long hairs inside in the upper half, throat usually constricted, often hairy, lobes twisted to the left in the bud, white or greenish-white to pink, tube often reddish outside; stamens inserted in the widening of the corolla tube, alternating with corolla lobes, filaments very short, anthers not or hardly exserted, free from stigma, medifixed, acute; disk annular or cupular; ovary, superior, with 2 carpels which are free or connate, style 1, glabrous, stigma provided at the base with a collar and with a bifid apical cusp. Fruit consisting either of 2 free drupelets or a single, entire or bilobed drupe with 1–2 tuberculate pyrenes, usually about 1 cm in diameter, ripening blackish. Seeds laterally compressed, obliquely ovate or elliptical, with a large embryo; endosperm fairly abundant. Seedling with epigeal germination; cotyledons leafy, green; first 2–3 nodes with decussate leaves, subsequent leaves whorled.

Growth and development Ramification in *Rauvolfia* is determined by the verticillate leaves; branches terminate in 2–5 elements, consisting of branchlets or inflorescences. The number of elements is the same as the number of leaves in the whorl. This results in an umbellate ramification and a candelabra-shaped habit.

R. serpentina and *R. verticillata* flower throughout the year in Peninsular Malaysia. The flowers are pollinated by insects like small bees and flies.

Other botanical information Full-grown flowers and ripe fruits are indispensable for a reliable identification of *Rauvolfia*. *R. javanica*, *R. reflexa* and *R. sumatrana* are difficult to distinguish, and might be considered as one polymorphous species.

Rauvolfia resembles *Ervatamia* and *Kopsia*, but *Ervatamia* differs in its opposite leaves and seeds with red or orange sarcotesta, and *Kopsia* in its

opposite leaves, corolla segments overlapping to the right and disk consisting of 2 scales alternating with the carpels.
The roots or root rind of *R. cambodiana* Pierre ex Pitard, *R. chaudocensis* Pierre ex Pitard, *R. indochinensis* Pichon and *R. vietnamensis* Ly are used in Vietnam to treat high blood pressure, and sometimes also to treat dysentery and as antibiotic and antiseptic. *R. vomitoria* Afzel. is an important species from West and Central Africa with high alkaloid concentration. *R. tetraphylla* L. is from tropical America. Both species are used for industrial alkaloid extraction; *R. tetraphylla* is cultivated very locally in gardens in India, Vietnam and China, *R. vomitoria* in Vietnam.

Ecology *Rauvolfia* species occur scattered in forest, often in secondary forest, and scrub vegetation. Several tolerate shade well, but some (e.g. *R. serpentina*) occur especially in more open places, e.g. in forest edges and along rivers. Slightly acid soils (pH 5–6.5) are favourable, but some *Rauvolfia* spp. also grow well on limestone soil. Experiments with *R. serpentina* grown in different soil media in the Philippines showed no significant difference in root production.

Propagation and planting *R. serpentina* is usually propagated by seed, although stem and root cuttings can also be used. The germination rate can be very low, therefore it is recommended to select mature and heavy seeds and to sow them within 6 months after ripening. In Vietnam, fruits are soaked in water for 12 hours, they are then crushed and the seeds are cleaned and subsequently soaked in warm water (40–45°C) for a further 12 hours. The seeds are sown in nursery beds, and start germinating within 3 weeks. Seedlings 10–12 cm tall are usually transplanted during the rainy season at a planting distance of 45 cm × 30 cm. A planting distance of 50 cm × 50 cm is recommended for *R. verticillata*. Propagation of *R. serpentina* in India gave a success rate of 40–65% from stem cuttings, 50–80% from root cuttings; a success rate of up to 90% has been obtained in Vietnam under careful management.
Successful in vitro propagation techniques have been developed for *R. serpentina*. Sterilized shoot tips can be cultured in Murashige and Skoog medium containing 3% sucrose. Best shoot response was obtained in the presence of 0.5 mg/l naphthalene acetic acid and 2 mg/l benzyladenine, with 15–20 shoots arising from one shoot tip. For rooting it is essential to replace benzyladenine by kinetin. When the resulting plantlets were planted in the field the survival rate was 60% and the plantlets were cytologically stable. Plantlets have also been successfully regenerated from shoot cultures of *R. serpentina* initiated from auxiliary meristems on medium containing benzyladenine (4.5 μM) and naphthalene acetic acid (0.5 μM). Rooting was initiated in White's basal medium supplemented with 0.5 μM naphthalene acetic acid. The resulting plants were similar to normal ones in their morphological characteristics and chemical constitution, but produced more biomass.
Nodal cultures of *R. serpentina* could be maintained for 9 months at 25°C on a standard Murashige and Skoog medium. Low-temperature incubation of in vitro cultures appeared highly promising because cultures exhibited normal health even after 15 months of storage at 15°C. Temperatures of 5–10°C were found to be deleterious to the growth of the cultures.
The total indole alkaloid content of *R. serpentina* roots from plants regenerated from stem and root callus was slightly higher than in the parental stock, but the content of ajmaline, serpentine and reserpine was lower.

In vitro production of active compounds Cell suspension cultures of *R. serpentina* have proved to be an excellent source of the enzymes involved in the biosynthesis of the alkaloids of the ajmalane and sarpagane class. Moreover, cell suspension culture is one of the most efficient methods for indole alkaloid formation. So far, about 30 different indole alkaloids have been isolated and identified from cultivated *Rauvolfia* cells. Alkaloid production under optimum conditions ranges from micrograms to grams per litre medium (e.g. yields of up to 1.6 g/l of raucaffricine have been obtained). A cell suspension culture of *R. serpentina* continuously treated with hydroquinone produced up to 18 g/l of p-hydroxyphenyl-O-β-D-glucoside (arbutin), which is the highest transformation rate ever observed with a plant cell culture system for a single natural product.
Raucaffricine (vomilenine-galactoside) has been shown to be the major indole alkaloid of cell suspension cultures of *R. serpentina* grown in alkaloid production medium. This compound is converted by an enzyme to its aglycon vomilenine, which has a key function in the biosynthesis of ajmaline. A higher content of intracellular indole alkaloids of the ajmaline type was found in a transgenic hairy root culture in liquid Murashige and Skoog medium than in the leaves and roots of the intact plant. It has also been found that phytosterols, including stigmasterol, β-sitosterol and

cholesterol, are produced in callus tissue cultures. It has been demonstrated that there are significant genome rearrangements in *R. serpentina* callus cultivated for a long time. These can occur at early stages of cultivation, but the process of subsequent subculturing in vitro leads to more significant genome changes. A highly productive cell line was found to be a partially synchronized myxoploid stable cell population in which tetraploid and multiploid cells and cells with a low level of structural mutations of the chromosomes predominated. The content of indole alkaloids in the tissue was positively correlated with the increase in the frequency of tetraploid and multiploid cells.
Hybrid cell suspension cultures have also been generated (e.g. from *R. serpentina* and *Rhazya stricta* Decne., and from *R. serpentina* and *Vinca minor* L.). Alkaloids not previously detected in the parental cell cultures may be formed in the hybrid culture, and in a cell line of a *R. serpentina* and *Vinca minor* hybrid a 10-fold increase in raucaffricine accumulation was observed relative to the parental *Rauvolfia* strain.

Husbandry Regular weeding and hoeing (2–3 times during the growing season in India) is needed to maintain satisfactory development of the roots. A top dressing of ammonium sulphate given after weeding will promote the development of a vigorous stand. *R. verticillata* grows more vigourously than *R. serpentina* and will soon shade out weeds. In Malaysia, *R. serpentina* has been found very sensitive to magnesium deficiency, causing severe chlorosis; application of moderate amounts of potash fertilizers is therefore recommended. In India, application of farmyard manure and compost showed a beneficial effect on the growth of *R. serpentina*.

Diseases and pests In India, wilting caused by *Fusarium* is the most serious disease in cultivated *R. serpentina*, followed by *Alternaria* leaf blight, powdery mildew, mosaic virus disease and root-knot disease, resulting in stunted growth. Leaf spot and blight caused by *Rhizoctonia solani* result in premature defoliation in the rainy season; weeding up to a distance of 45 cm from the plants effectively controlled the pathogen, as weeds serve as host. Young branches are sometimes infected with green bugs.

Harvesting The roots of *R. serpentina* are usually harvested from the wild, although it is cultivated to a limited extent, e.g. in India. When cropped, the roots are harvested after 1.5–3 years. Care should be taken to keep the root bark intact as it has a high alkaloid content. In Vietnam, it is recommended not to gather the roots of *R. verticillata* in spring because the concentration of active compounds is low then. Preferably, only roots with a diameter over 3 cm should be collected, leaving small-diameter roots for a next harvest.

Yield The average yield in *R. serpentina* plantations in India is 2 t/ha when roots are harvested 15 months after planting, and 36 t/ha when harvested after 3 years. However, harvesting after 15 months was found to be most lucrative. Under favourable soil conditions in Vietnam, 3-year-old plants produced on average 50 g of dried root rind. In a small-scale experiment in Peninsular Malaysia, the average yield of dried root per *R. verticillata* plant was 200 g 1.5 years after planting, 600 g after 2 years and 930 g after 3 years.

Handling after harvest Roots of *Rauvolfia* are usually cut into pieces 10–15 cm long. To prevent fungus infection they should be dried before storage to approximately 8% moisture content. Dried roots are usually packed in jute bags or bales, smaller quantities for regional markets are packed in polyethylene bags of 2–5 kg. Material to be packed in polyethylene bags must be adequately dried.

Genetic resources and breeding Natural populations of *R. serpentina* have been overexploited in many regions, particularly because roots are usually harvested, which destroys the plants. The species may now be extinct in Sri Lanka, due to intense exploitation, and in India and Java it has become rare. Several *Rauvolfia* species are threatened with extinction in Vietnam, e.g. *R. chaudocensis*, *R. indochinensis* and *R. vietnamensis*. These valuable plant resources must be protected by ex situ and in situ conservation. There are no known germplasm collections.

Prospects The use of *Rauvolfia* in galenic preparations and the use of reserpine have declined significantly in recent decades in industrialized countries because of their strong side effects and the availability of more effective alternatives. Moreover, reserpine has been suspected of having carcinogenic effects (causing breast neoplasm) and, although this effect has not been confirmed, its use has declined considerably and is unlikely to regain its former level. In developing countries, products based on *Rauvolfia* are still in demand owing to their easy availability and comparatively low prices, but it is expected that in the South-East Asian countries they will be gradually replaced by modern alternatives. As long ago as 1958, commercial cultivation of *Rauvolfia* was considered uneconomic in Malaysia, mainly because of the apparently adequate stocks of Indian origin, although trials had shown that it could be brought into cultivation at short notice. However, continued research might reveal new possibilities.

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Selection of species

Rauvolfia amsoniifolia DC.

Prodr. 8: 338 (1844).

Vernacular names Indonesia: parempasa, pamedang (Sulawesi). Philippines: sibakong (Tagalog), banogan (Panay Bisaya), maladita (Bikol, Bukidnon).

Distribution The Philippines, Timor, southern Sulawesi, southern Moluccas (Tanimbar Islands and Kai Islands).

Uses In the Philippines, a decoction of the bark is used as a stomachic and young leaves are used to treat stomach disorders in babies. In Indonesia, a decoction of the leaves is used as a laxative and febrifuge, and to stimulate delivery, the bark to treat framboesia.

Observations A shrub or small tree up to 15 m tall; leaves verticillate, lanceolate, 6–12 cm × 1.5–3 cm; flowers with campanulate-infundibuliform corolla tube at most twice the length of the calyx; fruit nearly obreniform. *R. amsoniifolia* occurs in lowland rain forest and in secondary thickets.

Selected sources 332, 580, 905, 1178.

Rauvolfia javanica Koord. & Valeton

Bijdr. 1: 191 (1894).

Vernacular names Indonesia: lameh, lameh utan (Sumatra).

Distribution Sumatra, Java and the Lesser Sunda Islands.

Uses Pounded leaves are used externally to treat wounds.

Observations A small to medium-sized tree up to 22(–30) m tall with bole up to 65 cm in diameter; leaves 3–4-verticillate, lanceolate, 14–30 cm × 3.5–6.5 cm, petiole rather thick, up to 1 cm long; flowers with campanulate-infundibuliform corolla tube at most twice the length of the calyx; fruit obversely trapezoid. *R. javanica* is closely related to *R. reflexa* and *R. sumatrana*. It occurs in lowland to lower montane rain forest up to 1800 m altitude, sometimes in open places.

Selected sources 97, 580, 905.

Rauvolfia reflexa Teijsm. & Binnend.

Nat. Tijd. Ned. Ind. 3: 329 (1852).

Vernacular names Indonesia: ki benteli (Sundanese), lameh, lameh utan (Java).

Distribution Java and the Lesser Sunda Islands.

Uses The bark is reported to serve as a laxative.

Observations A small tree up to 15 m tall with bole up to 25 cm in diameter; leaves 3–4-verticillate, obovate-elliptical, 6–21 cm × 3.5–6.5 cm, petiole thin, up to 1.5(–2.5) cm long; flowers with campanulate-infundibuliform corolla tube 2–3 times the length of the calyx; fruit subglobose with a broad obtuse base. *R. reflexa* is closely related to *R. javanica* and *R. sumatrana*. It occurs in lowland rain forest, also in forest edges, open places and beach forest, up to 1000 m altitude.

Selected sources 97, 580, 905.

Rauvolfia serpentina (L.) Benth. ex Kurz

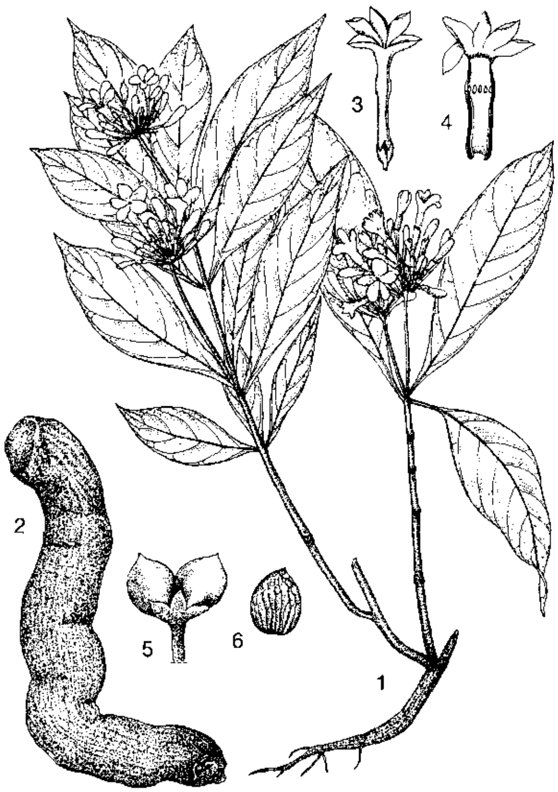
For. Fl. Burma 2: 171 (1877).

Synonyms *Ophioxylon serpentinum* L. (1753).

Vernacular names Indonesia: pule pandak (Javanese). Thailand: khem daeng (northern), ra yom (central), ka yom (peninsular). Vietnam: ba g[aj]c [aas]n d[ooj], ba g[aj]c hoa d[or], ba g[aj]c thu[oos]c.

Distribution India, Sri Lanka, Indo-China, southern China (Yunnan), Thailand, northern Peninsular Malaysia, Java and the Lesser Sunda Islands (Flores, Timor); cultivated in Pakistan, Nepal, India, Java, Ambon, Vietnam, southern China and Georgia.

Uses An extract of the root rind is considered as a highly effective remedy against high blood pressure and to relieve the central nervous system. Besides this, it is also used to treat dysentery, diarrhoea, psychoses, insanity, epilepsy and snake bites, and to stimulate uterine contraction and to promote the expulsion of the foetus. In Thailand, besides these uses, the roots are used to enhance appetite and as a galactagogue. In a mixture with other plants, *R. serpentina* is also used to treat cholera and fever. The leaf juice is applied against opacity of the cornea and to treat wounds and itch. The root is also used as a vermifuge in veterinary medicine.



Rauvolfia serpentina (L.) Benth. ex Kurz – 1, plant habit; 2, piece of root; 3, flower; 4, opened corolla; 5, fruit; 6, stone.

Observations A small shrub up to 0.6(–1) m tall, with prominent tuberous usually unbranched root and usually unbranched slender stem; leaves opposite or 3(–5)-verticillate, oblanceolate or obovate, 7–16 cm × 3–9 cm, petiole up to 1.5 cm long; flowers with narrowly cylindrical tube much longer than calyx; fruit consisting of 1–2 globose drupelets connate at base. *R. serpentina* occurs in sunny or shaded places in well-drained rain forest and secondary thickets up to 2100 m altitude, sometimes as a weed in sugar cane fields.

Selected sources 49, 78, 97, 118, 193, 476, 549, 580, 652, 796, 879, 905, 987, 1126, 1253, 1266, 1277, 1302, 1320.

Rauvolfia sumatrana Jack

Mal. Misc. 1(5): 22 (1820).

Synonyms *Cyrtosiphonia madurensis* Teijsm. & Binnend. (1823), *Cyrtosiphona sumatrana* (Jack) Miq. (1856), *Rauvolfia madurensis* (Teijsm. & Binnend.) Boerl. (1899).

Vernacular names Indonesia: lame lalaki (Sundanese), polay lakek (Madurese), tampa badak (Sumatra). Malaysia: pulai pipit, pelir kambing (Peninsular). Thailand: teenpet lek (Surat Thani), ra yom teenpet (Bangkok).

Distribution The Andaman Islands, Burma (Myanmar), Thailand, Peninsular Malaysia, Sumatra, Java, the Lesser Sunda Islands, Borneo, Sulawesi, the Moluccas, the Aru Islands and the Philippines.

Uses The bark is used to treat dysentery. In the Philippines, the dried bark is reported as an antimalarial. The lightweight wood is sometimes used for planks and small objects such as knife handles.

Observations A small to medium-sized tree up to 20 m tall; leaves 3–5-verticillate, elliptical-obovate to elliptical, 7–26 cm × 3–5 cm, petiole thin, up to 3 cm long; flowers with campanulate-infundibuliform corolla tube 2–3 times the length of the calyx; fruit subglobose with a broad obtuse base. *R. sumatrana* is closely related to *R. javanica* and *R. reflexa*. It occurs in lowland dipterocarp forest and teak forest, sometimes also in forest edges and secondary vegetation, up to 1400 m altitude.

Selected sources 97, 118, 202, 580, 905, 1564.

Rauvolfia verticillata (Lour.) Baillon

Bull. Soc. Linn. Paris 1: 768 (1888).

Synonyms *Dissolena verticillata* Lour. (1790), *Rauvolfia chinensis* (Spreng.) Hemsl. (1889), *Rauvolfia perakensis* King & Gamble (1907).

Vernacular names Indonesia: salung-salung (Sumatra). Malaysia: pokok batu pelir kambing (Peninsular). Thailand: cheepuk (northern), chaek (Trang), yaa kae haak khom (Chiang Mai). Vietnam: ba g[aj]c v[of]ng, t[is]ch ti[ee]n, sam t[oo].

Distribution India, Sri Lanka, Burma (Myanmar), Indo-China, southern China, Taiwan, Thailand, Peninsular Malaysia, Sumatra, Java, Lombok, Borneo and the Philippines (Luzon).

Uses The root is valued in Indo-Chinese and Chinese medicine as hypertensive and sedative. Fresh leaves are applied externally to treat snake bites, wounds and inflamed eyes.

Observations A shrub up to 3 m tall; leaves (2–)3-verticillate, elliptical, (8–)10–20 cm × (2–)4–6 cm, petiole up to 1.5 cm long; flowers with narrow cylindrical corolla tube much longer than calyx; fruit consisting of 1–2 elliptical drupelets. *R. verticillata* occurs in lowland to montane rain forest and monsoon forest, up to 1700 m altitude, often in open places in hills and mountains, e.g. along rivers, near villages and rice fields.

Selected sources 49, 118, 202, 850, 879, 905, 1035, 1564.

Tran Dinh Ly & Pham Duy Mai

Rhinacanthus nasutus (L.) Kurz

Journ. Asiat. Soc. Bengal 39, pt. 2, Nat. Hist.: 79 (1870).

ACANTHACEAE

$2n = 30$

Synonyms *Rhinacanthus communis* Nees (1832).

Vernacular names Indonesia: daun burung (Malay, Ambon), tarebak (Sundanese), tereba jepang (Malay, Jakarta). Philippines: parajito (Spanish), ibon-ibonan, tagak-tagak (Tagalog). Burma (Myanmar): anitia. Laos: thong kan[2] sang. Thailand: thong khan chang, thong phan chang, yaa man kai (central). Vietnam: b[aj]ch h[aj]c, ki[ees]n c[of].

Origin and geographic distribution *R. nasutus* is probably native to Sri Lanka, India, Indo-China and southern China, but has been introduced long ago in Madagascar, tropical East Africa, Thailand and the Malesian region (Peninsular Malaysia, Java, the Moluccas, the Philippines) where it is now widely naturalized and often common.

Uses The roots and leaves of *R. nasutus* are applied externally as a remedy for certain skin disorders such as ringworm, eczema, scurf and herpes. They are either soaked in vinegar or alcohol, pounded with lemon or tamarind, or made into a decoction. In Peninsular Malaysia, they are prepared with sulphur and benzoin or vaseline. In Thailand the leaves may be pounded with alcohol, lemon and tamarind juice. The resulting extract is applied on the infected skin. In Vietnam, an infusion of *R. nasutus* has a reputation in folk medicine for the treatment of hypertension. In China, the stem and leaves are also applied to treat ringworm infections, as well as in early stages of tuberculosis. When applied internally the leaf is used as an antipyretic, antihypertensive, anti-inflammatory and detoxicant, and against snake venom. *R. nasutus* is considered to be aphrodisiac. In Thailand, anti-cancer activity has been reported.

R. nasutus is also regularly planted as a hedge plant and has been applied for erosion control in road construction. Moreover, in Thailand it is planted for its ornamental value. In Madagascar, the seeds are used for scenting clothes.

Production and international trade The roots of *R. nasutus* used to be imported in Europe from China under the name 'tong pamg chong'.

Properties *R. nasutus* is reported to contain several naphthoquinones: rhinacanthin-A and -B have been isolated from roots collected in Thailand. Bioassay-directed fractionation showed significant cytotoxicity for the latter compound in the Kenacid Blue (KB) cell line with ED_{50} values of 3 μg/ml. The naphthoquinones rhinacanthin-C and -D, isolated from the aerial parts, exhibited potent inhibitory activity against human and murine strains of human cytomegalovirus (CMV) in vitro (ED_{50} values of 0.02 and 0.22 μg/ml, respectively). Several other naphthoquinones have been isolated. Most of these showed significant cytotoxicity, particularly rhinacanthin-D, -H, -K, -M and -Q, whereas they also showed inhibition of rabbit platelet aggregation.

From the methanol extract of stems and leaves of *R. nasutus* collected in south-eastern Thailand, an antifungal naphthoquinone was isolated with an ED_{50} value of 0.4 ppm on spore germination of *Pyricularia oryzae* (causing rice blast disease) and with 82% inhibition at 100 ppm. Originally the chemical structure of this naphthoquinone was thought to be 3,4-dihydro-3,3-dimethyl-2H-naphtho[2,3-b]pyran-5,10-dione, a p-quinone,

which is very similar to the structures of the rhinacanthins. Recently however, this structure was revised into 3,4-dihydro-3,3-dimethyl-2H-naphtho[1,2-b]pyran-5,6-dione, an o-quinone, also known as rhinacanthone.
Furthermore, two lignans, rhinacanthin-E and -F isolated from the aerial parts, exhibited significant antiviral activity against influenza virus type A.
A 95% alcohol extract of the aerial parts exhibited antimicrobial activity against *Staphylococcus aureus* at a dose of 100 mg/disk. The chloroform and alcohol extracts of aerial parts show antifungal activity against *Epidermophyton floccosum*, *Microsporum gypseum* and *Trichophyton rubrum*. The crude ethanol extract proved to possess relatively high acaricidal activity (71–85% mortality) tested in vitro on cattle ticks.
The aqueous extract of *R. nasutus* has a high anti-alkylating effect against ethyl methane sulphonate; anti-alkylating substances are associated with anti-carcinogenic activity.
Finally, phytochemical investigations have furthermore revealed the presence of flavonoids (lupeol) and phytosterols (β-sitosterol, stigmasterol and their glucosides).

Description An erect, branched shrub up to 2(–3) m tall; stems obtusely quadrangular, puberulent when young. Leaves opposite, simple, ovate to lanceolate or elliptical, 3–10 cm × 1–5 cm, base acute to attenuate, margin entire, apex acute, puberulent; petiole 0.5–2 cm long; stipules absent. Inflorescence an axillary, peduncled, lax cyme often combined into a leafy, terminal panicle, densely appressed pubescent. Flowers subsessile; calyx with 5 narrow lobes which are shortly connate at base, 5–6 mm long; corolla 2-lipped, tube narrowly cylindrical, green, upper lip with 2 teeth, 8–10 mm × 2–3 mm, white, lower lip with 3 large lobes, the central one 10–14 mm × 9–13 mm, white with red markings at base; stamens 2, inserted near the corolla tube apex, anther cells inserted at unequal level; disk present; ovary superior, 2-locular with 2 ovules in each cell, style 1, with a 2-fid stigma. Fruit a clavate, loculicidal, puberulous capsule, 17–25 mm long, basal part sterile. Seeds held up on well-developed hooks (retinacula), orbicular, flat, pubescent.

Growth and development In Java *R. nasutus* flowers throughout the year, but in the Philippines it flowers only in December–March. Pollination is by insects. Fruits apparently do not ripen in Java. The seeds are ejected from the capsule by the retinacula.

Rhinacanthus nasutus (L.) Kurz – 1, flowering twig; 2, upper part of flower; 3, fruit.

Other botanical information *Rhinacanthus* comprises about 10–15 species. It belongs to the tribe *Justicieae* of the subfamily *Acanthoideae*.

Ecology *R. nasutus* is found in thickets, hedges and waste places up to 750 m altitude. It thrives best on moist, well-drained soils, but it is also found in much drier habitats such as rock crevices.

Propagation and planting *R. nasutus* can easily be propagated by stem cuttings. Cuttings of about 10 cm, comprising 2–3 nodes, are planted under partial shade during the rainy season. Propagation by in vitro culture is another option. To obtain complete callus initiation and highest callus production in stem explants of *R. nasutus*, the Murashige and Skoog basal medium should be supplemented with the growth regulators 2,4-dichlorophenoxyacetic acid (2,4-D; 1.0 mg/l) and kinetin (1.0 mg/l).

Harvesting Mature leaves are hand picked when required, preferably shortly before flowering.

Yield Rhinacanthone has antifungal properties but occurs only at low concentration in *R. nasutus*.

Methyl 1-methoxy-2-naphthoate is one of several precursors also isolated from *R. nasutus*. This precursor can easily be transformed to rhinacanthone, thereby increasing the yield to 30%.

Prospects The naphthoquinones and lignans from *R. nasutus* display some very interesting effects, e.g. cytotoxic, antifungal or antiviral, which merit further attention.

Literature |1| Achararit, C., Panyayong, W. & Ruchatakomut, E., 1983. Inhibitory action of some Thai herbs to fungi. Undergraduate Special Project Report 1983. Faculty of Pharmacy, Mahidol University, Bangkok, Thailand. 13 pp. |2| Farnsworth, N.R. & Bunyapraphatsara, N., 1992. Thai medicinal plants. Prachachon Co. Ltd., Bangkok, Thailand. pp. 216–217. |3| Greshoff, M., 1894. Schetsen nuttige Indische planten [Sketches of useful Indonesian plants]. Series 1 (1–50). Extra Bulletin van het Koloniaal Museum. J.H. De Bussy, Amsterdam, the Netherlands. pp. 41–42. |4| Kernan, M.R. et al., 1997. Two new lignans with activity against influenza virus from the medicinal plant Rhinacanthus nasutus. Journal of Natural Products 60(6): 635–637. |5| Kodama, O., Ichikawa, H., Akatsuka, T., Santisopasri, V., Kato, A. & Hayashi, Y., 1993. Isolation and identification of an antifungal naphthopyran derivative from Rhinacanthus nasutus. Journal of Natural Products 56(2): 292–294. |6| Kuwahara, S., Nemot, A. & Hirmatsu, A., 1991. Synthesis of an antifungal naphthopyran derivative isolated from Rhinacanthus nasutus, Acanthaceae. Agricultural and Biological Chemistry 55(11): 2909–2912. |7| Nguyen Van Duong, 1993. Medicinal plants of Vietnam, Cambodia and Laos. Mekong Printing, Santa Ana, California, United States. pp. 35–36. |8| Sendl, A. et al., 1996. Two new naphthoquinones with antiviral activity from Rhinacanthus nasutus. Journal of Natural Products 59(8): 808–811. |9| Sinchaisri, P., 1989. Phon khong suan sakat khong phut totan mateng thimi, to alkylating activity khong ethyl methane sulphonate [Effects of solvent fractions of some anti-carcinogenic plants on the alkylating activity of ethyl methane sulphonate]. Warasan Wicha kan kaset 7(1–3): 27–33. |10| Wu, T.S., Tien, H.J., Yeh, M.Y. & Lee, K.H., 1988. Isolation and cytotoxicity of rhinacanthin A and B, two naphthoquinones from Rhinacanthus nasutus. Phytochemistry 27(12): 3787–3788.

Other selected sources 88, 97, 142, 190, 202, 287, 350, 580, 741, 801, 921, 933, 1126, 1128, 1178, 1287, 1380, 1508, 1525, 1530, 1600.

Wongsatit Chuakul, Noppamas Soonthornchareonnon & Promjit Saralamp

Schefflera J.R. Forster & J.G. Forster

Char. gen. pl.: 45, t. 23 (1775).
ARALIACEAE
$x = 12$; *S. elliptica*: $n = 24$

Major species *Schefflera elliptica* (Blume) Harms, *S. heptaphylla* (L.) Frodin.

Vernacular names Schefflera (En, Fr).

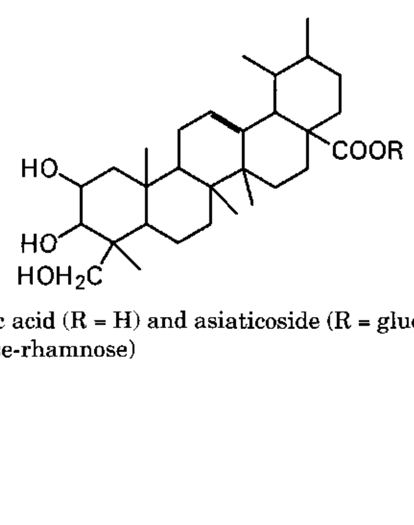
Origin and geographic distribution *Schefflera* probably comprises over 400 species and is widely distributed in the tropics and subtropics. In Asia it occurs from Sri Lanka north to the Himalayas and Japan, in Indo-China, Thailand and throughout the Malesian region towards northern Australia, New Zealand and east to Samoa in the Pacific.

Uses The leaves and bark of several *Schefflera* species are used as a remedy for cough and as a diuretic and tonic. The leaves show astringent properties and are, for example, given to women after childbirth. A decoction of the leaves of *S. elliptica* has been proved to be an effective antiscorbutic. The resin has been applied as a vulnerary. In Thailand, an infusion of the leaves is used to relieve asthma.

A great number of other *Schefflera* species are popular pot plants of considerable economic importance worldwide. In Vietnam, *S. leucantha* R. Vig. and *S. heptaphylla* are reported to be cultivated as ornamentals and pot plants. The wood of *S. heptaphylla* is soft, light and easy to work, and can be used for paper, musical instruments and matchboxes. The leaves and young branches are used as green manure.

Production and international trade Medicinal products from *Schefflera* are only used and traded on a local scale.

Properties Phytochemical investigations have revealed the presence of terpenoid saponins in the leaves and bark of *S. heptaphylla*. Asiaticoside and its aglycone asiatic acid have been isolated



asiatic acid (R = H) and asiaticoside (R = glucose-glucose-rhamnose) from the bark, together with cauloside D and several new related triterpene saponin glycosides. In general, the glycosides mentioned can be divided into two series of six corresponding ursene and oleanene glycosides, all of which have the same triose moiety in the C-28 position. This is why the names scheffursosides A–F and scheffoleosides A–F have been proposed for these corresponding pairs of glycosides, respectively (asiaticoside = scheffursoside A, cauloside D = scheffoleoside C). From the leaves of *S. heptaphylla*, 3-epi-betulinic acid and some of its (acetylated) glycosides (3,28-bidesmosidic saponins), oleanonic acid and other closely related triterpene saponins have been isolated. A betulinic acid glycoside has also been isolated from *S. elliptica*; moreover, its leaves also contain saponins.

Asiaticoside and asiatic acid are known to have several pharmacological effects, mainly involved in wound healing. There are literature reports of stimulation of human fibrinoblast collagen I synthesis (in vitro), just as bacteriostatic actions in tuberculosis models.

An aqueous extract from the leaves of *S. elliptica* showed bronchodilator activity on the isolated smooth muscle preparation of the respiratory tract of guinea-pigs (constrictions induced by addition of histamine). The effect was similar to other well known bronchodilators such as terbutaline and theophylline (as aminophylline). Therefore, the extract appears promising for the prevention and relief of asthmatic attacks, although the exact nature of the components involved in the action remains to be investigated. Furthermore, a leaf extract of *S. elliptica* showed a dose-related positive inotropic action on an atria preparation of rats.

Finally, saponins from the leaves of *S. leucantha* were found to have bronchodilator action.

Adulterations and substitutes Asiatic acid and asiaticoside have also been reported in extracts of *Centella asiatica* (L.) Urb., which is a pantropical species extending into some subtropical regions. Asiatic acid has also been found in ether extracts from the wood of *Terminalia brassii* Exell and *T. complanata* K. Schumann.

Description Evergreen or deciduous trees, shrubs and woody climbers, often epiphytic; twigs with stellate hairs or glabrous; leaves and bark fragrant when crushed. Leaves arranged spirally, palmately compound, rarely unifoliolate or 2–3 times palmately compound; stipules often elongate, connate and intrapetiolar; leaflets usually entire or occasionally coarsely toothed. Flowers in umbellules or small heads arranged in a panicle or rarely in a raceme or spike, bisexual, actinomorphic; pedicel not articulated; calyx rim-like, undulate or 5-toothed; petals 5 or more, valvate in bud; stamens usually 5, sometimes up to 12 or rarely more; disk epigynous; ovary inferior or half-inferior, 5–12-locular or rarely more, with a single ovule in each cell, styles as many as locules, united or free or absent and then the stigmas sessile. Fruit a smooth or slightly ribbed drupe, fleshy or dry, dark red or black when mature; pyrenes compressed.

Growth and development Many *Schefflera* species develop according to the architectural tree model of Leeuwenberg, in which 2 or more orthotropic modules develop below an inflorescence and these are equivalent and determinate by terminal flowering. Development according to the architectural tree model of Tomlinson, which is characterized by the repeated development of equivalent orthotropic modules in the form of basal branches, has been reported for an unidentified *Schefflera* species. Inflorescences may be terminal or lateral, growth of the modules is usually continuous, sometimes rhythmic. Several species develop strangling roots whereas others are unbranched treelets. Flowers are pollinated by insects.

Other botanical information *Schefflera* includes several previously recognized genera, the most important being *Agalma*, *Brassaia*, *Heptapleurum*, *Paratropia*, *Schiefflerapsis*, *Sciadophyllum* and *Tupidanthus*, although some authors still prefer to distinguish some or all of these separately. *Schefflera* includes several complexes in which species boundaries are still unclear; the Malesian species are in need of a thorough taxonomic revision. In the light of recent taxonomical insight, the species known almost universally since the 1890s as *Schefflera octophylla* (Lour.) Harms should be called *S. heptaphylla* (L.) Frodin. It is a renowned medicinal plant from Indo-China, southern China, Taiwan and the Ryukyu Islands.

Ecology Most medicinal *Schefflera* are found in the understorey of primary lowland rain forest, occasionally also in secondary forest and thickets. Individual species may be found on limestone hills, and up to 2500 m altitude.

Propagation and planting *Schefflera* can be propagated from ripe seed sown under humid conditions. Alternatively, propagation by air-layering, stem and softwood cuttings are common practice for the popular ornamental *Schefflera*.

Harvesting In Vietnam, the bark of stem and root of *Schefflera* are collected all year round, but the best time for harvesting is autumn or just before flowering.

Handling after harvest The stem bark of *Schefflera* is scraped off and the root-bark washed to remove the outer layer. The bark is then wrapped for 24–48 hours to develop the aroma as a result of fermentation, and dried in the shade.

Genetic resources and breeding *Schefflera* species confined to primary forest habitats and those with limited geographical distribution are potentially threatened by ongoing deforestation in South-East Asia. *S. elliptica* is widespread and commonly found in a wide range of habitats, including disturbed anthropogenic vegetation, and is less likely threatened.

Prospects *Schefflera*'s wound-healing properties and soothing effect on itching skin are probably related to the presence of the triterpenes asiatic acid and asiaticoside. The pharmacological effects of *Schefflera* triterpenes in general deserve further attention.

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Selection of species

Schefflera blancoi Merr.

Philipp. Journ. Sci. 1, Suppl.: 109 (1906).

Synonyms *Cephaloschefflera blancoi* (Merr.) Merr. (1923).

Vernacular names Philippines: sainat (Filipino), abkal (Igorot), sagaba (Iloko).

Distribution The Philippines.

Uses *S. blanco* is reputed to be used as a fish poison.

Observations A large climber; leaves with 10 leaflets, petiole about 1/3 of the length of the leaf, leaflets lanceolate, entire; flowers in rounded umbellules, 4–6-merous, stigma sessile. *S. blancoi* is commonly found on exposed ridges in mossy forests at 700–1500 m altitude.

Selected sources 190, 935.

Schefflera caudata (S. Vidal) Merr. & Rolfe

Philipp. Journ. Sci. 3, Bot.: 118 (1908).

Synonyms *Heptapleurum caudatum* S. Vidal (1885), *Schefflera acuminatissima* Merr. (1906), *Schefflera piperoidea* Elmer (1908).

Vernacular names Philippines: himainat (Filipino), lima-lima (Tagalog, Bisaya).

Distribution The Philippines (Luzon).

Uses A decoction of *S. caudata* is given as a tonic to women after childbirth.

Observations An epiphytic vine; leaves few, crowded towards the ends of twigs, 3-foliolate, leaflets elliptical, over 15 cm long, pointed at both ends; inflorescence terminal, with 1–5 main branches along which the rounded umbellules are racemosely displayed. The formerly recognized species *S. piperoidea* is now regarded as a variety: *S. caudata* var. *piperoidea* (Elmer) Frodin. *S. cau-*

data is found in primary forest at low to medium altitude.

Selected sources 190, 935, 936, 1178.

Schefflera cumingii (Seem.) Harms

Engl. & Prantl, Nat. Pflanzenfam. 3(8): 39 (1894).

Synonyms *Heptapleurum cumingii* Seem. (1865).

Vernacular names Philippines: kalkugamat (Filipino), kolokagama (Negrito).

Distribution The Philippines (Luzon).

Uses *S. cumingii* is reputed to be used to cure stomach troubles.

Observations A small shrub or scrambler or climber; leaves palmately 3–5-foliolate, petiole longer than the petiolules, leaflets thin, elliptical to ovate-elliptical, 10–15 cm long, pointed at two ends, without an intramarginal vein; main inflorescence axis shorter than its branches; flowers in umbellules; fruit obovoid, 5-locular. *S. cumingii* is found in primary forest at low altitudes; most localities have a relatively high and consistent rainfall.

Selected sources 190, 434, 936, 1126, 1178.

Schefflera elliptica (Blume) Harms

Engl. & Prantl, Nat. Pflanzenfam. 3(8): 39 (1894).

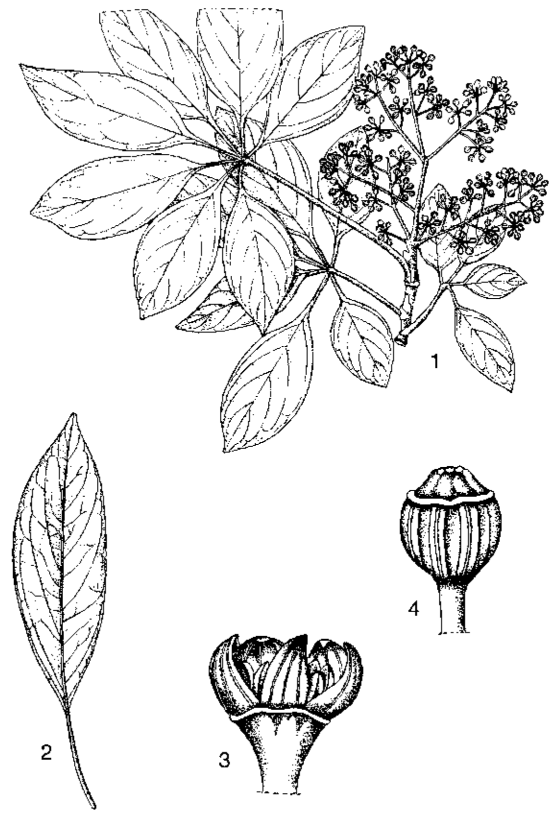
Synonyms *Schefflera venulosa* (Wight & Arn.) Harms (1894), *Schefflera odorata* (Blanco) Merr. & Rolfe (1908), *Schefflera bengalensis* Gamble (1919).

Vernacular names Indonesia: panakomo (Timor), putiana ma gitipi (Halmahera), tanganan (Javanese). Malaysia: ara bebari, chenamah gajah (Peninsular). Philippines: lima-lima (Filipino), arasagat (Iloko), galamai-amo (Tagalog). Laos: lep mu nang, pha nha hay, tang[2] to[1]. Thailand: mue phranaaraai (Trat), nuat plaa muek khao (Chiang Mai), waan oi chaang (Loei). Vietnam: d[as]ng nhi[eef]u g[aa]n, d[as]ng thu[oo]n, ch[aa]n chim leo.

Distribution From India to Indo-China, southern China, Thailand and throughout the Malesian region except for New Guinea.

Uses The bark is employed as a bechic, the resin as a vulnerary. A decoction of the leaves is an effective antiscorbutic and may also be used in aromatic baths. The wood has been chewed to relieve toothache. In India, the roots mixed with rice are eaten to cure dropsy.

Observations An epiphytic or terrestrial climber or shrub up to 10 m tall; leaves palmately



Schefflera elliptica (Blume) Harms – 1, flowering twig; 2, narrower leaflet; 3, flower; 4, fruit.

(4–)5–7-foliolate, petiole 10–12 cm long, leaflets ovate-elliptical to obovate-elliptical, 7–18 cm × 3–10 cm, apex acute or obtuse, entire, leathery, glabrous, petiolules 1.5–6 cm long; inflorescence with some branches as long as or shorter than the main axis, glabrescent, 10–20 cm long; flowers 5-merous, very small, in 10-flowered umbellules which are arranged racemosely along the branches; fruit globose to ovoid, usually 5–6-locular, yellow or orange becoming black. *S. elliptica* is common in secondary forest and thickets, often along rivers and also frequent along the coast and in mangrove vegetation, up to 2500 m altitude.

Selected sources 97, 190, 202, 287, 434, 580, 1126, 1291, 1314, 1380, 1435, 1476, 1525, 1526, 1564.

Schefflera elliptifoliola Merr.

Philipp. Journ. Sci. 13, Sect. C, Bot.: 320 (1918).

Vernacular names Philippines: galamai (Filipino).

Distribution The Philippines.

Uses A decoction of the leaves is used as a tonic by women after childbirth.

Observations An epiphytic shrub or woody climber; leaves palmately 9–11-foliolate, petiole 13–18 cm long, clasping the stem, leaflets elliptical to obovate-elliptical, 7–15(–25) cm × 4.5–7 cm, rounded at base, pointed at apex, entire, glabrous, on 3–5.5 cm long petiolules; inflorescence up to 20 cm long, primary branches 15–20; flowers 8–12 together in rounded umbellules, 5-merous, 8–12 mm long; fruit ellipsoid, 3–4 mm long. *S. elliptifoliola* is found in damp forest.

Selected sources 190, 934, 935, 1126, 1178.

Schefflera heptaphylla (L.) Frodin

Bot. Journ. Linn. Soc. 140: 314 (1990).

Synonyms *Vitis heptaphylla* L. (1771), *Schefflera octophylla* (Lour.) Harms (1894).

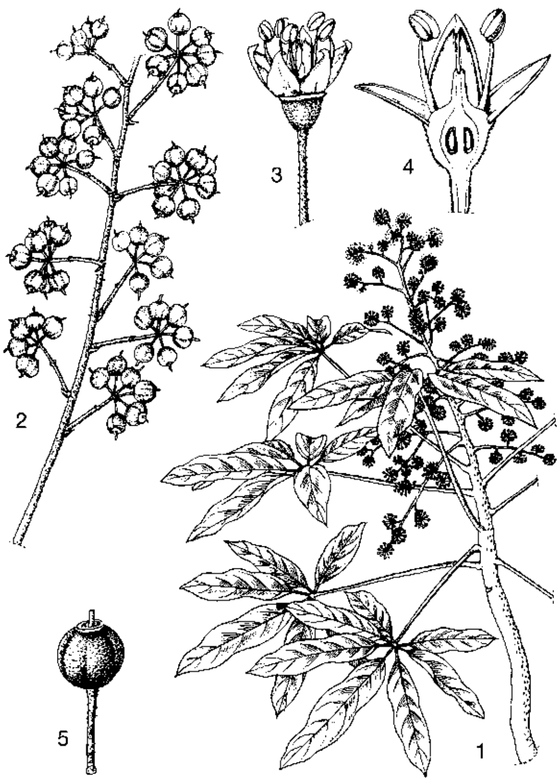
Vernacular names Laos: ko tan. Vietnam: ch[aa]n chim, nam s[aa]m.

Distribution Burma (Myanmar), Thailand, Indo-China, the Philippines (Batan Island), southern China, Taiwan, the Ryukyu Islands and southernmost Japan.

Uses The bark is widely used in folk medicine for its diuretic properties and as a tonic. The ashes are sometimes used to treat dropsy. In Hong Kong the fresh branchlets are used as a wash to soothe itching of the skin.

Observations A small to medium-sized, semi-deciduous or evergreen tree up to 25 m tall, bole up to 80 cm in diameter; leaves palmately 6–8(–11)-foliolate, polymorphic, petiole 8–35 cm long, leaflets elliptical to ovate-elliptical, 7–20 cm × 3–6 cm, base attenuate, apex narrowly pointed, margin entire, glabrous, petiolules unequal, 1–5 cm long; inflorescence a well-developed panicle with hairy branches; flowers in many-flowered umbellules or sometimes solitary at the top of secondary axes; flowers 5-merous, ovary 5–8(–10)-locular; fruit globular, 3–4 mm in diameter, black. *S. heptaphylla* is found in relatively open forest and forest edges. In southernmost Japan it occurs near sea-level; in the Ryukyu Islands up to 600 m elevation. Southward in the tropics its maximum altitude rises to 1200(–1400) m, or it even becomes entirely montane. Its distribution corresponds with the 20°C average January isotherm. Exploited from wild sources as well as from cultivation, this species can probably be grown easily at higher elevations in the Malesian region.

Selected sources 363, 435, 884, 1035, 1070, 1126, 1128, 1314, 1416, 1417, 1418, 1419, 1526.



Schefflera heptaphylla (L.) Frodin – 1, flowering twig; 2, part of infructescence; 3, flower; 4, flower in longitudinal section; 5, fruit.

Schefflera heterophylla (Wallich ex G. Don) Harms

Engl. & Prantl, Nat. Pflanzenfam. 3(8): 38 (1894).

Synonyms *Heptapleurum junghuhniana* (Miq.) Seem. (1865), *Schefflera junghuhniana* (Miq.) Harms (1894), *Schefflera curtisii* (King) Ridley (1922).

Vernacular names Malaysia: akar chabang lima, seregang (Peninsular). Thailand: khan haam suea (Nakhon Si Thammarat).

Distribution Thailand, Peninsular Malaysia and Java.

Uses A decoction of the leaves is given after childbirth.

Observations A large scrambling shrub; leaves 2–3 times palmately 3–5-foliolate, petiole 9–20 cm long, leaflets ovate to elliptical, 3.5–15 cm × 2–4.5 cm, oblique at base, long acuminate at apex, entire or with some coarse teeth above the middle, stellate-hairy when young; inflorescence branches about as long as the main axis, up to 30 cm long;

flowers 8–14 in each umbellule, 5–6-merous. *S. heterophylla* occurs in lowland to lower montane primary forest, up to 1700 m altitude.

Selected sources 97, 202, 1126, 1380, 1564.

Schefflera insularum (Seem.) Harms

Engl. & Prantl, Nat. Pflanzenfam. 3(8): 39 (1894).

Synonyms *Heptapleurum insularum* Seem. (1865), *Schefflera mindanaensis* Merr. (1908).

Vernacular names Philippines: galamai-amo (Filipino), kalangkang (Panay Bisaya), pararan (Bagobo).

Distribution The Philippines.

Uses The juice of pounded fresh leaves is used as a purgative.

Observations A woody climber; leaves palmately 7–9-foliolate, petiole about 20 cm long, leaflets oblong to oblong-elliptical, 10–24 cm × 3–8.5 cm, base cuneate, often slightly unequal, apex narrowly pointed, margin toothed in the upper half, glabrous, on 2.5–7 cm long petiolules; inflorescence 15–30 cm long, with only 1–3 branches of up to 20 cm long; flowers 9-merous, in small, 3–6-flowered umbellules, ovary 9–11-locular; fruit ovoid, 7–9 mm in diameter, orange. *S. insularum* is common in primary forest, often along streams, at low altitudes.

Selected sources 190, 932, 935, 1126, 1178.

Schefflera oxyphylla (Miq.) R. Vig.

Ann. Sci. Nat., Bot. IX, 9: 355 (1909).

Synonyms *Schefflera subracemosa* R. Vig. (1909), *Schefflera subulata* (Miq.) R. Vig. (1909), *Schefflera klossii* Ridley (1920).

Vernacular names Malaysia: akar pesat bedak, akar sepakan, akar sesudu (Peninsular).

Distribution Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses A decoction of the roots has been given as a sedative to calm frightened children and has been used externally against fevers.

Observations An epiphytic or terrestrial creeper or climber; leaves 3–5-foliolate, leaflets usually with 1–2 steeply ascending basal lateral veins; inflorescence branches spike-like, few-branched; flowers in very short-stalked umbellules. *S. oxyphylla* is a variable, common species occurring in lowland and hill forest, occasionally in submontane rain forest, sometimes on limestone, up to 1200 m altitude.

Selected sources 202, 1126, 1564.

Schefflera simulans Craib

Kew Bull.: 421 (1930).

Synonyms *Schefflera affinis* (King) R. Vig. (1909) non Baillon.

Vernacular names Malaysia: bekak rengat, pokok bajang beranak (Peninsular).

Distribution Thailand and Peninsular Malaysia.

Uses A decoction of the leaves has been used to cure stomach trouble, and that of the root and leaves has been applied as a protective medicine after childbirth.

Observations A terrestrial or epiphytic shrub up to 3 m tall; leaves palmately 5–7-foliolate, petiole 6.5–9 cm long, leaflets oblong-oblanceolate, 7–11 cm × 2–3.7 cm, base cuneate and unequal, apex acuminate, glabrous, petiolules 1.5–3.5 cm long; inflorescence 10 cm long, 15–20 cm wide, hairy but glabrescent; flowers about 10 per umbellule, 6–7-merous. *S. simulans* occurs locally in montane forest at 1300–1650 m altitude.

Selected sources 202, 291, 1564.

Schefflera trifoliata Merr. & Rolfe

Philipp. Journ. Sci. 3, sect. C, Bot.: 118 (1908).

Vernacular names Philippines: sinat (Filipino), gauai-gauai, himainat (Tagalog).

Distribution The Philippines.

Uses Crushed leaves, with or without oil, are applied externally against tympanites of children. Internally, the leaves are given to women after childbirth and to treat irregular menstruation.

Observations A woody vine; leaves 3-foliolate, petiole 3–8 cm long, leaflets oblong to oblong-ovate, apex caudate-acuminate, entire, petiolules 1.5–4 cm long; inflorescence 20–25 cm long, with few branches; flowers many, in 3–6-flowered umbellules, pedicels 4–5 mm long; fruit oblong, 6 mm × 3 mm, 5-locular. *S. trifoliata* is found in primary forest at low and medium altitudes.

Selected sources 190, 935, 936, 1126, 1178.

Nguyen Tap & M.S.M. Sosef

Scutellaria L.

Sp. pl. 2: 598 (1753); Gen. pl. ed. 5: 260 (1754).

LABIATAE

x = unknown; *S. discolor*: $2n = 24, 26$

Major species *Scutellaria javanica* Jungh.

Vernacular names Skullcap (En). Scutellaire (Fr). Vietnam: thu[aax]n.

Origin and geographic distribution *Scutellaria*, with 360 species, is almost cosmopolitan.

Originally it was absent only from the Amazon Basin, lowland tropical Africa, South Africa, deserts of Central Asia, most of the Pacific Islands and New Zealand, and north of the Arctic circle. The centres of diversity are found in the mountain regions of Central Asia and China, which are also considered to be the regions where *Scutellaria* originated; only 3 species are native in Malesia.

Uses A multitude of *Scutellaria* species are used internally in the form of infusions and decoctions to alleviate stomach complaints and as a diuretic and antipyretic. Various species are used externally as a decoction or poultice to treat fungal skin infections as well as boils or scabies.

Outside the Malesian region *S. baicalensis* Georgi is an important medicinal plant, cultivated extensively for its roots in China, Korea and Japan. The roots are used in traditional Vietnamese medicine as a general tonic to balance the body, to treat bacterial infections of the respiratory and gastro-intestinal tracts, and this species has been successfully grown in northern Vietnam.

Properties *Scutellaria* species, like many other *Labiatae,* contain an essential oil. The constituents of this oil are referred to as belonging to the monoterpenoids, sesquiterpenoids, phenylpropane derivatives or iridoid glycosides without further specification. *Scutellaria* species are also reported to contain diterpenes (in aerial parts e.g. of the neoclerodane type), large amounts of triterpenes, phytosterols and phenolic constituents (e.g. caffeic acid, flavonoids).

The presence and biological activities of flavonoids in *Scutellaria* have been particularly well studied. The aerial parts of *S. discolor* were found to contain chrysin, chrysin-7-O-glucuronide, apigenin, luteolin, wogonin, 5,7-dihydroxy-8,2'-dimethoxyflavone, 5,7,8-trihydroxyflavone-8-O-βD-glucuronide, 5,7,2',6'-tetrahydroxy-8-methoxyflavone-2'-O-βD-(2-O-caffeoyl)-glucoside, 5,7-dihydroxy-8,2'6'-trimethoxyflavone and 5,7,4'-trihydroxy-8-methoxyflavone. The latter two compounds are also present in the roots of *S. discolor*, together with pinocembrin, wogonin, wogonin-7-O-glucuronide, norwogonin, norwogonin-7-O-glucuronide, 7-hydroxy-5,8-dimethoxyflavone, 7-hydroxy-5,8,2'-trimethoxyflavone, 5,7-dihydroxy-8,2'-dimethoxyflavone, 5,7,2'-trihydroxy-8-methoxyflavone, 5,7,2'-trihydroxy-8,6'-dimethoxyflavone, 2(S)-5,7-dihydroxy-8,2'-dimethoxyflavanone, 2(S)-7-hydroxy-5,8,2'-trimethoxyflavanone, 5,2'-dihydroxy-7,8,6'-trimethoxyflavanone, 5,2'-dihydroxy-6,8,6'-trimethoxyflavanone and 2'4'-dihydroxy-2,3',6'-trimethoxy-chalcone.

The flavonoids scutellarin, found in *S. baicalensis* and *S. javanica*, and baicalein (= 5,6,7-trihydroxyflavone) inhibit the activity of partially purified rat brain protein kinase C. Various flavonoids present in *S. baicalensis* also show inhibitory effects against a considerable number of viruses: e.g. baicalin (= 5,6-dihydroxyflavone-7-O-βD-glucuronide) against the human T cell leukaemia virus type 1 and the human immunodeficiency virus (HIV-1), 5,7,2'-trihydroxy- and 5,7,2',3'-tetrahydroxyflavone against the Epstein-Barr virus, and 5,7,4'-trihydroxy-8-methoxyflavone against A-H3N2 subtype and B-subtype of the influenza virus. 2(S)-5,7,2',6'-Tetrahydroxyflavanone showed a remarkable antibacterial activity against e.g. *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus*.

Furthermore, baicalein shows antiproliferative activity in cultured rabbit vascular muscle cells, and lipoxygenase-inhibitory activity. It may be useful as a template for the development of drugs to prevent the pathological changes of atherosclerosis and restenosis. The pharmacological action of baicalein may be partially attributed to its free radical scavenging activity. Other pharmacological activities of the flavonoids include: anti-inflammatory activity of baicalein in the rat adjuvant arthritis model, inhibition of LPS-induced IL-1 production by baicalin, baicalein and wogonin, and inhibition by baicalein of leukotriene C-4 biosynthesis by rat resident peritoneal macrophages. Another effect of the flavanoids is the inhibition of the release of slow reacting substances of anaphylaxis (SRS-A) from sensitized guinea-pig lungs after antigen challenge.

Description Perennial or rarely annual herbs or small shrubs; stems prostrate to erect, often 4-angled. Leaves opposite, simple, margin entire to pinnatifid, petiolate to subsessile, exstipulate. Flowers solitary, opposite or in small false whorls, in the axil of leaves or bracts, in terminal or axillary, 1-sided or all-sided racemes or spikes; calyx with a short tube, 2-lipped, the lips entire, upper lip deciduous, with a large shield- or pouch-like appendage or rarely both lips expanded to form a bladder-like structure; corolla 2-lipped, with a usually long tube which is bent upwards at base or bent distally or both, upper lip hooded, entire or notched, lower lip 3-lobed; stamens 4, inserted on the corolla tube, didynamous, anterior pair longest, anthers of the anterior pair 1-celled, those of the posterior pair 2-celled; disk tubular; ovary superior, on a short gynophore, 2-carpellate but 4-locular with a single ovule in each cell, style with a 2-fid stigma. Fruit consisting of 4 dry, ovoid to globose nutlets. Seeds without endosperm. Seedling with epigeal germination; cotyledons free, leafy; hypocotyl elongated; all leaves opposite.

Growth and development Malesian *Scutellaria* species have been found flowering throughout the year. In Taiwan *S. indica* has been observed flowering and fruiting from September to May. Pollination is by insects, mainly bees. The nutlets are simply shed when the wind tosses the inflorescence to and fro, without a distinct dispersal mechanism.

Other botanical information *Scutellaria* takes a rather isolated position within the *Labiatae*, being the only genus of the subfamily *Scutellarioideae*. Its subdivision into subgenera and sections has been subject to much debate, but the most recent view recognizes 2 subgenera, *Scutellaria* and *Apeltanthus*, and 7 sections. All Malesian species belong to the subgenus *Scutellaria* and section *Scutellaria* which harbours about 240 species.

Ecology *Scutellaria* species generally occur on grassy plains, along forest tracks and streams, in forest edges, but also in open primary forest and savanna forest, in Malesia from the lowland up to 2400(–3300) m altitude.

In vitro production of active compounds Research on in vitro production of flavonoids in *Scuttelaria* is restricted to *S. baicalensis*. Cell suspension culture as well as stem callus culture yielded a range of flavonoids, with the major constituents being baicalin and wogonin-7-0-glucuronic acid.

Harvesting *Scuttelaria* plants are uprooted to collect the roots.

Handling after harvest The roots are washed and dried before being stored.

Prospects The flavonoids isolated from various *Scutellaria* species show a broad range of interesting pharmacological effects that merit further research, e.g. the inhibition of several pathological viruses, activities on the immune system (including inhibition of immune factors) and free radical scavenging activity.

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Selection of species

Scutellaria discolor Wallich ex Benth.

Wallich, Pl. asiat. rar. 1: 66 (1830).

Synonyms *Scutellaria cyrtopoda* Miq. (1859), *Scutellaria heteropoda* Miq. (1859), *Scutellaria zollingeriana* Briq. (1898).

Vernacular names Indonesia: jawer kotok (Sundanese), amperu lemah (Javanese), daun kukur (Moluccas). Malaysia: nilam bukit (Peninsular), toma (Sakai, Peninsular). Vietnam: thu[aax]n nhi[eef]u m[af]u.

Distribution From northern India and Nepal to Burma (Myanmar), Indo-China, southern China, Thailand, Peninsular Malaysia, Java, the Lesser Sunda Islands, the Moluccas and New Guinea.

Uses In Java, *S. discolor* has been used to treat pain in the loins. In China, it is applied as a folk remedy for colds, fever, sore throat, and enteritis.

Observations A small herb up to 50(–100) cm tall, stems hirsute, usually simple; leaves broadly elliptical to rounded or rarely ovate, (3.5–)4–6(–11) cm × (2–)2.5–5(–10) cm, base rounded to cordate, margin coarsely crenate, sparsely pubescent to hirsute; bracts 1–3 mm long; flowers in small false whorls of 2–4(–5), in a simple, terminal, all-sided raceme of 5–24 cm long, glandular pubescent, corolla blue or pale blue to purple-violet, 9–12 mm long. *S. discolor* is subdivided into three varieties: var. *hirta* Handel-Mazzetti occurring in Yunnan (China), var. *cyrtopoda* (Miq.) Adelb. found at 1600–3200 m altitude in Java, and var. *discolor* occurring throughout the range of *S. discolor*. It is found in grassland along streams, shady and moist places in rain forest, in Irian Jaya in oak forest, in Timor on limestone in *Podocarpus* forest, up to 2400(–3200) m altitude.

Selected sources 202, 287, 580, 720, 854, 1118, 1126, 1461, 1462, 1463, 1476.

Scutellaria indica L.

Sp. pl. 2: 600 (1753).

Synonyms *Scutellaria copelandii* Merr. (1912).

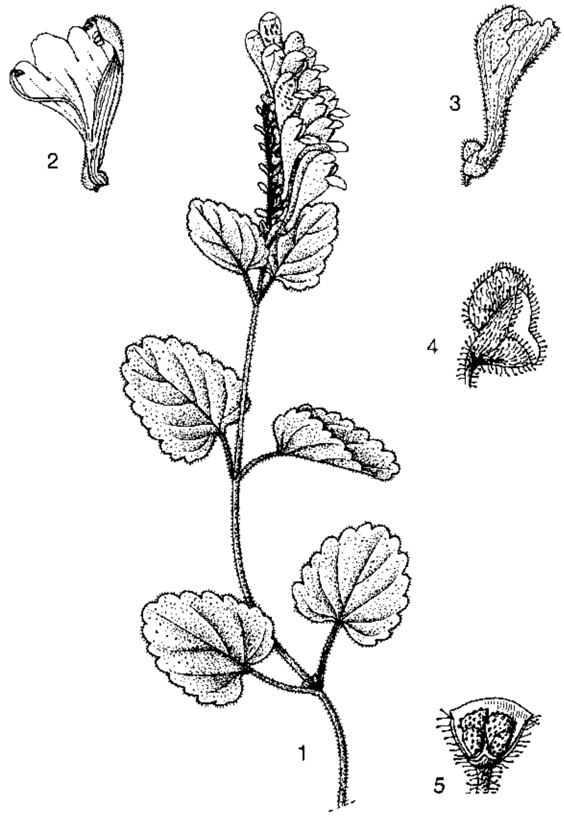
Vernacular names Indonesia: bangun bangun batu (Batak), daun kukuran (Java). Philippines: banod (Bagobo). Vietnam: thu[aax]n [aas]n d[ooj].

Distribution From India to Indo-China, China, Japan, Taiwan, the Philippines, Thailand, Sumatra, West Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and New Guinea.

Uses In China, a decoction of *S. indica* is used as a folk remedy for traumatic injuries, whereas a poultice is applied to skin affected by fungal diseases. It is also carminative, tonic and resolves blood clots. In Indo-China its roots are regarded as febrifuge and also recommended for skin diseases such as scabies and boils.

Observations A small herb up to 30 cm tall, stems prostrate to ascending, often simple; leaves broadly ovate to rounded or reniform, 1.5–2(–3) cm × 1.5–2 cm, base cordate to truncate or rarely cuneate, margin crenate, appressed hirsute on both surfaces; bracts 2–3 mm long; flowers opposite, in a simple, terminal, 1-sided raceme of 2–8(–12) cm long, hirsute to puberulent, corolla pale to deep purple, (10–)15–20 mm long. *S. indica* has been subdivided into several varieties, but within Malesia only var. *indica* occurs. It is found infrequently on cliffs and boulders along streams, grassy open plains, along tracks in secondary forest, up to 2300 m altitude.

Selected sources 624, 720, 854, 1118, 1126, 1476.



Scutellaria indica L. – 1, flowering stem; 2, opened corolla; 3, flower; 4, calyx with scutellum; 5, nutlets.

Scutellaria javanica Jungh.

Java 1, ed. 2: 661 (1853).

Synonyms *Scutellaria horsfieldiana* Miq. (1859), *Scutellaria sumatrana* Miq. (1859), *Scutellaria russeliaefolia* Vatke (1872), *Scutellaria luzonica* Rolfe (1884).

Vernacular names Indonesia: kapunten, upar upar (Javanese), bangun bangun na gerger (Karo-Batak). Philippines: lupingan, sidit (Igorot). Vietnam: thu[aax]n java.

Distribution Indo-China, the Philippines, Sumatra, Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and New Guinea.

Uses In the Philippines, a decoction of *S. javanica* is used to cure stomach pains.

Observations A herb or slender shrub up to 1 m tall, stems procumbent to erect, branched; leaves lanceolate to broadly ovate, 0.5–5(–10) cm × 0.3–2.5(–3.5) cm, base slightly cuneate or rounded to subcordate, margin usually remotely crenate or dentate, puberulent on both surfaces; bracts

(2–)3–6 mm long; flowers opposite, in a simple, terminal, 1-sided raceme of (2–)4–10(–20) cm long, hirsute to puberulent, corolla blue or white, 14–16 mm long. *S. javanica* has been subdivided into 4 varieties, mainly on characters concerning the leaves. One of these, var. *luzonica* (Rolfe) H. Keng is sometimes regarded as a distinct species. It is found in open, primary or secondary, lowland to montane forest, coffee estates, savanna forest, in ravines, on ridges in mossy forest, on various soils including peat overlying sand, up to 2850(–3300) m altitude.

Selected sources 190, 720, 854, 1118, 1126, 1178.

H.P. Hernandez

Senna Miller

Gard. Dict. abr. ed. 4, vol. 3 (1754).

LEGUMINOSAE

x = 11, 12, 13, 14; *S. alata*: $2n$ = 28, *S. garrettiana*: $2n$ = 28, *S. sophera*: $2n$ = 28

Major species *Senna alata* (L.) Roxb., *S. sophera* (L.) Roxb., *S. tora* (L.) Roxb.

Vernacular names Malaysia: bebusok. Cambodia: angkanh. Laos: khi lek. Vietnam: mu[oof]ng.

Origin and geographic distribution *Senna* comprises about 260 species and has a pantropical distribution; a few species extend to temperate regions. Tropical Asia has far fewer *Senna* species than tropical America, Africa and Australia. Only about 7 species occur naturally in tropical Asia, and only about 5 in the Malesian region, including *S. tora*. Approximately 10 species have been introduced in Malesia and have become naturalized or even weedy (e.g. *S. alata* and S. sophera) others are planted as ornamentals and are only rarely found as escapes. *S. garrettiana* (Craib) Irwin & Barneby, which is an important medicinal species, is endemic to Indo-China and northern Thailand.

Uses The main medicinal uses of *Senna* in South-East Asia are in the treatment of skin problems and as a laxative or purgative. Skin problems treated with *Senna* include ringworm (e.g. *S. alata*, *S. garrettiana*, *S. hirsuta* (L.) Irwin & Barneby, *S. occidentalis* (L.) Link, *S. sophera* and *S. tora*), scabies (e.g. *S. alata*, *S. timoriensis* (DC.) Irwin & Barneby), eczema (*S. hirsuta*, *S. occidentalis*) and itching (*S. alata*, *S. timoriensis*). Laxative properties have been reported for *S. alata*, *S. garrettiana*, *S. obtusifolia* (L.) Irwin & Barneby, *S. occidentalis*, *S. siamea* (Lamk) Irwin & Barneby, *S. surattensis* (Burm. f.) Irwin & Barneby and *S. tora*.

The wood of *S. alata*, *S. garrettiana* and *S. siamea* is included in recipes for decoctions to treat liver problems, urticaria, rhinitis and loss of appetite caused by gastro-intestinal problems. The heartwood of *S. garrettiana* is the Thai drug 'Sae mae sarn', which is used as a mild purgative. *S. siamea* and *S. timoriensis* are used as vermifuge. In Indonesia, a decoction of young *S. siamea* leaves has been suggested for the treatment of malaria. In Burma (Myanmar), leaves, flowers and fruits of *S. siamea* are ingredients of a broth which is used as a tonic and to treat stomach problems. In Thailand, the heartwood of *S. siamea* is considered as a tranquillizer, antipyretic, and used in the treatment of venereal diseases; the leaves are used in the treatment of leucorrhoea; antihypertensive and antipyretic properties are ascribed to the flowers. The leaves of *S. obtusifolia* are used against vomiting and stomach-ache. The leaves of *S. occidentalis* are used in cases of toothache and headache. The seeds act as an emeto-cathartic and in the Philippines are used to treat fever. A decoction of the roots of *S. surattensis* is used against gonorrhoea, a decoction of the leaves is used against dysentery.

The bark of *S. alata* contains tanning material; the seeds are a promising source of gums. The bark of *S. auriculata* (L.) Roxb. is used as a source of tannin, but the astringent properties are also of medicinal importance. Toasted leaves of *S. alata* and the seeds of *S. tora* are sometimes used as a coffee substitute. The young pods of *S. alata* and the young leaves of *S. tora* may, in small quantities, be eaten as a vegetable. In West Africa, the roots of *S. tora* are used for tattoos or tribal markings.

Properties Many of the pharmacological effects of *Senna* species can be attributed to the presence of anthraquinone derivatives. The basic structure of these compounds is the 9,10-anthraquinone. They differ in the arrangement of the attached substituents. The derivatives may occur in various oxidation stages; anthraquinones can be reduced to anthrones, which may be oxidized to dianthrones. Dianthrones, on the other hand, can be reduced back to anthrones, which may oxidize to anthraquinones relatively easily.

Anthraquinone and dianthrone drugs are used as laxatives. The presence of sugar in the molecule is a prerequisite for their pharmacological action; it enhances their solubility in water, thus facilitating their transport to the site of action (the colon).

Bacteria in the colon hydrolyse the glycosides and dianthrones to anthraquinones, a reaction which is immediately followed by the local reduction of the anthraquinones to their corresponding anthrones. The latter compounds act directly on the large intestine, to stimulate peristalsis. However, laxative drugs containing anthraquinone derivatives should be used with caution, as daily and prolonged use can lead to dependence and 'cathartic colon'.

In anthrones, the explicit chemical structure is very reactive. An imperfectly understood mechanism enables these compounds to completely inhibit cell growth and thymidine incorporation in human cultured cells, and inhibit both DNA replication and repair synthesis. Because of these effects on the cell cycle, anthrones may be used as topical agents in the treatment of psoriasis. Their (topical) use in the treatment of skin infections, and their fungicidal properties (treatment of ringworm) have also been reported in the literature. Furthermore, their reactiveness makes these compounds very irritant to the eyes and mucous membranes; they should never be used systemically.

Extensive phytochemical investigations have revealed much information about the constituents of several *Senna* species. Components isolated from the leaves of *S. alata* include the anthraquinone derivatives rhein (cassic acid), rhein-anthrone and aloe-emodin-anthrone, and flavonoids (e.g. kaempferol, glycosides). The yellow phenolic pigment cassiaxanthone has been isolated from the roots. *S. sophera* has been reported to contain the anthraquinones chrysophanol (chrysophanic acid) and emodin.

The reported constituents from *S. tora* seeds include anthraquinone derivatives (emodin, physcion, chrysophanol (chrysophanic acid), chrysophanol-triglucoside, chrysophanol-tetraglucoside, chryso-obtusin, aurantio-obtusin and obtusifolin-glucoside), naphtho-γ-pyrones (cassiaside, rubrofusarin-gentobioside, rubrofusarin-glycoside), toralactone-gentobioside (a naphtho-α-pyrone), cassitoroside (a naphthalene glycoside) and β-sitosterol (a sterol). *S. tora* also contains the flavonoid glycoside kaempferol-3-sophoroside. Anthraquinone derivatives (chrysophanol (chrysophanic acid), chrysophanol benzanthrone, chrysophanol dianthrone, cassialoin, (–)-11-deoxyaloin), bibenzyl derivatives, flavonoids, stilbene derivatives and polyphenolic compounds (cassigarol A–G, scirpusin B) have been isolated from the heartwood of *S. garettiana*. Seeds of several *Senna* species (including *S. alata*, *S. hirsuta*, *S. occidentalis*, *S. siamea* and *S. tora*) are reported to contain the enzyme urease.

Some other pharmacological activities of anthraquinone derivatives and other *Senna* constituents in addition to the purgative effect are mentioned in the literature. In an assay with *Salmonella typhimurium* the methanol extract of *S. tora* seeds showed antimutagenic activity against aflatoxin B1. The numbers of revertants per plate decreased significantly when this extract was added to the assay system. The extract was not able to inhibit the direct-acting mutagen N-methyl-N'-nitro-N-nitrosoguanidine; this suggests that it may prevent the metabolic activation of aflatoxin B1 or scavenge the electrophilic intermediate capable of inducing mutations. Activity guided isolation yielded the anthraquinones chrysophanol (chrysophanic acid), chryso-obtusin and aurantio-obtusin, and the naphtho-γ-pyrones cassiaside and rubrofusarin-gentobioside as pure compounds. All of these demonstrated significant antimutagenic activity.

S. alata extracts have shown antibacterial and antifungal properties (e.g. against *Pityriasis versicolor* in humans) and anti-tumour activity; they might be useful in the treatment of opportunistic infections in AIDS patients. Leaf extracts of *S. tora* also have antifungal activity. The major antifungal principle has been shown to be chrysophanol-anthrone (chrysophanic acid-anthrone), which is also present in the seeds.

Furthermore, the polyphenol cassigarol A (from *S. garrettiana*) inhibits H^+/K^+-ATPase, resulting in a reduced gastric acid secretion. The flavonoid glycoside kaempferol-3-sophoroside (from *S. tora*) has analgesic activity, as has been shown by intraperitoneal injections in mice and rats. Naphtha-pyrone glycosides in *S. tora* seeds have been found to protect the liver against galactosamine damage. The leaves of *S. siamea* exhibits central nervous system depressant effects, and the compound responsible for the activity is barakol.

Raw *S. tora* seeds have furthermore been found to be highly toxic in experiments with rats; pigs fed on leaves and pods of *S. siamea* in the Philippines died.

Adulterations and substitutes It is reported that in China *S. occidentalis*, *S. sophera*, *S. tora* and *Chamaecrista mimosoides* (L.) Greene are used medicinally almost without distinction. Anthraquinone glycosides and sennosides are also found in *Cassia* species, which are also used for their laxative and purgative properties.

Description Herbs, shrubs or small to medium-sized trees up to 20(–30) m tall; bole usually short, up to 50 cm in diameter, bark surface smooth, greyish. Leaves alternate, paripinnate with up to 24(–40) pairs of leaflets, sometimes with extra-floral nectaries; stipules small, usually caducous. Inflorescence an axillary raceme, often becoming corymbose-paniculate towards the tips of branchlets, 1–many-flowered. Flowers bisexual, 5-merous; sepals imbricate, obtuse at apex; corolla with subequal to heteromorphic petals, yellow; androecium basically 10-merous, filaments all straight and never more than twice as long as anthers, accrescent towards the abaxial side of the flower; ovary superior, linear and curved. Fruit a stipitate, often strap-shaped, terete to compressed, indehiscent or inertly dehiscent pod, usually with septae between the numerous seeds. Seeds with distinct areole. Seedling with epigeal germination; cotyledons emergent, semi-fleshy.

Growth and development *S. alata* has Scarrone's architectural model: an indeterminate trunk with tiers of orthotropic branches, which branch sympodially because they have terminal inflorescences. Most of the medicinally important *Senna* species are reported to flower and fruit throughout the year, though fluctuations occur in pronounced monsoon climates. Growth of *S. tora* is affected by photoperiod, and pods are only produced when plants receive 8–11 hours of light. Flowers are produced at 6–12 hours of light.

Other botanical information Until the beginning of the 1980s *Cassia* was considered to be a very large genus of over 500 species, but then it was split into 3 genera: *Cassia* sensu stricto, *Senna* and *Chamaecrista*. *Cassia* now has only about 30 species, whereas *Senna* and *Chamaecrista* comprise about equal numbers of species (about 260 and 270 respectively). *S. tora* is closely related to *S. obtusifolia*, which is similar in appearance, but *S. obtusifolia* can easily be recognized by its longer pedicels. *S. sophera* is closely related to *S. occidentalis*, and the two are often confused.

Ecology In South-East Asia, *S. alata*, *S. sophera* and *S. tora* are found in a multitude of habitats, but preferably in disturbed, rather open (anthropogenic) vegetation: roadsides, river banks, rain forest edges, lake shores, margins of ponds and ditches, in open forest and wet areas, in orchards and around villages. *S. alata* is found up to 1400(–2100) m altitude but is more common at lower elevations. The other species are only found at lower elevations: *S. sophera* up to 400 m and *S. tora* up to 1000 m altitude. *S. alata* and *S. tora* are reported to tolerate an annual rainfall from 600 mm to 4300 mm and average yearly temperatures of 15–30°C. Soils should retain moisture adequately, although *S. tora* is tolerant of considerable drought, whereas the pH may range between 4.3–8.0.

Propagation and planting *Senna* can be propagated by seed. Propagation by stem and root cuttings has not been successful. *S. tora* has hard seeds and mechanical and acid scarification are equally effective in breaking dormancy. *S. tora* germinates in continuous light or darkness and under alternating light conditions. No germination occurs below 13°C or above 40°C. Seed stored at 15–20°C germinates when scarified and placed in a 30°C environment. The stage of maturity at harvest affects seed viability and germination. In dry storage seed loses viability somewhat rapidly (germination 22% after 3 years). Germination is optimal when soil moisture is 75% of field capacity. Shoot and root dry matter production diminish at densities above 20 plants/m^2. The number of flowers and fruits per plant drop at densities between 10 and 20 plants/m^2. The average number of seeds/m^2 increases from about 40 (1 plant/m^2) to a maximum of about 570 (17 plants/m^2); it drops to about 145 at a density of 40 plants/m^2.

In vitro production of active compounds Anthraquinones have been obtained from plant cell cultures of *S. tora*, with yields of 0.33% of the fresh weight.

Diseases and pests In Indonesia, brown leaf blight caused by *Cercospora* sp. is reported on *S. alata*. In Uganda, common bean mosaic necrosis virus has been isolated from *S. sophera*. In India, *S. tora* is reported to be attacked by the defoliator *Myllocerus viridanus* and the bruchids *Callosobruchus chinensis*, *Bruchidius cassiae* and *Caryedon lineatonota*. The seed bruchid *Sennius instabilis* has been suggested as a potential biological agent for controlling *S. tora* in pastures.

Harvesting The leaves of *S. alata* are harvested when needed. The active constituents are probably most abundant prior to flowering, which is why the leaves are preferably collected at that time. The pods of *S. tora* are collected when mature.

Handling after harvest After harvesting, *S. alata* leaves are dried and sometimes stored in containers until needed. The mature pods of *S. tora* are sun-dried; prior to use the seeds are removed and roasted.

Genetic resources and breeding *S. alata*, *S. sophera* and *S. tora* are widely found wild and cultivated in and outside South-East Asia, and they are neither endangered nor liable to genetic erosion.

Prospects As *Senna* species have various medicinal properties, ornamental value, and are used for various other purposes, they are true multipurpose plants. The antifungal and anti-tumour properties seem to justify more research.

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Selection of species

Senna alata (L.) Roxb.

Fl. ind., ed. 2, 2: 349 (1832).

Synonyms *Cassia alata* L. (1753).

Vernacular names Ringworm bush, seven golden candlesticks (En). Dartrier (Fr). Brunei: raun suluk (Dusun), paa-ul, tarump (Malay). Indonesia: daun kupang, ketepeng (Malay, Manado), ketepeng kebo (Javanese). Malaysia: daun kurap, gelenggang, ludanggan (Peninsular). Papua New Guinea: kabaiura (Harigen, Sepik), levoanna (Gaire and Tubusereia, Central Province), Orere (Awala, Northern Province). Philippines: andadasi (Iloko), katanda (Tagalog), palochina (Bisaya). Cambodia: dang het, dang het khmoch. Laos: khi let ban. Thailand: kheekhaak (northern), chumhet thet (central, peninsular), chumhet yai (central). Vietnam: mu[oof]ng l[as]c, mu[oof]ng tr[aa]u.

Distribution Native to South America, now pantropical; abundantly naturalized in South-East Asia, and occasionally planted throughout the region for medicinal and ornamental purposes.

Uses *S. alata* is used against ringworm and various other skin diseases, such as scabies. Ringworm is treated by externally applying the leaves, which might be pounded first, the sap of the leaves, the roots, or the pods. *S. alata* is also used as a laxative or purgative. For laxative purposes, a decoction of the leaves, the flowers, the roots or the wood may be used. In India, the leaves are taken as a purgative, while leaf decoctions are used as an expectorant in bronchitis and dyspnea, as an astringent, a mouthwash and a wash in cases of eczema. *S. alata* is sometimes a weed in pastures; it is not eaten by livestock and sometimes even reported to be poisonous.

Observations A shrub, 1–2(–5) m tall, with thick branches, pubescent; leaves with 8–20 pairs of leaflets, petiole 2–3 cm long, rachis 30–60 cm long, leaflets oblong-elliptical, 5–15 cm × 3–7 cm, obtuse at the ends, glabrous; inflorescence an axillary raceme, robust, dense, 20–50 cm long, many-flowered; flowers with oblong sepals, 10–20 mm × 6–7 mm, orange-yellow, petals ovate-orbicular, 16–24 mm × 10–15 mm, bright yellow, 2 large stamens with stout filaments 4 mm long and anthers 12–13 mm long, 4 small stamens with filaments 2 mm long and anthers 4–5 mm long, 3–4 staminodes, ovary puberulous, sessile, with many (up to 58) ovules, style filiform, stigma small; fruit tetragonal, 10–15 cm × 1.5–8 cm, winged, wings 4–8 mm, black, glabrous, up to 50-seeded; seeds quadrangular, flattened, 7–8 mm × 5–8 mm, shiny. *S. alata* occurs up to 2100 m altitude in New Guinea but is most abundant below 500 m altitude. It has a wide ecological amplitude, but prefers rather open, not too dry habitats.

Selected sources 97, 190, 202, 287, 295, 308, 336, 350, 357, 364, 402, 409, 522, 553, 580, 597, 653, 817, 829, 1035, 1105, 1126, 1128, 1178, 1220, 1277, 1287, 1520.

Senna sophera (L.) Roxb.

Fl. ind., ed. 2, 2: 347 (1832).

Synonyms *Cassia sophera* L. (1753).

Vernacular names Indonesia: enceng-enceng (Javanese). Philippines: andadasi (Iloko), tambalisa (Tagalog). Laos: ngot. Thailand: phak khlet (Bangkok), phak waan baan (central). Vietnam: mu[oof] ng[os]t, mu[oof]ng h[of]e.

Distribution Originating from the New World tropics, but now pantropical.

Uses In Indonesia, extracts of all plant parts are used to treat epilepsy. In the Philippines, the seeds are used to treat fever. In India, the juice of the leaves is applied against ringworm, while it is also employed as an expectorant, an anthelminthic and as a remedy for rheumatic and inflammatory fevers. Besides these applications, in Thailand the leaves are used for wound healing and as an antipyretic.

Observations An erect shrub, 1–2(–3) m tall, almost glabrous; leaves with 4–10 pairs of leaflets, petiole 3–5 cm long, with a thin, subulate or clavate gland 5–10 mm above the petiole joint, leaflets lanceolate, 2–5(–8) cm × 1–2 cm, upper leaflets largest, base rounded, apex acute; inflorescence an axillary corymb, few-flowered; flowers with ovate sepals 5 mm long, petals obovate, 10–14 mm × 6–8 mm, yellow, 2 longer stamens with filaments 5–7 mm long and anthers 5–6 mm long, 4 shorter stamens with filaments 2 mm long and anthers 5 mm long, 3–4 staminodes, ovary pubescent, style thin, glabrous, stigma slightly dilated, strongly incurved; fruit 6–10 cm × 0.5–1 cm; seeds 30–40 per pod, ovoid, compressed, 3–4 mm long. *S. sophera* occurs in secondary habitats such as roadsides and wast places at lower elevations.

Selected sources 97, 190, 336, 357, 580, 653, 817, 1178.

Senna tora (L.) Roxb.

Fl. ind., ed. 2, 2: 340 (1832).

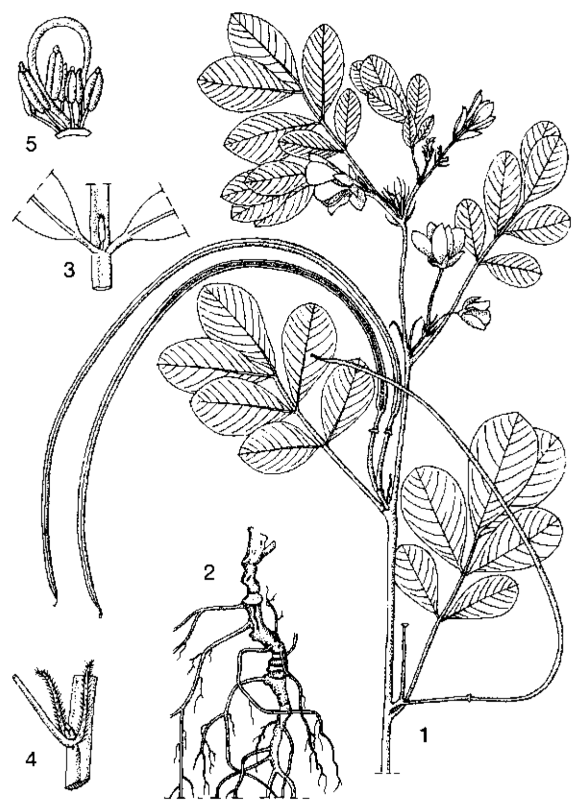
Synonyms *Cassia tora* L. (1753), *Cassia borneensis* Miq. (1850).

Vernacular names Foetid cassia, panicled milkwort (En). Casse fétide (Fr). Indonesia: gelenggang kecil, ketepeng kecil (Malay), katepengleutik (Sundanese). Malaysia: gelenggang kechil, gelenggang padang. Philippines: katanda, balatong-aso (Tagalog). Cambodia: d[aa]ng'hët khmaoch ni. Laos: nha leung meum, nha lap mun. Thailand: chum het tai, chum het lek (central), lapmuen noi (northern). Vietnam: th[ar]o quy[ees]t minh, mu[oof]ng h[oo]i, mu[oof]ng ng[ur].

Distribution The origin of *S. tora* is unknown, but nowadays it is only found in the Old World tropics.

Uses A decoction of the leaves may be used as a purgative, vermifuge or to treat cough. The leaves and seeds are used in the treatment of ringworm and scabies, as a diuretic and an antipyretic. In Indonesia and the Philippines, pounded leaves are smeared on the head of restless children. In Vietnam, seeds are used as a laxative, and roasted seeds are employed to treat insomnia, hypertension and ophthalmia. In India, pounded seeds are used to treat itching. In Chinese medicine, *S. tora* is used to improve vision. Cattle do not eat the green plant, but do eat silaged plants and dry pods.

Observations A foetid smelling herb or under-



Senna tora (L.) Roxb. – 1, twig with flowers and fruits; 2, root system; 3, detail of gland on leaf rachis; 4, detail of stipules; 5, detail of stamens and pistil.

shrub, up to 1 m tall, almost glabrous, with a stout taproot; leaves with 3 pairs of leaflets, petiole 1–4 cm long, rachis 2–3 cm long, with a subulate, 2 mm long gland between the two lowest pairs of leaflets, leaflets obovate, 2–5 cm × 1.5–2.5 cm, upper leaflets largest, thin, base cuneate to rounded, apex rounded; inflorescence a short axillary raceme, 1–2(–3)-flowered; flowers with ovate sepals, 5 mm × 2–4 mm, petals obovate, unequal, up to 10 mm × 6 mm, yellow, stamens 7, almost equal, filaments 1.5–2 mm long, 3 larger anthers, 4 smaller ones 1.5–2.5 mm long, staminodes absent, ovary densely pubescent, style glabrous, stigma truncate; fruit linear, terete, 10–15 cm × 0.5 cm; seeds 20–30 per pod, rhomboidal, 5 mm × 3 mm, glossy, with an areole (1.5–2 mm wide) covering part of the seed surface. *S. tora* is common throughout South-East Asia in anthropogenic habitats at lower altitudes. It is reported to be an important weed in pastures and cropped fields in South-East Asia, partly because of its high seed production.

Selected sources 8, 97, 190, 202, 253, 254, 272, 336, 357, 364, 402, 429, 503, 553, 580, 817, 986, 988, 1035, 1126, 1178, 1189, 1197, 1220, 1277, 1287, 1520, 1594.

Anny Victor Toruan-Purba

Smilax L.

Sp. pl. 2: 1028 (1753); Gen. pl. ed. 5: 455 (1754).
SMILACACEAE

$x = 16$; *S. bracteata*: $2n = 32$, *S. china*: $2n = 30$, 60, 90, *S. leucophylla*: $2n = 32$, *S. zeylanica*: $2n = 32$

Major species *Smilax china* L., *S. glabra* Wallich ex Roxb., *S. leucophylla* Blume.

Vernacular names Indonesia: gadung cina. Malaysia: akar gadong. Philippines: sarsaparilla, banag. Cambodia: voë pâprâ:hs. Laos: khua:ng. Thailand: khueang. Vietnam: d[aa]y kim cang.

Origin and geographic distribution *Smilax* contains approximately 200 species which are distributed in tropical and subtropical regions, with some herbaceous species extending their range into the temperate regions of North America, Europe and Asia.

The greatest diversity is found in eastern Asia. In Indo-China 27 species have been found, in Thailand 24 species, and the number of species is probably slightly less in Malesia.

Uses In South-East Asia, decoctions of *Smilax* roots and rhizomes are rather commonly used internally to treat syphilis, gonorrhoea, rheumatism and coughs and as a tonic (e.g. after childbirth) and aphrodisiac, and externally to treat skin diseases including psoriasis, wounds, inflammations, swellings, ulcers and boils. Leaf tops have been reported to be eaten with food as contraceptive in Papua New Guinea. A decoction of the leaves is used as a purgative to expel worms and reduce swelling of the stomach in the Central Province in Papua New Guinea. The rhizomes of *S. calophylla* and *S. myosotiflora* are reputed to be used in Peninsular Malaysia as an aphrodisiac. *Smilax* species, particularly *S. china*, are used in anticancer drugs in Chinese medicine, and have been reputed to be effective as diuretic and anti-inflammatory agents. A decoction of *S. glabra* rhizomes is used in China in orally administered mixtures of medicinal plants for the treatment of psoriasis, and in Vietnam as an antiphlogistic to treat rheumatic arthritis, psoriasis and inflammations, and as a tonic. In Australia, an infusion of the leaves of *S. australis* R.Br. and *S. glycophylla* Smith has been used medicinally. In Guatemala and other Central American and West Indian countries, *S. regelii* Killip & C. Morton ('Honduras-sarsaparilla') and *S. officinalis* Kunth are used to treat dermatophyte infections and rheumatism. *S. aristolochiifolia* Miller from Mexico, known as 'Veracruz-sarsaparilla', is reputed as a diuretic, increasing both volume and chloride and uric acid concentration of the urine. *S. papyracea* Duhamel from Mexico, Brazil and Guyana is also known as 'sarsaparilla'. In Saudi Arabia *S. sarsaparilla* L. is used for the treatment of rheumatism, arthritis, gout and other forms of inflammation. The roots of *S. zeylanica* and *S. wightii* A.DC. are used medicinally in India against amongst others, rheumatism, urinary complaints and venereal diseases.

Thickened roots of *S. china* can be used as bait for subterranean termites, in conjunction with insecticides. The stems are sometimes used as cane to make baskets. The edible but acid fruits of *S. macrocarpa* Blume are commonly collected from the wild in Java, eaten fresh, as an ingredient of fruit salad or preserved in syrup. Young shoots and leaves of *S. leucophylla* and rhizomes of *S. megacarpa* are edible.

Production and international trade The rhizomes of some *Smilax* spp. are much sought after and are exported in fairly large quantities; for example, rhizomes of *S. glabra* in Laos. Roots of *S. china* and *S. glabra* are mainly imported from China and sold as herbal medicine in Chinese pharmacies throughout South-East Asia.

Properties Roots and rhizomes of *Smilax* species are a well known source of steroidal saponins (1–3%): mainly glycosides of the furostanol and spirostanol aglycones sarsapogenin, smilagenin, tigogenin, neotigogenin, diosgenin and yamogenin. In the plant, the bisdesmosidic glycoside form of these aglycones seems to be the genuine component. Several steroidal saponins have been isolated from *S. china* rhizomes; they include dioscin, protodioscin, methylprotodioscin, gracillin and methylprotogracillin. The aglycones of these saponins are of great industrial interest as starting material for steroid hormone semisynthesis in the production of corticosteroids and sex hormones (androgens, oral contraceptives). The spirostanol saponins dioscin and gracillin are reported to have antimutagenic activity, but their similar furostanol glycosides have not shown this activity. Hot water extract of *S. china* shows histamine release inhibition and cytotoxic activities. Methanol extract brings about uterine relaxation and decreases barbiturate sleeping time.

The flavonoids astilbin, taxifolin and engeletin have been isolated from the dried rhizomes of *S. glabra*, together with some organic acids (ferulic acid, 3-O-caffeoylshikimic acid) and β-sitosterol. Quercetin and kaempferol were isolated from leaf extracts of the same plant after acid hydrolysis. A methanol extract of *S. glabra* rhizomes showed hypoglycaemic effects in normal and diabetic mice. *S. glabra* extracts showed anthelmintic activity against the trematode *Clonorchis sinensis*. The extracts also exhibit antiviral and anti-inflammatory activities. Extracts of *S. china* have been demonstrated to inhibit the mutagenicity of benzo(a)pyrene completely. Tests in Saudi Arabia showed significant inhibition of carrageenan-induced inflammation in rats when an oral dose of 500 mg/kg of *S. sarsaparilla* extract was applied; this extract also inhibited cotton pellet-induced exudation. In tests in Guatemala, extracts of *S. lundellii* Killip & C. Morton showed activity against *Candida albicans*, a parasitic imperfect fungus causing thrush.

In tests in China, a mixture of medicinal plants including a decoction of *S. glabra* rhizomes showed a lower relapse rate and longer remission in comparison with aminopterin therapy and the topical application of psoriasin to treat psoriasis.

Adulterations and substitutes The nodular growths found on the roots of fir (*Abies*) trees and produced by a fungus, and similar growths on *Liquidambar* roots are sometimes sold as a substitute for China root (from *S. china*). Saponins of the same type are found in various *Yucca* species; other sapogenins which are interesting as starting material for steroid hormone semisynthesis include diosgenin from *Dioscorea* spp. and hecogenin from *Agave* spp.

Description Dioecious climbers up to 20 m long with woody or herbaceous stems up to 12 mm in diameter, or becoming shrubby with suberect stems; stem and branches often prickly; rhizome and/or roots often thickened. Leaves alternate, simple and entire, mostly ovate-orbicular, ovate to lanceolate, with 3–7 veins connected by reticulate lateral veinlets; petiole sheathing in lower part with a pair of wings, often with tendrils arising immediately above the apex of the sheath. Inflorescence an axillary umbel or an umbellate raceme whose main axis bears a prophyll at the base. Flowers unisexual, small, usually greenish or greenish-white; perianth with 6 free, usually recurved or patent tepals, inner tepals much narrower than outer ones; male flowers with 6(–18) free or almost connate stamens having unilocular anthers; female flowers with a superior, 3-locular ovary, style very short and with 3 elongate, recurved stigmas, 3–6 needle-like staminodes present. Fruit a globose berry, usually containing 1–2 seeds.

Growth and development In Java, most *Smilax* spp. flower in the period from April to September and sometimes also January–February. Pollination is by insects.

Other botanical information *Smilax* has often been treated as a genus of the family *Liliaceae*, but is nowadays considered as a separate family *Smilacaceae*, together with *Heterosmilax*, which differs in its connate perianth segments and 3 stamens (rarely up to 12) and occurs from India to Japan, and *Rhipogonum*, which differs by not having sheaths and tendrils on the petioles, or bilocular anthers, and occurs in New Guinea, Australia and New Zealand. Chromosome features support the removal from the Liliaceous assemblage.

Ecology *Smilax* species are often common climbers in evergreen lowland and lower montane forest up to 2400 m altitude. Several species are frequently found in scrub vegetation, open forest and shrub savanna, often on stony soils.

Propagation and planting Tests with seed of the Australian *S. australis* showed a germination rate of only 10–20% after 12 months. Adventitious roots are formed in some species (e.g. *S. zeylani-*

ca), which might enhance modes of vegetative propagation. Cuttings are a successful method of propagation. Mature 3-leaved stem sections treated with rooting powder and placed in pots with 10 cm diameter sealed in plastic bags and with a 1:1 sand/peat mixture showed callus tissue formation in the leaf axils within one month, when kept at 25°C and in 70% shade. The aerial calli developed roots and shoot buds after a further 3–4 weeks, and about 60% of the cuttings established successfully.

Harvesting In China, the tuberous rhizomes of *S. china* are dug out and dried for the market.

Handling after harvest In China, the rhizomes are often peeled after drying. Usually the crude drug is extracted with boiling water for 2 hours, to prepare the drug for oral application.

Genetic resources and breeding Those *Smilax* spp. that are generally used medicinally are widespread and common and seem not to be easily endangered. Despite the multiple uses, no serious attempts have been made either to conserve the genetic variation, or to domesticate these species.

Prospects The medicinal uses of *Smilax* are more or less the same world-wide, which may indicate a certain consensus on activity of the drug. *Smilax* has good prospects as starting material for steroid hormone semisynthesis. Research on properties has been carried out mainly on Chinese and Japanese *Smilax* species, but little is known about those found in Malesia. The taxonomy of Malesian species is also very incompletely investigated, and this hampers the interpretation of findings in literature.

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Selection of species

Smilax blumei A.DC.

Monogr. phan. 1: 202 (1878).

Distribution The Andaman Islands, peninsular Thailand, Peninsular Malaysia, Java, New Guinea and north-eastern Australia.

Uses *S. blumei* is probably used for similar medicinal purposes as *S. leucophylla*. The roots are boiled by the Kedayan people in Sarawak to make a drink for treating rheumatism.

Observations A climber up to 20 m long with sparsely prickly stem and branches; leaves ovate-elliptical, up to 25 cm long, petiole up to 3 cm long, wings of petiolar sheaths distinct, tendrils present; inflorescence with (1–)3–10 umbels; fruit about 8–12 mm in diameter, dark purple to black at maturity. *S. blumei* occurs in evergreen forest up to 1500 m altitude. It has often been confused with *S. leucophylla*, which can be distinguished by its glaucous leaf undersurface and thicker leaves.

Selected sources 278, 779, 780, 1227.

Smilax bracteata K. Presl

Reliq. haenk. 1: 131 (1827).

Vernacular names Philippines: banag (general), kamagsa-obat (Tagalog), banagan (Bisaya). Cambodia: voë pâprohs dâmrèi (Pursat). Laos: khua:ng khua (Xieng Khouang), khua:ng th'ô:n (Vientiane). Thailand: khueang thon (Loei). Vietnam: c[aaj]m k[eej]ch.

Distribution From southern Japan, through the Ryukyu Islands and Taiwan to Cambodia, Laos, Vietnam, Thailand, Peninsular Malaysia, Java, Borneo and the Philippines.

Uses In the Philippines, a decoction of the rhizomes is used as an emmenagogue; it is considered as depurative.

Observations A climber up to 6 m long with smooth or sparingly prickly, sometimes verruculose stem and branches; leaves broadly elliptical to broadly ovate-elliptical or lanceolate, up to 22 cm long, petiole up to 3 cm long, wings of petiolar sheaths weakly developed, tendrils up to 20 cm long; inflorescence with (2–)3–7 umbels; fruit 5–12 mm in diameter, dirty yellow-brown turning purple-brown or shiny black at maturity; seeds dark red. Two subspecies have been distinguished: subsp. *bracteata* (synonym: *S. stenopetala* A. Gray) with usually smooth or nearly smooth stem and branches, and subsp. *verruculosa* (Merr.) T. Koyama (synonyms: *S. odoratissima* Blume, *S. verruculosa* Merr.) with densely verruculose and usually sparingly prickly stem and branches; the latter subspecies occurs in Taiwan, northern Thailand, the Philippines, Java and Borneo. *S. bracteata* occurs in evergreen or lower montane forest up to 2400 m altitude.

Selected sources 97, 190, 779, 780, 781, 1178, 1491.

Smilax calophylla Wallich ex A.DC.

Monogr. phan. 1: 60 (1878).

Vernacular names Malaysia: dawai-dawai, sedawai, akar kancil (Peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, New Guinea and north-eastern Australia.

Uses Rhizomes are used in Malaysia to treat gonorrhoea and as an aphrodisiac and tonic. A decoction is administered after childbirth. Leaves are smeared with coconut oil, heated and applied to swellings.

Observations An erect to straggling slender shrub up to 2.5 m tall with smooth stems and branches; leaves elliptical to lanceolate-elliptical or narrowly ovate, up to 20 cm long, petiole up to 2 cm long, wings of petiolar sheaths not well developed, tendrils absent; inflorescence with 2–7 umbels; fruit 7–9 mm in diameter, reddish-brown at maturity. *S. calophylla* occurs in evergreen forest up to 1600 m altitude.

Selected sources 202, 779, 780, 1227.

Smilax china L.

Sp. pl. 2: 1029 (1753).

Vernacular names China root, Chinese sarsaparilla (En). Racine de Chine, squine (Fr). Indonesia: gadung cina (general), peundang (Aceh), ghadhung tambha (Madurese). Malaysia: gadong china, gadong saberang, akar restong. Philippines: sarsaparillang-china (Tagalog), buanal (Igorot), palipit (Bontok). Vietnam: kim chang trung qu[oos]e.

Distribution From Japan and southern China, through the Ryukyu Islands to Laos, Vietnam, northern Thailand, Burma (Myanmar) and the Philippines. *S. china* has long been cultivated in China and Japan as a medicinal plant. The rhizomes are imported in Indonesia and Malaysia.

Uses Rhizomes had a long-standing reputation as a remedy for syphilis, complaints of the genito-urinary system, rheumatism and skin diseases. *S. china* is used in anticancer drugs in Chinese medicine. In Malaysia, the imported rhizomes are used against syphilis and gonorrhoea, as a tonic and after childbirth; in Indonesia against syphilis and framboesia; in the Philippines against herpes, syphilis, chronic rheumatism, skin diseases and asthma.

Observations A climber up to 5 m long with smooth or sparingly prickly stem and branches; leaves ovate-orbicular, broadly elliptical to ovate-elliptical or narrowly elliptical, up to 12 cm long, petiole up to 1.5 cm long, wings of petiolar sheaths

Smilax china L. – 1, rhizome; 2, part of flowering stem; 3, male flower.

rather weakly developed, tendrils up to 15 cm long; umbels solitary; fruit 10–12 mm in diameter, red at maturity; seeds red-purple. In China, two types can be distinguished, one with big berries and the other with small berries; these types can be distinguished by pyrolysis-high resolution gas chromatography. In tropical Asia *S. china* occurs only in scrub vegetation and open forest in mountains above 1000 m altitude, but in more temperate regions it also grows in the lowland; in the Philippines it is found in moss forest at 1600–2400 m altitude.

Selected sources 190, 202, 549, 580, 735, 779, 780, 781, 832, 1178, 1288, 1570.

Smilax corbularia Kunth

Enum. pl. 5: 262 (1850).

Vernacular names Cambodia: voë chon (Koh Kong). Laos: khua:ng khau (Xieng Khouang). Thailand: hua khaao-yen wok, hua khaao-yen nuea (northern). Vietnam: d[aa]y g[aj]o (Thanh Hoa), d[aa]y kim cang (Thanh Hoa, Quang Nam-Da Nang), t[aaf]u mu[oos]i (Ha Tuyên).

Distribution From Burma (Myanmar) and southern China through Indo-China and Thailand, to Peninsular Malaysia and Borneo.

Uses In Thailand, rhizomes are used for the treatment of gonorrhoea, urinary infections, inflammation, skin diseases and as diuretic. Leaves are used as antipyretic. A decoction of the rhizome is applied to wounds in Cambodia. A decoction of the stems is used to stimulate the appetite in Vietnam, and in Laos the leaves are used to prepare a popular drink.

Observations A climber up to 4 m long with smooth stem and branches; leaves elliptical to ovate or broadly ovate, up to 10 cm long, petiole up to 1.5 cm long, wings of petiolar sheaths rather weakly developed, tendrils up to 9 cm long; umbels solitary, sometimes up to 3 together; fruit 6–8 mm in diameter, purple-black at maturity. Two subspecies are distinguished: subsp. *synandra* (Gagnepain) T. Koyama (synonym: *S. synandra* Gagnepain) and subsp. *corbularia* (synonyms: *S. balansaeana* H. Bon ex Gagnepain, *S. hypoglauca* Benth., *S. peguana* A.DC.). The former differs from the latter in the partly connate perianth and stamens, and tetragonous stems, and it is found in China, Vietnam and north-eastern Thailand. *S. corbularia* occurs in evergreen and lower montane forest up to 2000 m altitude, in Peninsular Malaysia on exposed rocks in the mountains.

Selected sources 779, 780, 781, 1227.

Smilax glabra Wallich ex Roxb.

Fl. ind., ed. 1832, 3: 792 (1832).

Vernacular names Cambodia: pâprâ:hs (Koh Kong), voë srâ:m (Kampot). Laos: ya: hu:a (general), khua:ng la:y (Khammouane). Thailand: yaa hua (north-eastern). Vietnam: th[oor] ph[uj]c linh (general), d[aa]y ch[aws]t (Vinh Phu), d[aa]y khum (Phu Khanh).

Distribution India, Burma (Myanmar), Cambodia, Laos, Vietnam, Thailand, central and southern China and Taiwan.

Uses A decoction of rhizomes is used in China in orally administered mixtures of medicinal plants for the treatment of psoriasis, and as anthelmintic, and in Vietnam as antiphlogistic to treat rheumatism and inflammations.

Observations A climber with smooth stem and branches; leaves lanceolate to lanceolate-elliptical or narrowly ovate, up to 18 cm long, petiole up to 3 cm long, wings of petiolar sheaths weakly developed, tendrils up to 15 cm long; umbels solitary;

Smilax glabra Wallich ex Roxb. – 1, rhizome; 2, stem with male inflorescences; 3, stem with infructescences; 4, female flower; 5, male flower.

fruit 5–8 mm in diameter, blue-black at maturity. In Thailand and Indo-China, *S. glabra* occurs in evergreen forest and shrub savanna at 300–1500 m altitude, often on stony soils.

Selected sources 235, 249, 449, 549, 779, 780, 781, 1035, 1128, 1224, 1633.

Smilax lanceifolia Roxb.

Fl. ind., ed. 1832, 3: 792 (*'lanceaefolia'*, 1832).

Vernacular names Thailand: dao, naam dao (northern), thao yang dong (south-eastern). Vietnam: d[aa]y kim cang.

Distribution From the Indian Himalayas, south-eastern China and Taiwan to Burma (Myanmar), Cambodia, Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines.

Uses Leaves and fruits are used in traditional medicine in Vietnam. A decoction of the roots is used against syphilis and rheumatism. The fruits are edible.

Observations A climber up to 5 m long with smooth or sometimes sparsely prickly stem and branches; leaves broadly lanceolate to elliptical or ovate-oblong, up to 15 cm long, petiole up to 2.5 cm long, wings of petiolar sheaths weakly developed, tendrils up to 20 cm long; umbels usually solitary; fruit 5–7 mm in diameter, yellowish-reddish at maturity. Two subspecies are distinguished: subsp. *reflexa* (Norton) T. Koyama (synonym: *S. chapaensis* Gagnepain) and subsp. *lanceifolia* (synonyms: *S. laevis* Wallich ex A.DC., *S. micropoda* A.DC., *S. opaca* (A.DC.) Norton). The former differs from the latter in its verrucose and often also prickly stem and branches, and is found in China and northern Vietnam. *S. lanceifolia* is a common climber in evergreen and lower montane forest and shrub savanna at 500–2000 m altitude.

Selected sources 779, 780, 781, 1227.

Smilax leucophylla Blume

Enum. pl. Javae 1: 18 (1827).

Vernacular names Indonesia: canar bokor (Sundanese). Philippines: sarsaparillang-puti (Tagalog), banag (Tagbanua), kaguno (Negrito). Papua New Guinea: wanabekira.

Distribution Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines to New Guinea and northern Australia (once collected).

Uses Pounded rhizomes and leaves are applied to ulcerations of the nose in Malaysia. In the Philippines, the rhizomes are considered as a purifier of the blood and used in cases of syphilis, rheumatism and skin diseases. In Papua New Guinea, the sap from the top shoot is sucked as a poison antidote. Young shoots and leaves are edible.

Observations A climber up to 20 m long with sparsely prickly stem and branches; leaves broadly ovate to ovate-oblong, up to 32 cm long, glaucous beneath, petiole up to 4 cm long, wings of petiolar sheaths distinct, tendrils present; inflorescence with 2–6 umbels; fruit about 10 mm in diameter, black at maturity. *S. leucophylla* occurs in mixed forest and teak forest, in Java up to 1100 m altitude. It has been much confused with *S. blumei*, which can be distinguished by its non-glaucous leaf undersurface and thinner leaves.

Selected sources 97, 190, 202, 278, 580, 601, 608, 779, 1178, 1227, 1356, 1491.

Smilax luzonensis K. Presl

Reliq. haenk. 1: 131 (1827).

Synonyms *Smilax helferi* A.DC. (1878).

Vernacular names Malaysia: akar banar, akar gadung tikus, banar babi (Peninsular). Cambodia: voë bâng-he:t khmô:t (Ratanakiri). Thailand: khueang (eastern), yaan thaat, faa laep (peninsular). Vietnam: d[aa]y kim cang.

Distribution India, Burma (Myanmar), Cambodia, Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java and the Philippines.

Uses Pounded rhizomes are used for poulticing boils in Malaysia, often together with leaves of *Macaranga triloba* (Blume) Muell.-Arg.

Observations A climber up to 5 m long with smooth or sparsely prickly stem and branches; leaves broadly elliptical to elliptical, sometimes lanceolate-elliptical, up to 15 cm long, petiole up to 2 cm long, wings of petiolar sheaths weakly developed, tendrils up to 12 cm long; inflorescence with 1–3 umbels; fruit 5–6 mm in diameter, dirty yellow at maturity; seeds dark red. *S. luzonensis* is locally frequent in evergreen forest up to 1000 m altitude, in Malesia also in bushes in open country.

Selected sources 202, 779, 780, 1227.

Smilax megacarpa A.DC. & C.DC.

Monogr. phan. 1: 186 (1878).

Vernacular names Malaysia: akar banar, akar rebanar, akar lampu bukit (Peninsular). Laos: kh'u:a hmu: 'wa:k, kê:ng hmu: (Louang Prabang), khua:ng th'ô:n (Vientiane). Vietnam: cam [is]ch (Quang Nam-Da Nang), kim cang (Sông Bé), d[aa]y man [ees]t (Quang Nam-Da Nang).

Distribution India, Burma (Myanmar), Cambodia, Laos, Vietnam, Hainan, Thailand, Peninsular Malaysia and Singapore; possibly also Java, Borneo and the Moluccas.

Uses *S. megacarpa* is used in local medicine in Laos; it plays a role in medicines given after childbirth and against cough. Rhizomes are eaten in Peninsular Malaysia.

Observations A climber up to 6 m long with smooth stem and branches; leaves broadly elliptical to broadly ovate or ovate, up to 27 cm long, petiole up to 5 cm long, wings of petiolar sheaths rather weakly developed, tendrils up to 25 cm long; inflorescence with 2–3 umbels; fruit 15–20 mm in diameter, dark red or purple at maturity. *S. megacarpa* occurs locally frequent in evergreen forest up to 1200 m altitude, in Malesia also in bushes in open country.

Selected sources 202, 779, 780, 1227, 1356.

Smilax myosotiflora A.DC.

Monogr. phan. 1: 65 (1878).

Vernacular names Malaysia: akar ali, akar tanding, akar dedingin (Peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and Singapore.

Uses Rhizomes are used in Malaysia as an aphrodisiac and leaves and fruits to cure syphilis.

Observations A herbaceous climber with slender smooth stem and branches; leaves broadly elliptical to lanceolate-elliptical, up to 15 cm long, petiole up to 2.5 cm long, wings of petiolar sheaths weakly developed, tendrils up to 13 cm long; umbels solitary; fruit 7–9 mm in diameter. *S. myosotiflora* occurs in evergreen forest, often climbing on bushes and low trees, up to 1400 m altitude.

Selected sources 202, 779, 780, 1227.

Smilax verticalis Gagnepain

Bull. Soc. Bot. Fr. 81: 74 (1934).

Synonyms *Smilax simulans* T. Koyama (1967).

Vernacular names Cambodia: voë më:m thnam chön (Koh Kong), voë pâpâhs (Pursat). Laos: kh'a:ng lua:yx, khua:ng th'ô:n (Vientiane), khua:ng no:yz (Savannakhet). Thailand: khrua daao (northern). Vietnam: kim chang d[uws]ng.

Distribution Cambodia, Laos, Vietnam and Thailand.

Uses Rhizomes and leaves are used in local medicine in Cambodia and Laos.

Observations A sub-erect to straggling slender shrub up to 2 m tall, somewhat tufted at base with smooth or sparsely prickly stem and branches; leaves elliptical to ovate-elliptical, ovate or lanceolate-oblong, up to 15(–18) cm long, petiole up to 2 cm long, wings of petiolar sheaths not well developed, tendrils absent or short; inflorescence with 1–2 umbels; fruit 8 mm in diameter, reddish at maturity. *S. verticalis* occurs in shrub savanna and open forest up to 1000 m altitude.

Selected sources 780.

Smilax zeylanica L.

Sp. pl. 2: 1029 (1753).

Vernacular names Indonesia: kayu cina utan, saihe maruani, asaihe tuni (Moluccas).

Distribution Sri Lanka, India, Burma (Myanmar), northern Thailand and Java, possibly also Sulawesi, the Moluccas and New Guinea.

Uses *S. zeylanica* is used as a medicinal plant in India, and possibly as a substitute for *S. china* in the Moluccas.

Observations A climber up to 6 m long with smooth or sparingly prickly stem and branches; leaves elliptical to ovate, oblong or lanceolate, sometimes ovate-orbicular, up to 24 cm long, petiole up to 3 cm long, wings of petiolar sheaths rather weakly developed, tendrils up to 20 cm long; inflorescence with 1–5 umbels; fruit 6–10 mm in diameter, dirty yellow to shiny black at maturity; seeds brown. Two subspecies are distinguished: subsp. *hemsleyana* (Craib) T. Koyama (synonym: *S. hemsleyana* Craib) and subsp. *zeylanica*. The former differs from the latter in its solitary umbels and comparatively broader leaves, and is only known from eastern India and northern Thailand. *S. zeylanica* occurs in primary and secondary forest, teak forest, brushwood and bamboo thickets, in Java up to 1600 m altitude. *S. celebica* Blume, a decoction of whose leaves has been reported to be used in the Moluccas as tonic after childbirth, might be merely a form of *S. zeylanica* differing only in the leaves.

Selected sources 97, 140, 580, 779, 780, 1491.

Stephen P. Teo

Solanum L.

Sp. pl. 1: 184 (1753); Gen. pl. ed. 5: 85 (1754).

SOLANACEAE

$x = 12$; *S. capsicoides*: $2n = 24$, *S. erianthum*: $2n = 24$, *S. mammosum*: $n = 11, 12$, *S. nigrum*: $2n = 72$, *S. trilobatum*: $2n = 24$

Major species *Solanum erianthum* D. Don, *S. nigrum* L.

Vernacular names Solanum, nightshade (En). Solanum, morelle (Fr).

Origin and geographic distribution Estimates differ greatly, but *Solanum* probably comprises some 1000–1100 species. It is cosmopolitan, except in boreal, alpine and aquatic habitats. The principal centre of diversity is located in Central and South America, with secondary centres in Africa and Australia. With a total of 60 wild and cultivated species, New Guinea is probably the area in Malesia with the most species; by comparison, Peninsular Malaysia has about 15 species and Java and the Philippines about 25 species each.

Uses *Solanum* is used to cure digestive and intestinal problems, including stomach-ache, diarrhoea, piles and dysentery, and for various skin problems such as sores, boils, cuts, wounds and bruises. Many species are also employed to treat fever and malaria, headache and rheumatism. Some are considered to be stimulants whereas others have sedative properties. Furthermore, *Solanum* is frequently used for various diseases of the respiratory tract, such as coughs, sore throat, bronchitis and asthma. Finally, many species are applied to treat urinary problems.

Solanum shows insecticidal and fungicidal properties. The leaves and stems of many species are often cooked or steamed and eaten as a vegetable. The unripe fruits are eaten in curries, whereas the ripe ones of some *Solanum* species are edible either cooked or raw. Caution must be taken when eating *Solanum*, as several species are poisonous.

Production and international trade The fruits of *S. sanitwongsei* are on sale in Bangkok markets, and have been cultivated commercially in Manila.

Properties The steroidal alkaloids of the *Solanaceae* occur as glycosides (hence glycoalkaloids). The known steroidal alkaloids are based on a C_{27} cholestane skeleton and can be divided into 5 groups: solanidanes, spirosolanes, 22,26-epiminocholestane, α-epiminocyclohemiketal and 3-aminospirostane. The first 2 groups have attracted the most research. The solanidanes, with important alkaloids such as solanidine, leptidine and demissidine, are characterized by an indolizidine moiety. Important spirosolane alkaloids include solasodine, tomatidine and tomatidenol. The spirosolanes are structurally similar to saponins of the diosgenin type, except that the oxygen in the spiro-alketal pattern has been replaced by nitrogen.

Solanidine is present in *S. capsicoides*, whereas solasodine is found in *S. erianthum*, *S. nigrum* and *S. trilobatum*. The total alkaloid content of air-dried leaves and fruits is respectively 0.26% and 0.14% for *S. capsicoides*, 0.37% and 0.39% for *S. erianthum*, 0.43% and 0.10% for *S. nigrum* and 0.36% and 0.96% for *S. trilobatum*. The solasodine content in *Solanum* fruits from Indian samples is 0.01–0.70% in *S. erianthum* and 0–0.28% in *S. nigrum*, whereas the total glycoalkaloid content in fruits of *S. trilobatum* has been found to be 3.5%. Leaf samples of *S. erianthum* from Vietnam contained 0.26% solasodine, 0.05% tomatidine and 0.01% solaverbascine. *S. erianthum* also has steroidal saponins and free genins. As well as solasodine, *S. nigrum* contains the sapogenins diosgenin and tigogenin. The unripe berries have 0.68% solasodine, 0.19% diosgenin and 0.15% tigogenin, whereas leaves contain 1.28% tigogenin.

Glycoalkaloids are toxic to animals when injected. Like saponins, they are surface-active and haemolytic, and possess antifungal and cytostatic properties. *Solanum* steroidal glycoalkaloids affect the body mainly in two ways: the intact glycoalkaloid is an irritant, whereas the steroidal alkamine affects the nervous system. The pharmacological effects of these compounds may possibly be attributable to the ability of the steroidal glycoalkaloids to impair the functioning of membranes of strategic muscle and nerve cells in mammals. Evidence to support this is the toxicity of alkaloids to plants and fungi where complexation has been demonstrated with membrane sterols; it has been shown that the alkaloid sensitivity in *Pythium* and *Phytophthora* increases when these fungi are grown on a medium containing sterol and incorporate the sterol into their membranes. However, aglycones also have a still unexplained deleterious effect on certain tissues and organisms, and other mechanisms may be involved in the toxicity of *Solanum* alkaloids. Furthermore, the toxicity of the alkaloids is highly pH-dependent: lower pH levels greatly reduce toxicity.

The physiological and pathological effects of steroidal glycoalkaloids on mammals are numerous. Solanine has been observed to depress the central nervous system in rabbits; solanine, chacoine and tomatine have been observed to induce tachycardia in rabbits and rats; chacoine, tomatine and solanine have been observed to induce tachypnea or bradypnea in rabbits. Other reported effects are hypotension induced by tomatine in rats and rabbits, positive inotropic (cardiotonic) action by tomatine, chacoine, solanine, demissine, commersonine and solanidine in frogs, hyperglycaemia induced by solanine in rats, haemolysis and haemorrhage induced by tomatine in rats, inhibition of plasma cholinesterase by solanine, solanidine, tomatine and demissidine in humans and embryotoxicity induced by solanine in rats and mice.

The powdered aerial parts of *S. nigrum* and its methanolic extract significantly reduced gastric ulcer formation in rats. The activity may be due to inhibition of acid and pepsin secretions and/or their in vitro ability to bind these; inhibition of the acid production alone by cimetidine did not decrease ulcer formation. 'Sobatum' is the partially purified component of *S. trilobatum* obtained from the 75:25 petroleum ether/ethyl acetate extract. It has been found to be cytotoxic in Dalton's Lymphoma ascites, Ehrlich ascites cell lines and tissue culture cells (L929 and Vero). 'Sobatum' significantly inhibited peritoneal tumours induced by Dalton's Lymphoma ascites and Ehrlich ascites tumour cells. It was also found to reduce solid tumour growth in mice, when given either simultaneously or prophylactically, and is more active in simultaneous administration in Ehrlich ascites cell lines. It was found that 'Sobatum' was more active against Ehrlich ascites-induced solid tumour than Dalton's Lymphoma ascites-induced solid tumours. It has been experimentally proven that 'Sobatum' has the ability to retard the development of solid tumours and 7,12-dimethylbenz(a)anthracene-induced carcinogenesis. In another experiment with mice, 'Sobatum' was administered intraperitoneally. It failed to influence the induction of micronuclei in bone marrow erythrocytes of mice 24 hours and 72 hours after the second administration, thereby demonstrating that 'Sobatum' has no cytogenic toxic potential. The rare sterol carpesterol isolated from *S. trilobatum* (also found in *S. torvum* Swartz) has anti-inflammatory activity on carrageenin-induced mouse paw oedema; it proved as effective as hydrocortisone and withaferin A (from *Withania somnifera* (L.) Dunal). The alcoholic extract of *S. nigrum* berries (100–400 mg/kg) showed significant inhibition of carrageenin-induced oedema in albino rats. The aqueous leaf extract of *S. erianthum* did not produce any significant suppression of *Plasmodium berghei* infection in mice.

A large number of fungi are inhibited in growth and development by steroidal alkaloids such as tomatine, solanine, and chaconine. An alcoholic extract of leaves of *S. nigrum* is active against *Staphylococcus aureus* and *Escherichia coli*. Leaf extracts of *S. nigrum* inhibited lesion production in leaves in response to the tobacco mosaic virus. The flavonoid-rich extract of *S. erianthum* possesses antibacterial and antifungal activity. Gram-positive bacteria are inhibited, but gram-negative ones are not, whereas the flavonoids have been found to be toxic to the fungi *Aspergillus flavus* and *Candida albicans*. Some other pharmacological activities of *Solanum* include antispasmodic, hypotensive, hypocholesterolaemic and anti-HIV-1 activity induced by *S. nigrum* in mammals, and insecticidal and molluscicidal activity of *S. nigrum* and of *S. mammosum* L.

Solanum steroidal alkaloids are useful in industry as steroid precursors. Solasodine is a nitrogen analogue of diosgenin, a compound often used as raw material for the production of medicinal steroids. The synthetic steroids have three main applications in medicine: as anti-inflammatory corticosteroids, as contraceptive sex steroids and as anabolic steroids.

Adulterations and substitutes Steroidal alkaloids (e.g. diosgenin and tigogenin) are also found in *Dioscorea* and *Smilax* species; these are also used as starting material for steroid hormone semisynthesis.

Description Annual or perennial, erect or ascending, unarmed or spiny herbs, shrubs or rarely small trees, with simple, branched, stellate or glandular hairs. Leaves alternate or rarely subopposite, simple and entire to lobed, pinnatisect or imparipinnate, petiolate, exstipulate. Inflorescence a terminal cyme but usually appearing lateral by growth of a lateral bud and extra-axillary cyme, appearing racemose, umbellate or paniculate or rarely reduced to a solitary flower. Flowers regular, bisexual or rarely andromonoecious; calyx campanulate, rotate or cupular, (4–)5(–10)-lobed; corolla stellate, rotate or campanulate, (4–)5(–10)-lobed, white, violet, purple or blue; stamens (4–)5, inserted on the corolla throat, alternating with the corolla lobes, anthers often connivent, opening by terminal pores or slits; ovary superior, 2(–4)-locular with many ovules in each cell, style simple, stigma capitate or bifid. Fruit a usually globose berry, with a persistent and sometimes enlarged calyx, few to many-seeded. Seeds orbicular to subreniform, compressed, often minutely pitted or reticulate. Seedling with epigeal germination; cotyledons emergent, ovate to linear-lanceolate; first leaves usually entire.

Growth and development Most *Solanum* species flower and fruit almost throughout the year. Flowers are pollinated by insects. Fruit maturation takes about 2–3 months. The fruits are eaten by birds and mammals which disperse the seeds.

Other botanical information *Solanum* has been subdivided into 7 subgenera and numerous sections and series. *S. nigrum*, being the type-species of the genus, belongs to subgenus *Solanum*, *S. erianthum* to subgenus *Brevantherum* and the other four species treated below to subgenus *Leptostemon* which also includes *S. melongena* L. and *S. mammosum* L., species well-known for their fruits. It is in South-East Asia that the taxonomy of *Solanum* is least known: a thorough taxonomic revision is urgently needed. Adding to the taxonomic confusion is the fact that *S. erianthum* has been extensively referred to as *S. verbascifolium* L., which actually proved to be identical with a South American species. Moreover, in South-East Asian literature, *S. capsicoides* has often been misinterpreted as *S. aculeatissimum* Jacq. Furthermore, *S. nigrum* belongs to a complex of very similar species (including e.g. *S. americanum* Miller and *S. villosum* Miller), which are sometimes regarded as mere forms of a single variable species. *S. nigrum* arose from hybridization of the diploid *S. americanum* and the tetraploid *S. villosum*. *S. villosum* is distinguished by its yellow, orange or red berries. *S. americanum* and *S. nigrum* are much more difficult to distinguish. The former has usually umbellate inflorescences, anthers 1.0–2.0 mm long, a glossy, purplish-black berry with generally 50–80 seeds and an enlarged calyx with reflexed lobes in fruit. For the latter, see below. *S. mammosum*, originally from Central and South America but introduced in the Malesian region for its decorative fruits, has poisonous fruits which are occasionally used as an insecticide against cockroaches and caterpillars. *S. procumbens* Lour., *S. spirale* Roxb. and *S. surattense* Burm.f. (synonym: *S. xanthocarpum* Schrad. & J.C. Wendl.) are used in folk medicine in Indo-China. *S. aviculare* J.G. Forster, *S. laciniatum* Aiton and *S. khasianum* C.B. Clarke are a reputed rich source of solasodine. Originating from outside the Malesian region, they have received special attention in breeding programmes for cultivation at higher elevation in Java. In particular *S. khasianum* merrits further research.

Ecology Most medicinal species of *Solanum* are weeds of gardens, fields and waste places, occurring in sunny or slightly shaded sites at low to medium altitudes, but *S. nigrum* is found up to 3100 m.

Propagation and planting Those *Solanum* cultivated as vegetables in South-East Asia can be propagated by seed, shoot cuttings and by division of rooted shoots.

In vitro production of active compounds Diosgenin and solasodine have been isolated from 6-month-old callus of *S. erianthum*; the undifferentiated callus tissue was established from sterilized seeds on Murashige and Skoog's revised medium. Blue light stimulated solasodine synthesis and green light stimulated diosgenin synthesis in the callus. Optimal growth was reached after 6 weeks when the dry weight of the tissue had increased 6.6-fold. After 6 weeks only about 147 μg diosgenin and 47 μg solasodine had been produced per g of dry-weight tissue; this is very little.

Diseases and pests In West Java *S. nigrum* grown as a leaf vegetable is fairly free from diseases and pests.

Harvesting Leaves, stems, berries and roots of *Solanum* are harvested for medicinal use. When used as a vegetable, leaves and young shoots of *S. nigrum* are hand-picked.

Yield In many species the steroidal alkaloid and sapogenin content decline as the fruit ripens. Leaf alkaloid and sapogenin content also decline with age. In India a method has been developed to estimate solasodine content in *S. nigrum* leaves 3 months after sowing by estimating their N content. At this stage of growth a top dressing or foliar sprays may be applied to increase solasodine yield.

Handling after harvest In general, *Solanum* fruits are used fresh. The other harvested parts are dried and can be stored in sealed containers, preferably in a cool well-aerated room.

Genetic resources and breeding *S. capsicoides* is resistant to *Pseudomonas* and is a non-host for potato cyst nematodes. There are no records of medicinally important *Solanum* in germplasm collections. In view of their weedy nature the risk of genetic erosion seems to be rather limited. The great variation in alkaloid content within species may offer possibilities for selection. However, the alkaloid content also varies substantially as a result of ecological conditions, drying and storage.

Prospects Several *Solanum* species containing the spirosolane alkaloids solasodine and tomatidenol are considered promising as alternatives to *Dioscorea* species as a source of raw material for steroid production, including 16 dehydropregnelone acetate. Hormonal derivatives of this steroid are used as active ingredients of the oral contraceptive pill. The ability of *S. trilobatum* components to retard the development of solid tumours and to act as anti-inflammatory deserves further research.

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Selection of species

Solanum capsicoides All.

Auct. synop. meth. stirp. hort. reg. Taurensis: 12 (1773).

Synonyms *Solanum ciliatum* Lamk (1794), *Solanum ciliare* Willd. (1809), *Solanum aculeatissimum* auct. non Jacq.

Vernacular names Indonesia: terong kori, terong tenang (Sundanese). Malaysia: terong asam hutan, terong perat, terong puyoh (Peninsular). Thailand: khuea hin (peninsular), ma khuea kham (northern), ma khuea khuen (Chiang Mai).

Distribution Originally from coastal Brazil, but now commonly naturalized in western Africa, the Caribbean, Central America, Mexico, Florida, Hawaii, the Ryukyu Islands, Taiwan, China, India, Sri Lanka and in South-East Asia in Thailand, Peninsular Malaysia, Sumatra and Java; to be expected elsewhere.

Uses The fruits, charred and pounded in oil, are used to treat skin complaints. In Peninsular Malaysia, the pounded roots have been applied to the gums against toothache. The smoke of dried, pounded and burned seeds has been inhaled to cure an ulcerated nose. The fruits are edible when roasted or cooked in curry. *S. capsicoides* is sometimes cultivated as an ornamental for its decorative fruits.

Observations A perennial, slightly woody, prickly herb up to 100 cm tall, stem and leaves glabrous or sparsely pilose with simple hairs; leaves broadly ovate to ovate-cordate, pinnately 5–7-lobed, 4.5–18 cm × 4–12 cm, cordate at base, apex acute; inflorescence extra-axillary, racemose, 1–7-flowered, on a short peduncle; calyx campanulate, 4–5 mm long, shortly glandular hairy, corolla rotate, about 3 cm in diameter, white, lobes lanceolate, anthers narrowed towards the apex, about 6 mm long, with apical pores; fruit solitary or sometimes 2–3 together, globose to depressed globose, 2.5–3 cm in diameter, glabrous, orange-red when mature, calyx slightly enlarged; seeds strongly flattened, winged all around, 4–6 mm in diameter. *S. capsicoides* is a common weed of slightly shaded places, along hedges, sugar-cane fields and roadsides up to 1500 m altitude.

Selected sources 97, 202, 287, 320, 580, 873, 1016, 1017, 1380, 1652.

Solanum erianthum D. Don

Prodr. fl. nepal. 96 (1825).

Synonyms *Solanum mauritianum* Blanco (1837) non Scop., *Solanum verbascifolium* auct. non L.

Vernacular names Potato tree, tobacco tree, tropillo (En). Indonesia: daun salawar, tembako utan (Malay, Moluccas), teter (Javanese, Sundanese). Malaysia: daun telinga kerbau, terong belah, terong raya (Peninsular). Papua New Guinea: kumboomba (Lesu, New Ireland), epiap (Gunantuna, New Britain). Philippines: malatalong (Tagalog), liuangkag (Bukidnon), ungali (Bisaya). Laos: sang mong peng, sang mou. Thailand: dap yaang (central), faa paeng (northern), khaa taai (peninsular). Vietnam: c[af] h[oo]i, c[aa]y la, la r[uwf]ng.

Distribution Originally from the West Indies, Central America and Mexico, but now an almost pantropical weed, although hardly penetrating South America. Probably introduced into the Philippines by the Spanish in the 16th Century, from where it has spread throughout the Malesian archipelago and to mainland Asia and Australia.

Uses The leaves act as an abortifacient and are considered a potent medicine for expelling all impurities through the urine, and in particular to treat leucorrhoea. Pounded leaves are poulticed to treat piles, haemorrhoids and scrofula. Heated leaves are applied as a cream to the forehead against headache. A decoction of the leaves is drunk against vertigo; an infusion of the plant is used for a bath after childbirth. A decoction from the roots is applied to treat violent pains all over the body or to relieve digestive troubles; it is also given to treat dysentery, diarrhoea and fever. In

Solanum erianthum D. Don – 1, flowering stem; 2, flower; 3, infructescence.

Papua New Guinea, the plant is used internally to treat stomach-ache and is applied externally to skin irritations and rashes. In the Solomon Islands, leaf juice is used as a rinse for sores in the mouth. *S. erianthum* is considered poisonous to livestock. The root bark is poisonous and can be used as an antiphlogistic and against arthritis. The fruits can be eaten when cooked.
In the Philippines, the velvety leaves are used to remove grease from dishes. *S. erianthum* is considered suitable as a shade plant for coffee.

Observations An unarmed shrub or small tree up to 4(–10) m tall with a dense indumentum of soft stellate hairs, stem up to 20 cm in diameter; leaves simple, ovate-elliptical, (7–)10–20(–29) cm × 3.5–15 cm, margin entire or slightly wavy, base rounded to cuneate, apex acute to acuminate; inflorescence appearing terminal, a compound cyme; calyx campanulate, 5 mm long, lobes ovate, corolla stellate, about 1.5 cm in diameter, white, anthers oblong, about 2 mm long, opening with apical pores, ovary densely pubescent, style 4–6 mm long, glabrous; fruit globose, 8–12 mm in diameter, pubescent, dull yellow when ripe; seeds many, compressed, 1–2 mm in diameter. *S. erianthum* is fairly common, occurring scattered in sunny or slightly shaded places, in brushwood, roadsides, field edges, on waste ground and in forest edges, up to 1500 m altitude.

Selected sources 13, 78, 97, 127, 164, 202, 287, 580, 665, 666, 873, 889, 1035, 1126, 1178, 1250, 1251, 1380, 1433, 1525, 1652.

Solanum nigrum L.

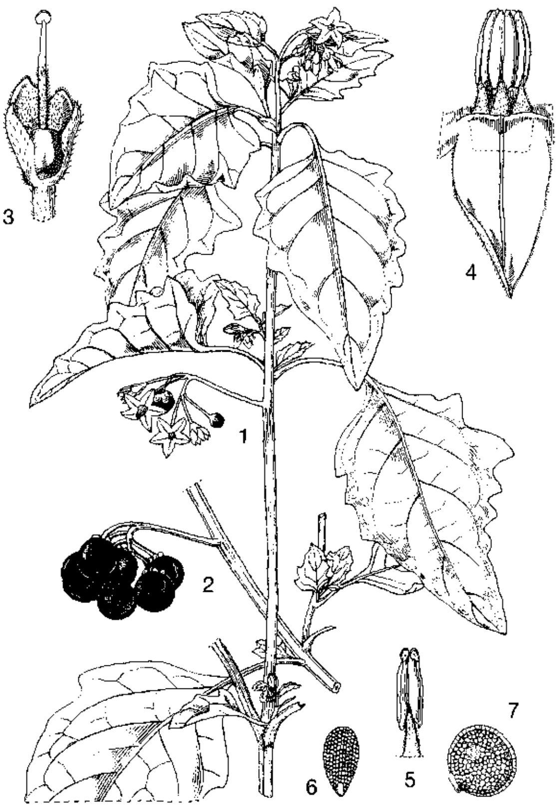
Sp. pl. 1: 186 (1753).

Synonyms *Solanum schultesii* Opiz (1843).

Vernacular names Black nightshade, common nightshade, garden nightshade (En). Herbe à calalou, morelle noire (Fr). Indonesia: ranti (Javanese), leunca (Sundanese), bobose (Ternate). Malaysia: ranti, terong meranti, terong parachichit (Peninsular). Papua New Guinea: takuta (Wapenamanda, West Sepik). Philippines: konti (Filipino), anti (Bontok, Tagalog), kuti (Bikol). Thailand: ma waeng nok (southern), ya tom tok (northern), kha om (Prachuap Khiri Khan). Vietnam: c[af] n[us]t [as]o, gia c[aaf]u, lu lu d[uwj]c.

Distribution Native to Europe and western Asia, introduced in North America, Africa, Asia and Australia; probably fairly widely distributed throughout the Malesian region.

Uses The medicinal use of *S. nigrum* goes back more than 2000 years. The plants are used as an emollient and antalgic in itching, burns and neuralgic pains, and are also considered expectorant and laxative. The leaves are said to have sedative and healing properties and are applied to cuts and ulcers. A decoction of the leaves is used to treat yaws. The fruit is considered to be a cure for diabetes. In Papua New Guinea, cooked leaves and stems are given to infants suffering from diarrhoea. In China, cooked young shoots are considered to be corrective and cooling, to increase the virility of men and to benefit menstrual disorders. A decoction of the leaves or seeds is used to treat wounds, cancerous sores and as an astringent. Diuretic properties are also attributed to the plant. The leaf juice is used against pain caused by an inflammation in the kidneys and bladder and by virulent gonorrhoea. In India, the leaves are used to treat inflammations on any part of the body, rheumatic and gouty joints and skin diseases. An extract of the leaves and stem is considered useful to treat dropsy, heart diseases, piles, gonorrhoea,



Solanum nigrum L. – 1, flowering stem; 2, part of fruiting stem; 3, opened calyx and gynoecium; 4, petal and stamens; 5, stamen; 6, seed from below; 7, seed in side view.

fevers, eye diseases and the chronic enlargement of liver and spleen. Young shoots are eaten as a vegetable either raw or cooked. The ripe fruits have been used for jam-making and in pies, but caution should be taken as unripe fruits are certainly poisonous and the fruits of European *S. nigrum* and possibly of other *Solanum* species are thought to be poisonous at all stages of their development.

Observations An annual or perennial unarmed herb up to 1 m tall, indumentum of simple eglandular and glandular hairs; leaves ovate, 4–10 cm × 2–7 cm, simple, margin entire to bluntly toothed, base cuneate, apex obtuse; inflorescence extra-axillary, a short raceme of (3–)4–8(–12) flowers; calyx campanulate, lobes up to 1 mm long, corolla stellate, 8–10 mm in diameter, white or rarely tinged with purple, anthers oblong, 2–3.5 mm long, ovary glabrous, style 5–6 mm long, stigma capitate; fruit globose to ellipsoid, 6–8(–10) mm in diameter, 2-locular, dull or somewhat shiny black or purplish-black, calyx not enlarged and with appressed or scarcely reflexed lobes; seeds (15–)25–35(–45) per fruit, 1.8–2.2 mm long. *S. nigrum* is common in open and disturbed places, in full sunshine or slight shade, also in light forest, up to 3100 m altitude.

Selected sources 21, 42, 78, 97, 164, 190, 202, 214, 287, 349, 375, 566, 749, 874, 999, 1035, 1087, 1178, 1235, 1244, 1245, 1260, 1297, 1356, 1380, 1432, 1652.

Solanum sanitwongsei Craib

Kew Bull.: 246 (1928).

Vernacular names Philippines: talong-siam (Filipino). Thailand: ma waeng khruea (central).

Distribution Thailand; cultivated in the Philippines.

Uses The fruits are effective against diabetes and even seem to be capable of curing it. They are also expectorant and diuretic.

Observations A small, stellately hairy shrub up to 1 m tall, leaves oblong-ovate, 5–9 cm × 3.5–8 cm, with 2–3 lobes on either side, base cordate to cuneate, apex obtuse; inflorescence an extra-axillary, short raceme on a short peduncle; sepals 5, connate up to halfway, corolla stellate, about 2 cm in diameter, purple, anthers 6 mm long, ovary glabrous except for the apex, stigma subcapitate; fruit subglobose, 1 cm in diameter, glabrous, orange when mature; seeds abundantly, minutely dotted, about 2 mm in diameter.

Selected sources 290, 1126, 1178, 1287.

Solanum sarmentosum Nees

Trans. Linn. Soc. 17: 58 (1837).

Synonyms *Solanum maingayi* O.Kuntze (1891).

Vernacular names Malaysia: terong pipit, terong puyoh, terong tikus (Peninsular).

Distribution Peninsular Malaysia and Singapore.

Uses The leaf juice is drunk as a remedy for fever. The seeds are used as a vermifuge.

Observations An armed, straggling shrub; leaves elliptical, 5–10 cm × 2–5 cm, lobed, almost glabrous above, sparsely hairy below; inflorescence composed of 1–2 flowers on a peduncle of about 2.5 cm long; calyx funnel-shaped, thorny, corolla about 2 cm in diameter, blue; fruit about 12 mm in diameter, glabrous, orange when mature, seated on an enlarged calyx. *S. sarmentosum* occurs as a weed in gardens and ruderal places.

Selected sources 202, 1126, 1227.

Solanum trilobatum L.

Sp. pl. 1: 188 (1753).

Synonyms *Solanum acetosaefolium* Lamk (1794), *Solanum canaranum* Miq. ex C.B. Clarke (1883).

Vernacular names Thailand: khwaeng khia (Tak), ma waeng khruea (central). Vietnam: c[af]ba th[uf]y.

Distribution India, Vietnam, Thailand and Peninsular Malaysia.

Uses In India, the bitter roots and young shoots have been given in the form of an electuary, a decoction or a powder for consumption. The medicine is mainly used for asthma, chronic febrile affections and difficult parturition. The fruit is edible, and the leaves are eaten cooked as a vegetable.

Observations A nearly glabrous, thorny herb, slightly woody at base; leaves broadly elliptical to broadly ovate, 4–7.5 cm × 2.5–4 cm, sinuate-lobed, base rounded to slightly cordate, apex rounded; inflorescence extra-axillary, composed of a few-flowered cyme or a 6–10-flowered raceme; calyx campanulate, 2–3 mm long, glabrous, not enlarged in fruit, corolla stellate, 2.5–3.5 cm in diameter, blue, anthers 5, 7–8 mm long; fruit about 1 cm in diameter, purple to blackish; seeds about 3 mm in diameter. *S. trilobatum* is found as a weed in gardens and on waste ground. In India it is reported to grow in tidal swamps.

Selected sources 78, 97, 148, 171, 202, 287, 962, 963, 1227, 1380.

M.M. Blomqvist & Nguyen Tien Ban

Sophora tomentosa L.

Sp. pl. 1: 373 (1753).

LEGUMINOSAE

$x = 9$; $2n = 18$

Synonyms *Sophora heptaphylla* L. (1754), *Sophora crassifolia* J. St.-Hil. (1806), *Sophora havanensis* Jacq. (1860).

Vernacular names Seacoast laburnum, silver bush (En). Indonesia: kayu penawar (Javanese), ki ucing (Sundanese), upas biji (Malay, Moluccas). Malaysia: pelochok, pelotok (Peninsular). Philippines: tambalisa (Filipino), mangguiau (Bikol, Tagalog), pangalangan (Tagalog, Bisaya). Cambodia: sândaèk préi srâmot. Thailand: saaraphat phit (Phetchaburi). Vietnam: (c[aa]y) chu[oox]i h[ooj]t, h[of]e l[oo]ng.

Origin and geographic distribution *S. tomentosa* has a pantropical, coastal distribution. It is common throughout the South-East Asian region, occurring north to China and the Ryukyu Islands, south to eastern Australia and east into Polynesia.

Uses The seed oil of *S. tomentosa* is reputed to be a good expectorant; in the Philippines it is applied externally to soothe painful bones. A decoction of the seeds and roots is given in bilious disorders. A decoction of the seeds, roots or bark has been used against cholera. The pounded seeds are used to cure colic and dysentery. Smaller doses are applied as an antidote in food poisoning and stings of poisonous fish, as well as to treat haemoptysis, painful urination and gonorrhoea. The root-bark is also used to treat such cases of poisoning. The Thai name 'saaraphat phit' means various poisons, probably referring to its use as an antidote. In East Africa *S. tomentosa* is used as a fish poison.

The timber of *S. tomentosa* is hard and heavy and used for small objects. It is occasionally grown as an ornamental in gardens close to the sea.

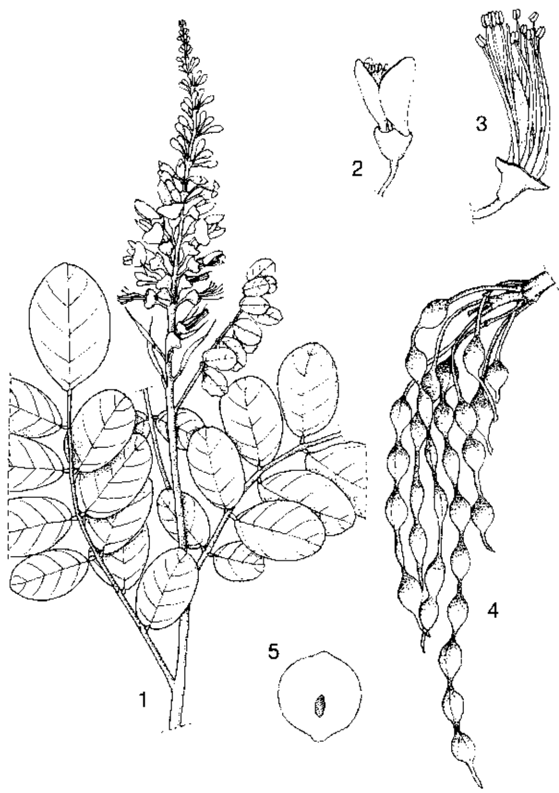
Properties The bitter seeds of *S. tomentosa* have astringent, febrifugal, stomachic and dangerous emetocathartic properties. The leaves are also strongly emetocathartic and toxic in large doses. *Sophora* species are relatively rich in alkaloids: these can be found in leaves, roots and seeds. Some of these alkaloids seem to be common, whereas others appear to be confined to a single or a limited number of species. Detailed phytochemical investigations have led to the isolation of (+)-matrine, (+)-matrine-N-oxide, (+)-sophocarpine-N-oxide, (–)-anagyrine, (–)-baptifoline, (–)-cytisine, (–)-N-methylcytisine, (–)-formylcytisine, (–)-

N-acetylcytisine, (±)-ammodendrine, (–)-epiamprolobine, (+)-epiamprolobine-N-oxide and 5-(3'-methoxycarbonylbutyroyl)aminomethyl-trans-quinolizidine from the various (fresh) parts of *S. tomentosa*. All compounds belong to the quinolizidine group of alkaloids (sometimes also called lupin alkaloids), which are biosynthesized from the amino acid lysine. The amounts of this amino acid in the leaves, stems, immature pods and immature seeds are respectively 0.15%, 0.22%, 0.37% and 0.64% of the fresh weight, with (+)-epiamprolobine-N-oxide, (+)-matrine-N-oxide, (+)-matrine and (–)-cytisine being the most abundant alkaloids. Together with (–)-N-methylcytisine, the latter three compounds are also found in *S. flavescens* Aiton from China, a species commonly traded in Chinese pharmacies throughout Malaysia.

The pharmacological actions of several of the alkaloids have been quite well investigated. Dried seed of *S. tomentosa* contains up to 2% (–)-cytisine (also known as sophorine or ulexine), which resembles the alkaloid nicotine in its action as a neurotransmitter, but is much less toxic as a poison. It also has insecticidal properties. The effects of (–)-N-methylcytisine and (+)-matrine isolated from *S. flavescens* on the motility of parasitic helminths and mouse ileum preparations have been experimentally tested. The two alkaloids acted antagonistically on all the preparations: (–)-N-methylcytisine acted spastically and (+)-matrine paralytically. From the results on interactions between these alkaloids and known neuropharmacological agents, it is suggested that the effects of both alkaloids are elicited through a neuropharmacological mechanism in parasitic helminths and host tissue. (+)-Matrine also has anti-inflammatory properties as well as anti-ulcer properties; this was demonstrated in an experiment in fundus strips of rats. (+)-Matrine isolated from the root of *S. subprostrata* Chun & Chen showed significant inhibition of ocular inflammation induced by lens proteins. Unlike corticosteroids, (+)-matrine did not facilitate the intra-ocular pressure recovery in rabbit eyes nor did it change the electrical potential difference across rabbit iris-ciliary body. These results indicate that (+)-matrine could become a safer ocular anti-inflammatory agent than corticosteroids. Furthermore, (+)-matrine was found to markedly increase the reaction time of a mouse placed on a hot plate; the results indicate that this component could be used as an analgesic as well. The effect of (+)-matrine, from *S. flavescens*, on glutamate-induced responses was investigated using electrophysiological techniques at the crayfish neuromuscular junction. At concentrations greater than 0.1 mM, (+)-matrine depressed both glutamate-induced responses and neurally evoked excitatory junctional potentials. In this assay (+)-matrine-N-oxide (= oxymatrine) also shows activity, although far less powerfully than (+)-matrine. Finally, (+)-matrine-N-oxide (oxymatrine) has a biphasic effect on cultures of rat myocytes: slowing the beating rate by α-adrenoreceptor stimulation (concentrations at 50 μmol/l) and accelerating it by β-adrenoceptor stimulation (250 μmol/l concentration).

Five isoprenylated flavonoids have been isolated from the aerial parts of *S. tomentosa*: sophoraisoflavanone A, sophoraflavanone B, sophoronol, isosophoranone and isobavachin. The structurally closely related flavonoid vexibiol, from *S. flavescens*, is known to exhibit anti-ulcer effects.

Adulterations and substitutes (–)-Cytisine (also known as sophorine or ulexine) as found in



Sophora tomentosa L. – 1, flowering twig; 2, flower; 3, flower with petals removed; 4, infructescence; 5, seed.

several *Sophora* species is also found in *Laburnum anagyroides* Medik. and *Ulex europaeus* L.

Description An evergreen shrub or small tree up to 7 m tall; bole branchless for up to 3 m, up to 45 cm in diameter; young twigs, leaf rachises, lower surface of leaflets, inflorescences, calyces and pods densely puberulous or tomentose. Leaves arranged spirally, imparipinnate, up to 30 cm long, with 9–23 leaflets, stipules absent; leaflets opposite, broadly elliptical to suborbicular, up to 4(–5) cm × 3 cm, apex rounded to slightly emarginate. Flowers in a terminal raceme up to 25 cm long, papilionaceous; bracteoles absent; pedicel 5–10 mm long; calyx campanulate, with 5 shallow teeth; petals yellow, standard 14–20 mm × 11–14 mm, wings and keel of equal length; stamens 10, free; ovary superior, densely appressed pubescent. Fruit a 3–10-seeded pod, 5–19 cm long, markedly constricted between the seeds. Seeds subglobose, 6–7 mm long, brownish. Seedling with hypogeal germination; cotyledons not emergent; hypocotyl elongated; epicotyl with a few scale leaves, followed by simple, then 2-foliolate, 3-foliolate, 5-foliolate, etc. leaves.

Growth and development In Indo-China, *S. tomentosa* flowers in December–January, in Malesia from October to June. Fruits mature in about 3–4 months and are dispersed by sea currents. Seeds are able to float for at least 3 months and in this period the germination capacity is not affected. However, germination significantly dropped following immersion in sea water. *S. tomentosa* has been observed nodulating in Hawaii.

Other botanical information *Sophora* comprises about 50 species and belongs to the tribe *Sophoreae* of the subfamily *Papilionoideae*. *S. tomentosa* has been subdivided into several subspecies; within Malesia only subsp. *tomentosa* occurs. The correct name for the well-known *Sophora japonica* L., which is used medicinally, as a dye and as an ornamental, is *Styphnolobium japonicum* (L.) Schott. The segregation of the small genus *Styphnolobium* from *Sophora* is supported by morphological evidence, a deviating somatic chromosome number and DNA research.

Ecology *S. tomentosa* is a coastal species, growing on sandy foreshores or open grassland along the beach, often locally abundant. It is more or less a pioneer species.

Propagation and planting In a germination experiment in Malaysia, seeds of *S. tomentosa* germinated in 0.5–11 months.

Genetic resources and breeding The risk of genetic erosion or depletion of *S. tomentosa* seems rather limited, since it is pantropical and locally common.

Prospects The pharmacological properties from alkaloids such as (–)-cytisine, (–)-N-methylcytisine, (+)-matrine and (+)-matrine-N-oxide might be of interest (e.g. as lead compounds) in the research and development of new pharmaceuticals.

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Other selected sources 50, 97, 202, 284, 334, 487, 580, 855, 1006, 1020, 1022, 1035, 1036, 1039, 1128, 1178, 1444, 1480, 1608, 1609.

J.L.C.H. van Valkenburg

Stephania Lour.

Fl. cochinch.: 608 (1790).

MENISPERMACEAE

$x = 11, 12, 13$; *S. japonica*: $2n = 22, 24$

Major species *Stephania japonica* (Thunb.) Miers, *S. sinica* Diels.

Vernacular names Vietnam: b[if]nh v[oo]i (general).

Origin and geographic distribution *Stephania* consists of approximately 45 species and occurs in tropical and subtropical regions and in the warmer parts of temperate regions of the Old World. In Malesia, 12 or perhaps 13 species have been found, some of which have very wide distribution, particularly *S. japonica*.

Uses Many *Stephania* species are used in local medicine against a variety of complaints. In the Philippines, *S. japonica* is known as a cure for itches; in Papua New Guinea, *Stephania* roots and juice are applied to sores, cuts and stings. In India, the roots are used in the treatment of diarrhoea, dyspepsia, urinary diseases and heart ailments. Roots of *Stephania* spp. are employed in India and Indo-China in the treatment of pulmonary tuberculosis, asthma, dysentery, fever, hypoglycaemia and intestinal complaints (decoction, reported dose 4–5 g/day). Stems are used to treat ascariasis and dysmenorrhoea, leaves to treat indigestion, wounds, headache, sore breasts, dysuria, oliguria and oedema (decoction, reported dose 6–12 g/day), and flowers to treat leprosy. Root extracts of *S. glabra* (Roxb.) Miers have a long-standing reputation in India as an anti-dysenteric, antipyretic and antiasthmatic. In Thailand, *S. venosa* is commonly known as 'blood-soap', due to the red colour of its latex. The plant is often employed as a bitter tonic. The roots of *S. pierrei* Diels are used in Thai folk medicine as a skeletal muscle relaxant and also as an analgesic and tonic. A number of *Stephania* species are well known in traditional Chinese medicine; the most important are *S. tetrandra* S. Moore (analgesic, diuretic and antihypertensive) and *S. cepharantha* Hayata (analgesic, diuretic and tuberculostatic). In Africa (e.g. in Nigeria), *Stephania* extracts are also used medicinally.

Drugs from the tuberous roots are usually administered in the form of a decoction, as tincture or as a tablet with high alkaloid content. In Vietnam, for instance, (–)-tetrahydropalmatine is prescribed to treat neurasthenia and psychoses in the form of a 0.05 g tablet with a daily dose of 1–3 tablets.

S. tetrandra has been used in slimming regimens because it eliminates oedema and 'stress-related water retention' but some cases of rapidly progressive fibrosing interstitial nephritis have been recorded in young women following this slimming regimen. However, the renal failure was not caused by the *Stephania* ingredient, since thorough investigations showed that *Stephania* had been confused with a species of *Aristolochia*, but these cases demonstrate how important it is to properly identify natural products to be used as medicines.

The leafy branches of *S. japonica* are sometimes used as forage.

Production and international trade *Stephania* species are only used on a local scale. However, recently the use of tuberous *Stephania* has gained importance, and in Vietnam they are much traded and also exported unregistered.

Properties Numerous alkaloids have been isolated from the tuberous roots and stems of *S. japonica*. Epistephanine and hypoepistephanine (major components), stepholine, stebisimine and insularine are alkaloids of the bisbenzylisoquinoline type. Stepinonine is a related alkaloid with a benzazepine structural element. A series of alkaloids derived from hasubanan (a structural isomer of morphinan) have also been isolated from the roots and stems of *S. japonica*: hasubanonine, metaphanine, homostephanoline, prometaphanine, stephamiersine, epistephamiersine, oxostephamiersine, stephasunoline, oxoprometaphanine, oxohasubanonine, oxoepistephamiersine and oxostephasunoline. Various other alkaloids have been isolated from the roots and/or stems, including stephadiamine (norhasubanan type), oxostephanine, lanuginosine and magnoflorine (aporphine type), cyclanoline and steponine (tetrahydroprotoberberine type), and protostephanine (bibenz[d,f]azonine type). The composition of alkaloid constituents seems to differ somewhat between plants collected in different habitats. The alkaloids oxostephamiersine and oxoprometaphanine (hasubanan type) and stebisimine (bisbenzylisoquinoline type) have been isolated from the leaves of *S. japonica*, and stephabenine, oxostephabenine and prostephanaberrine (all hasubanan type) from the fruits. Oxostephabenine can be converted by alkaline hydrolysis into N,O-dimethyloxostephine, whereas prostephanaberrine is converted into stephanaberrine upon treatment with aqueous HCl.

Four alkaloids have been isolated from the aerial parts of *S. japonica* var. *discolor*: (+)-epistephanine (bisbenzylisoquinoline type), magnoflorine (aporphine type), aknadinine (= 4-demethylhasubanonine) and hernandifoline (hasubanan type). (+)-Epistephanine possesses significant adrenergic neurone blocking activity. The compound acts like guanethidine, by selectively blocking the responses to sympathic nerve stimulation without affecting the responses to the receptor agonist adrenaline. Parallel dose response curves suggest that both components act by the same mechanism, although (+)-epistephanine is approximately one tenth as potent as guanethidine, and the onset of action was slower and duration shorter than that of the latter. Finally, the bisbenzylisoquinoline alkaloid insularine is reported to have a curare-like activity.

Four isoquinoline alkaloids with (–)-tetrahydropalmatine (tetrahydroprotoberberine type) as the major alkaloid have been isolated from the tuberous roots of plants identified as *S. rotunda* Lour. (its status is uncertain); cepharamine, a hasubanan alkaloid, has been isolated from the leaves and stems. The alkaloidal content of the aerial parts of the plant was found to be quite different from that of the tuberous roots.

Investigations of the roots of *S. glabra* resulted in the isolation of two bisbenzylisoquinoline alkaloids ((–)-cycleanine and (–)-N-desmethylcycleanine), five tetrahydroprotoberberine alkaloids ((–)-capaurine, (–)-corynoxidine, (–)-tetrahydropalmatine, (–)-corydalmine and (–)-stepholidine), two aporphine alkaloids ((+)-stepharine and (+)-pronuciferine), and five quaternary protoberberine alkaloids (palmatine, palmatrubine, dehydrocorydalmine, jatrorrhizine and stepharanine).

Several alkaloids isolated from plants identified as *S. rotunda* or *S. glabra* possess pharmacological activity. (–)-Cycleanine has shown significant inhibition of nitric oxide production in vitro, and reduced the level of tumour necrosis factor in vivo, using a mouse model for fulminant hepatitis.

(–)-Stepholidine has shown sedative and antispastic effects in experiments with animals. Detailed pharmacological investigations revealed the compound to be a dopamine (DA_2-subtype) antagonist in normal rats. Under certain experimental conditions (in 6-hydroxydopamine lesioned rats), however, dopamine (DA_1-subtype) agonistic effects could be demonstrated. Further investigations on the calcium metabolism suggest that (–)-stepholidine may modulate its pharmacological actions by altering Ca^{2+} regulating processes in the central dopaminergic nervous system.

(–)-Tetrahydropalmatine has been found to show antispasmodic (especially on the gastro-intestinal tract), sedative and cardiotonic activity. Investigations indicate the component to be a dopamine (DA_2-subtype) antagonist. The interaction also has stereoselectivity; (–)-tetrahydropalmatine is a DA_2 antagonist whereas (+)-tetrahydropalmatine seems not to be.

The identity of *S. erecta* Craib is somewhat controversial; it is usually considered a synonym of *S. pierrei*. Comparison of the alkaloid content of both species indicated that different types of isoquinoline alkaloids were produced. Bisbenzylisoquinolines were the major alkaloids of *S. erecta*, whereas aporphine and tetrahydroprotoberberine type alkaloids represented the major constituents of *S. pierrei*. Isolation procedures guided by biological activity resulted in the isolation and identification of 23 isoquinolines from the latter species, which were subsequently tested for antimalarial and cytotoxic effects. Only the aporphine type alkaloid (–)-asimilobine demonstrated appreciable antimalarial activity together with a lack of cytotoxicity and may thus provide a good starting point for further development of more potent analogues. However, (–)-cycleanine also showed selective antiplasmodial activity.

At least 23 alkaloids have been identified in *S. venosa*, belonging to the protoberberine or (oxo-) aporphine type. The major alkaloids found in the roots were (+)-stepharine (aporphine type) and (–)-crebanine (aporphine type), each about 5% by weight.

S. tetrandra and *S. cepharantha* are well known in traditional Chinese medicine. The roots of *S. tetrandra* are a rich source of bisbenzylisoquinolines, in which S,S-tetrandrine is the predominant (0.7–1.3%) alkaloid. S,S-Tetrandrine has interesting pharmacological properties, including Ca^{2+} channel blocking, anti-inflammatory and immunosuppressive activities (See under *Cyclea* for more detailed information). Cepharanthine, a bisbenzylisoquinoline alkaloid found in the roots of *S. cepharantha*, has been found to decrease leucopenia due to the use of antineoplastic agents, to inhibit collagen-induced blood platelet aggregation and to counteract the development of experimental silicosis. Cepharanthine has also been reported from dried roots of *S. pierrei* (about 1%); it is considered to be an immunostimulant and to decrease effectively the side effects of anti-cancer drugs, as well as to inhibit the growth of tuberculous bacteria. In in vitro experiments, cepharantine inhibited proliferation of cancer cells by inducing apoptosis, and it was a highly potent inhibitor of HIV-1 replication.

Extracts from the leaves of *S. japonica* showed mild insecticidal properties against fruit flies in Thailand.

Adulterations and substitutes Other plants that contain isoquinoline alkaloids and are used in Chinese medicine include *Berberis*, *Coptis*, *Corydalis* and *Cyclea* species and several *Menispermaceae* not mentioned here.

Description Mostly slender dioecious climbers up to 20 m long; stem herbaceous or woody, usually glabrous but sometimes puberulous; roots often tuberous. Leaves arranged spirally, simple and entire, peltate, palmately veined, petiole usually geniculate at base; stipules absent. Inflorescence axillary or cauliflorous, usually composed of peduncled umbelliform, solitary or racemose cymes, sometimes flowers in capitula. Flowers unisexual, calyx with 1–8 free imbricate sepals, corolla with 2–4 free petals; male flowers with stamens fused into a peltate synandrium with 4–8 anther cells; female flowers with 1 carpel having a short-lobed or divaricately laciniate stigma. Fruit an obovoid drupe with style scar near base; endocarp bony, dorsally ornamented with a horseshoe-shaped band of 2 or 4 longitudinal rows of processes or transverse ridges. Seed horseshoe-shaped; embryo with cotyledons equalling the radicle, embedded in endosperm.

Growth and development Some *Stephania* species can develop 2–3 tuberous roots under favourable conditions, but usually there is only one. Several species are deciduous in the dry or cold season. Flowers are pollinated by small flies, bees, and possibly also small beetles and moths. The leaves of *S. japonica* produce a fragrance and may also play a role in attracting insects. The fruits may be dispersed by water.

Other botanical information *Stephania* belongs to the tribe *Menispermeae* and is most closely related to *Cissampelos* and *Cyclea*. It can be recognized by the inflorescences composed of umbelliform cymes or disciform capitula.

The taxonomy and nomenclature of the Asian *Stephania* species is still very complex. In Vietnam many species are exploited under a single common name b[if]nh v[oo]i. The correctness of the name *Stephania rotunda* Lour. is still being debated; this name has often been applied to e.g. *S. glabra* (Roxb.) Miers, *S. venosa* (Blume) Spreng. and *S. pierrei* Diels. On nomenclatural grounds, these couplings are difficult to approve, since the *S. rotunda* Lour. is the oldest name. A large number of species not occurring in the Malesian region are used in Chinese and Indo-Chinese medicine, e.g. *S. cepharantha*, *S. kwangsiensis* H.S. Lo, *S. longa* Lour., *S. pierrei* and *S. tetrandra*.

Ecology *Stephania* species occur in primary and secondary forest, regrowths, hedges, thickets and on river banks, sometimes on limestone and along the seashore, up to 2000(–2700) m altitude. Most species are slightly ombrophilous and hygrophilous, especially during the seedling period.

Propagation and planting *Stephania* is rarely planted. Cultivation trials have been conducted in Vietnam (1983–1984) and Georgia (1965–1969). Plants were propagated from root cuttings and seed, and planted in the fields at a spacing of 70 cm × 20 cm.

In vitro production of active compounds Cell suspension cultures of *S. glabra* have been studied in Russia, using a Murashige and Skoog medium supplemented with saccharose (30 g/l), vitamins, mezoinozite, 2,4-D (1 mg/l) and kinetine (0.1 mg/l). Eleven alkaloids were found in the culture, with no less than 0.3–0.8% stepharine, which was not detectable in plants grown in Georgia. (–)-Tetrahydropalmatine, which is the main alkaloid in the roots, was not detectable in the culture.

Husbandry In trials in Georgia, a combination of organic and chemical fertilizers (5 t of organic fertilizer, 150 kg N, 200 kg P and 120 kg K per ha) increased yields of tuberous roots by 27%.

Diseases and pests Three nematode species have been isolated from *S. japonica* in India.

Harvesting In Vietnam, it is recommended to harvest only tuberous roots in the weight class of 800–1000 g. This ensures a good quality of the product and a fair rate of regeneration.

Yield The yield per ha of fresh tuberous roots in Georgia was 11–13 t for 1-year-old plants, 28–35 t for 2-year-old plants and 42–44 t at the age of 3 years.

Handling after harvest The harvested roots are sliced and dried in the sun or in ovens at not too high temperature. The quality of the product varies considerably; for instance, the content of (–)-tetrahydropalmatine may vary from 0.3–3.6% of the dry tuberous root in *S. glabra*.

Genetic resources and breeding The *Stephania* species described here are widely distributed, locally rather common, and occur particularly in disturbed forest. They seem to be not very liable to genetic erosion. However, several species are rare and threatened in Indo-China and China, partly because of overcollecting. Conservation and planting of these species is essential to counteract genetic erosion which is serious, since the drugs have become popular in recent years.

Prospects The alkaloids which are particularly present in the tuberous roots of *Stephania* have interesting properties, as is the case in many other *Menispermaceae*. The roots are used in traditional medicine in different parts of the world for similar purposes, which also seems to confirm their effectiveness.

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Selection of species

Stephania capitata (Blume) Sprengel

Syst. veg. 4(2): 316 (1827).

Vernacular names Indonesia: areuy geureung, areuy camcau minyak (Sundanese), sumpat kendi (Javanese).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, Java, Bali and Borneo.

Uses The leaves have been reported to be used in Java as a substitute for those of *Cyclea barbata* Miers to prepare 'cincau', which is used as a refreshment and as a medicine against stomach complaints.

Observations A slender woody climber up to 15 m long, root tuberous and fusiform; leaves lanceolate to broadly ovate, 6–17 cm × 2.5–10.5(–14) cm; flowers in peduncled capitula on a short axillary axis, sessile; fruit on a slender stalk, red, endocarp dorsally with 4 rows of capitate projections. *S. capitata* occurs scattered in forest on plains and mountains up to 2000 m altitude.

Selected sources 202, 421, 423, 580.

Stephania japonica (Thunb.) Miers

Ann. Mag. Nat. Hist. ser. 3, 18: 14 (1866).

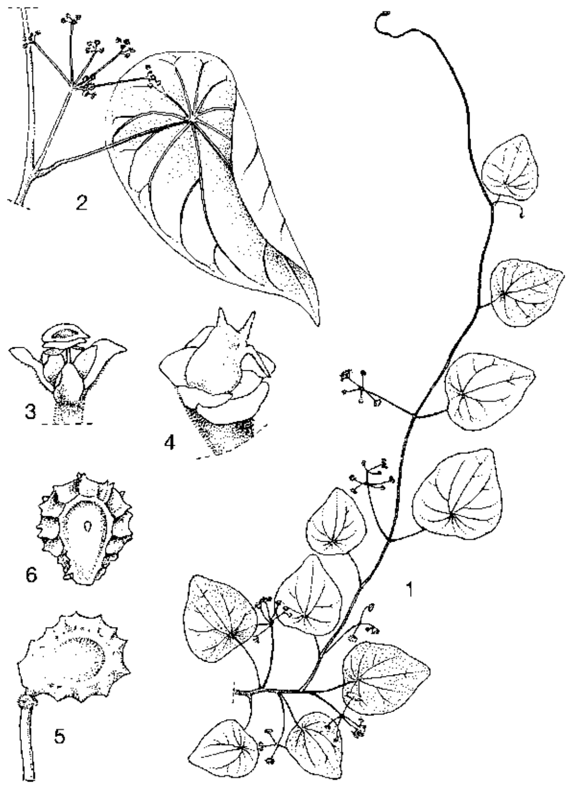
Vernacular names Indonesia: areuy geureung (Sundanese), kepleng (Javanese), ginato bobudo (Moluccas). Philippines: malabuta (Igorot), maratugi (Iloko), kuren (Ibanag). Thailand: kon pit (central), pang pon (northern), tap tao (peninsular). Vietnam: thi[ee]n kim d[awf]ng, d[aa]y l[ox]i ti[eef]n.

Distribution Nepal, India, Burma (Myanmar), Indo-China, southern China, Taiwan, Japan, Thailand, throughout Malesia, northern and eastern Australia and Polynesia.

Uses The tuberous root is used in local medicine to treat dysentery, stomach-ache, fever, urinary disorders, hepatitis, inflammation and itch. Crushed leaves in water are applied to breast infections.

Observations A slender climber up to 10 m long, root tuberous, stem herbaceous or thinly woody; leaves broadly triangular-ovate to ovate, (4–)6–12(–17) cm × 4–10(–14) cm; flowers in an axillary compound umbelliform cyme, sessile or subsessile; fruit sessile or subsessile, red, endocarp dorsally with 4 rows of processes. *S. japonica* is subdivided into 3 varieties based on the hairiness of lower leaf surface and inflorescence: var. *japonica*, var. *timoriensis* (DC.) Forman (synonym: *S. forsteri* (DC.) A. Gray) and var. *discolor* (Miq.) Forman (synonym: *S. hernandiifolia* (Willd.) Walp.). *S. japonica* occurs in secondary forest, regrowths, hedges, thickets and on river banks, also in *Nypa* swamp, up to 2000 m altitude.

Selected sources 190, 202, 421, 423, 580, 642, 643, 798, 915, 916, 917, 918, 919, 1031, 1035, 1178, 1209, 1436, 1611.



Stephania japonica (Thunb.) Miers – 1, flowering twig; 2, part of stem with leaf and inflorescence; 3, male flower; 4, female flower; 5, fruit; 6, endocarp.

Stephania sinica Diels

Engl., Pflanzenr. IV 94 (Heft 46): 272 (1910).

Vernacular names Vietnam: b[if]nh v[oo]i, c[ur] m[ooj]t, c[af] t[of]m.

Distribution Northern Vietnam, Laos and southern China.

Uses The tuberous roots are used as a remedy for neural anodyne, to treat insomnia, asthma, dysentery, acute stomach trouble and sore throat. The pounded fresh tuberous root is applied as a poultice on pimples and wounds.

Observations A twining climber, stem glabrous, root tuberous, up to 70 kg; leaves suborbicular, herbaceous-membranous, round or nearly so at the base, apex acuminate, palmately 10–11-veined; flowers in an axillary compound umbelliform cyme, orange pink; fruit globose compressed, up to 6.5 mm in diameter, endocarp with 4 transverse dorsal ribs.

Selected sources 1031, 1130.

Stephania venosa (Blume) Spreng.

Syst. veg. 4(2): 316 (1827).

Vernacular names Indonesia: gorong bodas (Sundanese). Thailand: plao lueat khruea (northern), kling klang dong (south-western), boraphet yang daeng (peninsular). Vietnam: l[ox]i ti[eef]n d[or].

Distribution The Andaman Islands, Vietnam, southern China, Thailand, northern Peninsular Malaysia, northern Sumatra, Java, Borneo (Sabah), south-western Sulawesi and the Philippines (Luzon).

Uses *S. venosa* is cultivated for medicinal purposes in Thailand. The red juice is used for tattooing by forest tribes in Thailand.

Observations A slender climber up to 20 m long, root tuberous, leafy stem herbaceous, containing red sap; leaves broadly triangular-ovate, 6–20 cm × 6–20 cm; flowers in an axillary umbelliform cyme, pedicellate; fruit stalked, red, endocarp with 4 dorsal rows of papilliform processes. *S. venosa* occurs scattered, but locally common, in forest on hillsides, plains and mountains, sometimes on limestone, up to 1600 m altitude.

Selected sources 238, 421, 423, 1132.

Nguyen Tien Ban, Bui Thi Bang,
Nguyen Tap & Nguyen Chieu

Strychnos L.

Sp. pl. 1: 189 (1753); Gen. pl. ed. 5: 86 (1754).

LOGANIACEAE

x = unknown; *S. ignatii*: $2n = 44$, *S. nux-vomica*: $2n = 44$

Major species *Strychnos ignatii* Bergius, *S. nux-vomica* L.

Vernacular names Malaysia: akar ipoh.

Origin and geographic distribution *Strychnos* consists of 150–200 species and is distributed throughout the tropics and subtropics. Approximately 25 species occur in the Malesian region.

Uses The seeds, bark, wood and roots (e.g. of *S. ignatii* and *S. nux-vomica*) had or have numerous applications in traditional medicine. *Strychnos* was already being used medicinally in China in the 14th Century. It has been prescribed as a stomachic, febrifuge, vermifuge, anticholeric and tonic and to treat sores, wounds, eczema and snake bites in Indonesia and the Philippines. In India, the seeds have been used to obstinate vomiting, to treat cholera, diarrhoea, asthma, dropsy, rheumatism, paralytic and neuralgic affections, spermatorrhoea, epilepsy, diabetes, anaemia and chlorosis, and as a tonic, febrifuge and vermifuge, and to treat alopecia. In Australia, the fruit pulp of *S. lucida* has been used to treat a variety of skin complaints. *S. wallichiana* Steudel ex DC. (synonym: *S. gautheriana* Pierre ex Dop p.p.) is used in traditional medicine in Vietnam to treat rabies, leprosy, and as an aphrodisiac. *S. potatorum* L. is used in both the Ayurvedic and Yunani systems of medicine in India where its bark is used to adulterate *S. nux-vomica* bark and its seeds are used as a natural coagulant to purify drinking water. Several *Strychnos* species are used medicinally in Africa and South America.

Strychnos has also been used as an ingredient in tonic preparations, but these are no longer used in modern therapy, except for a few rare proprietary products based on 'nux vomica' tincture (from *S. nux-vomica*) or Saint Ignatius beans (seeds of *S. ignatii*).

In general, all preparations containing *Strychnos* should be used in small doses, and with the greatest caution, because of their toxicity.

Strychnine was formerly used mainly to poison rodents. The drug was introduced in Europe as long ago as the 16th Century to eliminate pests.

S. axillaris Colebr. has apparently been used in Peninsular Malaysia in the preparation of arrow poison; its leaves have been used in India as a suppurative and the seeds internally as a febrifuge. The root bark of *S. vanprukii* Craib has been reportedly used to prepare an arrow poison in Peninsular Malaysia; *S. rufa* C.B. Clarke has been used similarly.

In Borneo and other regions *Strychnos* seeds, bark and roots are used for making dart poison for blowpipes, usually in combination with the sap of *Antiaris toxicaria* Lesch. In South America, *Strychnos* (mainly *S. castelnaei* Wedd., *S. guianensis* (Aubl.) Mart. and *S. toxifera* Schomb. ex Benth.) is used to prepare the so-called gourd or calabash curare. Tube (or bamboo) curare is made from lianescent *Chondrodendron* species (*C. tomentosum* Ruiz & Pavon). Both curares, alone or as a mixture, are used as arrow poison.

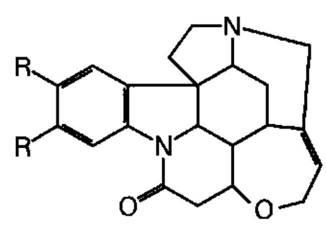
The stems of lianescent species are used for rough cordage. The wood of species with a tree habit is occasionally used for implements and cabinet work.

Production and international trade The annual production of *S. nux-vomica* seed in India was estimated at 2000 t at the beginning of the 1970s. In the period 1965–1971 the average production of strychnine and brucine from *S. nux-vomica* seeds in India was 18 000 kg/year. Most of the alkaloids are exported to the United States and Europe.

Properties The drug usually consists of dried seeds. The seeds of *S. nux-vomica* contain 1–3% total alkaloids (of the indole type; biosynthetically derived from tryptophan), chiefly represented by strychnine (1.1–1.5(–2.3%)) and its dimethoxylated derivative brucine (1.1–2.1(–3.6%)). Bark, wood, roots and flowers also contain these compounds, but with strychnine in smaller amounts. Wood collected from *S. lucida* in Java during the rainy season showed a higher alkaloid content than that of wood harvested in the dry period of the year. Several minor alkaloids, with closely related structures, have also been isolated from *S. nux-vomica* seeds (total concentration up to 1%): 12-hydroxy-strychnine, 15-hydroxy-strychnine, α-colubrine, β-colubrine, icajine, 11-methoxy-icajine, novacine, vomicine, pseudostrychnine, pseudobrucine, pseudo-α-colubrine, pseudo-β-colubrine, N-methyl-sec-pseudo-β-colubrine and isostrychnine.

The seeds of *S. ignatii* contain 1.5–2% of strychnine, 0.5% of brucine and the minor related alkaloids 12-hydroxystrychnine, α-colubrine, icajine, novacine and vomicine. Small amounts of berberine (an isoquinoline alkaloid) have also been reported. The major alkaloid in the wood of *S. lucida* is brucine. The bis-indole alkaloid longicaudatine has been isolated from several *Strychnos* spp., including *S. ignatii* and *S. nux-vomica*. This compound has strong reserpine-like activity.

Strychnine is a very toxic alkaloid. The lethal dose in adult humans may start at about 0.4 mg/kg. In small doses the compound produces excitation of all parts of the central nervous system. It acts as a competitive inhibitor of the neurotransmittor glycine at its receptor-binding site located at the Renshaw cells in the spinal cord. By binding, strychnine blocks the normal inhibitory action of glycine and the Renshaw cells on the motor-neurons, thus leading to a spread of motor-cell stimulation. Intoxication may cause anxiety, increased sensitivity to noise and light and periodic convul-



strychnine (R = H) and brucine (R = OCH_3)

sive attacks: all the muscles contract, forcing the patient into a position, with the back arched and resting only on the head and heels. Death may occur by asphyxia following the contraction of the diaphragm. Brucine is less active as a poison; about 50–100 less than a comparable dose of strychnine.

Strychnine and brucine can be distinguished by thin-layer chromatography of e.g. a macerate of the simplex in 70% ethanol. Quantification can be achieved by spectrophotometry on an alkaloid extract; the difference between the absorbances at 258 nm (λ^{max} of strychnine) and 300 nm (λ^{max} of brucine) is taken into account. Reversed-phase HPLC procedures for qualitative and quantitative analysis, and more recently a capillary zone electrophoresis method for quantitative estimation of strychnine and brucine in *S. nux-vomica* seeds are also available. According to the Netherlands Pharmacopoeia VI, for the drug to be of good quality the strychnine concentration should not be less than 1%.

Some alkaloids from African *Strychnos* species have shown potential as anti-cancer agents in animal tests, and also anti-amoebic and anti-plasmodial activity in mice. Alkaloids isolated from South American *Strychnos* have demonstrated a wide anti-microbial spectrum.

Galactomannans and galactans have been demonstrated in the seeds of *S. nux-vomica*. These polysaccharides, which have coagulant properties, are also present in the seeds of the Indian *S. potatorum*. The seed extract is efficient in the coagulation-flocculation of hydrophobic colloids (such as a clay suspension), but it is a poor flocculant in the case of hydrophilic colloids (such as bacteria). The seed extract of *S. nux-vomica* exhibits analgesic, anti-ulcer, cytotoxin and uterine stimulant activity.

Aqueous and ethanolic extracts of *Strychnos* leaves showed antifungal activity against several pathogens of rice in India.

Adulterations and substitutes As well as occurring in *Loganiaceae*, monoterpenoid indole alkaloids also occur particularly in *Rubiaceae* (e.g. *Cinchona*, *Uncaria*) and *Apocynaceae* (e.g. *Catharanthus*, *Rauvolfia*, *Voacanga*). Several species from these families and genera have uses comparable to *Strychnos*.

Description Lianas or sometimes shrubs (often scrambling) to treelets; stem usually with axillary simple or double tendrils, sometimes with axillary thorns. Leaves opposite, simple and entire, and except for the midrib having 1–2(–3) pairs of nearly equally strongly developed basal veins which do not fully reach the leaf apex; petiole mostly inserted upon distinct leaf-cushions; stipules reduced to a mostly ciliate and straight rim connecting the leaf bases. Inflorescence terminal or axillary, thyrsoid; bracts scale-like. Flowers bisexual, actinomorphic, (4–)5-merous; calyx divided nearly to the base, lobes ciliate on the margins, brown; corolla gamopetalous, rotate to salver-shaped, sometimes thickened towards the lobes, white to yellowish or greenish, lobes valvate in bud, spreading to reflexed, tube usually densely papillose outside, variably hairy inside; stamens inserted on the corolla tube alternating with the lobes, exserted, anthers basifixed, longitudinally dehiscent, introrse; ovary superior, 2-celled, style cylindrical, stigma faintly 2-lobed. Fruit a globose or ellipsoid berry, with hard shell, smooth or minutely warty, glabrous, orange to red when ripe, with fleshy, usually orange pulp, 1–many-seeded. Seeds lenticular, orbicular to ellipsoid, often convex on one side and concave on the other side, with a silky or felty testa or glabrous; endosperm copious, bony; embryo minute, straight, with small cotyledons. Seedling with epigeal germination; cotyledons emergent, thin and leaf-like, long persistent; hypocotyl long.

Growth and development The flowers of *Strychnos* are pollinated by insects. Mammals (e.g. monkeys and civet-cats) and birds digest the fruit pulp and disperse the seeds.

Other botanical information Flowers are essential when identifying *Strychnos* species. Fruits and seeds are also characteristic features of *Strychnos* species and should be kept in spirit (when collecting herbarium material) to preserve important characters that will disappear upon drying.

Ecology Most *Strychnos* are large lianas of the forest, but a few are scrambling to erect shrubs or small to medium-sized trees occurring in more open habitats (e.g. *S. lucida*).

Propagation and planting In India, *S. nux-vomica* plants have been successfully regenerated from hypocotyl tissue. Seeds were germinated on Murashige and Skoog medium supplemented with 1 mg/l gibberellic acid, and hypocotyls excised from the resulting seedlings were inoculated on Murashige and Skoog medium. The optimal growth of plantlets occurred when the medium was supplemented with 2 mg/l kinetin and 1 mg/l naphthalene acetic acid. In vitro multiplication was also successful using nodal explants excised from healthy mature trees.

Diseases and pests Leaf galls induced by the jumping plant louse *Diaphorina truncata* have been reported for *S. nux-vomica* in India, resulting in abscission of the leaves.

Harvesting Fruits of *S. nux-vomica* are usually gathered from the trees. Fallen fruits are considered to be of inferior quality.

Handling after harvest After collecting, seeds of *Strychnos* are cleaned and dried in the sun. Dried seeds can be stored in jute bags for a long period without any loss of alkaloidal content, but they should be kept in dry conditions to prevent deterioration by fungi such as *Aspergillus* and *Penicillium* species. Seeds are further processed in factories to obtain strychnine and brucine.
In traditional Chinese medicine, seeds of *S. nux-vomica* are usually processed to reduce their toxicity. Sand or sesame oil is heated in an iron pan up to 235°C and seeds are parched for about 3 minutes. This significantly reduces the contents of strychnine, brucine and β-colubrine and increases the amounts of isostrychnine, isobrucine, strychnine N-oxide and brucine N-oxide.

Genetic resources and breeding The *Strychnos* species mentioned have a large area of distribution and are, at least locally, common. They are too little used to be threatened at present. However, forest destruction may easily endanger *Strychnos* spp. with a narrow distribution. *S. nux-vomica* is widespread in India, Indo-China and Thailand, but is rare in the Malesian region. There are no records of *Strychnos* in germplasm collections.

Prospects The importance of *Strychnos* as a medicinal plant and vermin destroyer has diminished in recent years. It is now hardly used in modern phytotherapy. Some of the alkaloids present in the plants may play a role in the development of new anti-cancer or antimalarial drugs, but research is needed to establish the possibilities.

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Selection of species

Strychnos ignatii Bergius

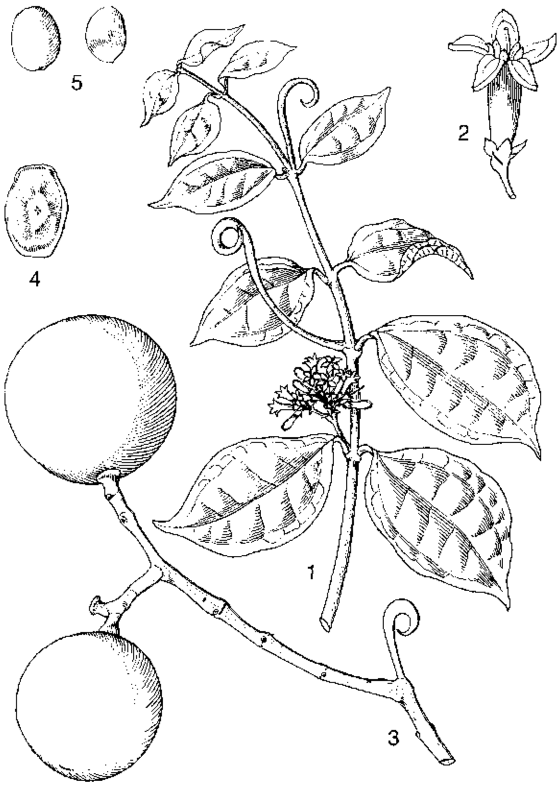
Mater. med. 1: 146 (1778).

Synonyms *Strychnos tieute* Lesch. (1810), *Strychnos ovalifolia* Wallich ex G. Don (1837), *Strychnos beccarii* Gilg (1897).

Vernacular names Saint Ignatius bean (En). Fèves de Saint-Ignace (Fr). Pepita de San Ignacio (Sp). Indonesia: pokru (Sundanese), cetek (Javanese), bina (Kalimantan). Malaysia: akar ipoh, belai hitam, ipoh akar besar (Peninsular). Philippines: katbalonga (Tagalog), igasud (Bisaya), pepita-sa-katbalogan (Tagalog, Bisaya, Pampango/Kapampangan). Thailand: phayaa mue lek (Krabi). Vietnam: lo[af]ng n[af]n.

Distribution Indo-China, Hainan, Thailand, Peninsular Malaysia, Java, Borneo and the south-eastern Philippines (Biliran, Samar, Leyte and Mindanao).

Uses The seeds and bark have been prescribed as a stomachic, febrifuge, anticholeric and tonic in the Philippines. In Thailand, the seeds, roots and wood are used as a stomachic, febrifuge and to treat malaria. Leaves are used to treat diabetes. In India, the seeds have been used to obstinate vomiting, to treat cholera, asthma, dropsy and rheumatism, and as a tonic and vermifuge. The seeds are commercially traded as a source of strychnine. The bark and the seeds are used to treat stomach-ache in Vietnam. The roots are



Strychnos ignatii Bergius – 1, flowering twig; 2, flower; 3, twig with fruits; 4, lenticular-shaped seed; 5, irregularly shaped seeds.

used in Indonesia and Malaysia as arrow poison, and sometimes as a fish poison.

Observations A liana up to 35 m long, with stem up to 5 cm in diameter, bark densely and finely lenticellate, brown or grey, tendrils simple; leaves ovate or elliptical to lanceolate, 4–18(–22) cm × 2–9(–12) cm, petiole 5–10 mm long; inflorescence axillary, 10–20-flowered; corolla 7–17 mm long, tube about 3 times longer than lobes, with some long woolly hairs inside in the lower half; fruit globose, 4–12 cm in diameter, about 10-seeded; seeds lenticular to ellipsoid or orbicular, 20–35 mm × 16–20 mm × 8–9 mm, silky to felty, or irregularly shaped like castor beans, about 20 mm × 10 mm × 10 mm and rough but glabrous. *S. ignatii* is usually found in dense forest, often in dipterocarp forest on sandy soil or in mixed rain forest, sometimes on river banks, up to 1500 m altitude.

Selected sources 160, 163, 202, 287, 580, 769, 839, 911, 1126, 1178, 1460, 1475.

Strychnos lucida R.Br.

Prodr.: 469 (1810).

Synonyms *Strychnos ligustrina* Blume (1836).

Vernacular names Indonesia: bidara laut (general), dara laut (Javanese), kayu ular (Sumatra, Timor). Thailand: phayaa mue lek, phayaa muun lek (central), sieo duuk (northern). Vietnam: m[ax] ti[eef] l[as]ng.

Distribution Indo-China, Thailand, eastern Java, the Lesser Sunda Islands, the southern Moluccas and northern Australia.

Uses The bark, wood and roots are used in traditional medicine in Indonesia to treat fever, snake bites, sores, wounds, eczema, and as stomachic and vermifuge. Australian aborigines apply the fruit pulp to the skin to treat skin complaints such as scabies, rashes, burns, leprosy, sores and cuts. The roots are used to treat diabetes. Leaves and fruits are used as a fish poison in Australia.

Observations A shrub or small deciduous tree up to 12 m tall, bole often crooked and up to 25 cm in diameter, spiny when young, branches densely and finely lenticellate, grey, tendrils absent; leaves ovate or elliptical to suborbicular, 2.5–10 cm × 1.5–6 cm, petiole 2–4 mm long; inflorescence terminal, c. 10-flowered; corolla 10–15 mm long, tube about 3 times as long as lobes, sometimes with a few woolly hairs inside; fruit globose, 2–2.5 cm in diameter, 2–3-seeded; seeds nearly disk-shaped, 12–15 mm × 10–12 mm × 2.5–5 mm, densely short pubescent. *S. lucida* occurs in regions with a monsoon climate, in teak forest and other dryland forest, often in secondary forest but also in scrubs and savannas, up to 200(–400) m altitude; in Thailand also on limestone hills.

Selected sources 160, 163, 202, 276, 580, 839, 957, 1126.

Strychnos minor Dennst.

Schlüss. Hortus malab.: 33 (1818).

Synonyms *Strychnos laurina* Wallich ex DC. (1845), *Strychnos multiflora* Benth. (1856), *Strychnos colubrina* auct. non L.

Vernacular names Indonesia: ranosandang (Sulawesi), ipu tanah (Kalimantan), wale ammelaum (Moluccas). Malaysia: lengkoyan, semiyo akar (Peninsular). Philippines: bukuan (Ibanag, Negrito), pamulaklakin (Tagalog), bugahin (Bisaya). Thailand: tum kaa khao, tum kaa daeng (Lampang). Vietnam: kim lu[oo]ng (Biên Hoa), thu[oor]c m[oj]i (Tây Ninh).

Distribution From India, Sri Lanka and Burma (Myanmar), through Indo-China (southern Vietnam), Thailand and the whole of Malesia (except Java), to the Solomon Islands and northern Australia.

Uses The wood, bark and roots are used medicinally; a decoction is prescribed in the Philippines as an emmenagogue and to treat throat complaints, and it is also used as arrow poison. In Thailand, the stems are used for their carminative, antipyretic and stomachic activity. The stems are used for tying.

Observations A liana up to 12 m long, with bark sometimes densely lenticellate, grey, tendrils double; leaves ovate or suborbicular to lanceolate, 8–25 cm × 3–12 cm, petiole 3–15 mm long; inflorescence axillary and/or terminal, many-flowered; corolla 3–6.5 mm long, tube about as long as lobes, inside in the upper half with woolly hairs; fruit globose, (1–)2–3 cm in diameter, sometimes ellipsoid and 3.5 cm long, about 1–8-seeded; seeds lenticular, 12–15 mm × 10–12 mm × 2–4 mm, minutely densely tomentose. *S. minor* occurs in primary and secondary forest, in New Guinea also in *Araucaria* forest, up to 1850 m altitude.

Selected sources 160, 163, 202, 276, 287, 839, 1126, 1178, 1460, 1475.

Strychnos nux-vomica L.

Sp. pl. 1: 189 (1753).

Vernacular names Nux-vomica tree, strychnine plant (En). Cambodia: slaêng, slaêng thom. Laos: 'sêng bua[1] (Vientiane). Thailand: krachee, tuumka daeng (central), salaeng thom (Nakhon Ratchasima). Vietnam: c[ur] chi (general), c[oo] chi (Khanh Hoa), m[ax] ti[eef]n.

Distribution India, Bangladesh, Sri Lanka, Burma (Myanmar), Indo-China (Cambodia, Laos, southern Vietnam), Thailand and northern Peninsular Malaysia; introduced and locally naturalized in the Philippines (Mindoro).

Uses The seeds have been used in traditional medicine in many regions as a nervine, stomachic, tonic, aphrodisiac and respiratory and cardiac stimulant, the bark as tonic and febrifuge. The seeds are used in Vietnam to treat rheumatic arthritis and paralysis. In Thailand the leaves are used in the treatment of skin diseases. In India, they are also used as mild irritating rubefacient product to treat alopecia by itensifying the capillary blood flow and keeping the scalp and hair follicles active. In traditional Chinese medicine the dried seeds have been used for promoting blood circulation, alleviating blood stasis and relieving pain. The seeds constitute a major source of strychnine, and the plant is cultivated for this purpose. The wood is used in India for agricultural implements and tool handles, cart wheels and fancy cabinet work.

Observations A small to medium-sized tree up to 25 m tall, bole up to 100 cm in diameter, sometimes a liana, branches not rough, yellowish-grey, sometimes with axillary thorns, tendrils absent; leaves broadly ovate to elliptical or suborbicular, 5–18 cm × 4–12.5 cm, petiole 5–12 mm long; inflorescence terminal on short axillary branchlets with usually one pair of leaves, fairly many-flowered; corolla 10–13 mm long, tube about 3 times longer than lobes, sparsely woolly hairy in lower half inside; fruit globose, 2.5–4(–6) cm in diameter, 1–4-seeded; seeds lenticular, orbicular to elliptical, 20–23 mm × 18–20 mm × 4 mm, densely sericeous. *S. nux-vomica* occurs often at the edge of dense forest, on river banks and along the shore, on loamy or loamy-sandy soil.

Selected sources 107, 160, 163, 193, 202, 208, 285, 287, 332, 580, 790, 839, 911, 1035, 1126, 1178, 1460, 1475.

Purwaningsih

Styphnolobium japonicum (L.) Schott

Wiener Zeitschr. Kunst. 3: 844 (1830).

LEGUMINOSAE

$2n = 28$

Synonyms *Sophora japonica* L. (1767).

Vernacular names Japanese pagoda tree, Chinese scholar tree, umbrella tree (En). Indonesia: sari cina, sari kuning. Vietnam: c[aa]y h[of]e.

Origin and geographic distribution *S. japonicum* is native to central and northern China and Korea, but now widely cultivated in temperate and subtropical regions of the world, in South-East Asia at least in Vietnam and Thailand.

Uses The flower buds of *S. japonicum* are astringent and possess styptic properties. They are a reputed remedy for the prevention of various types of haemorrhages (e.g. haemoptysis, epistaxis, metrorrhagia), haemorrhoids, and are useful for the treatment of hypertension. Flower buds and young pods are an important source of rutin, which has 'vitamin P'-like properties and is used in the treatment of conditions characterized by increased capillary permeability and fragility. An extract from the pods is toxic. *S. japonicum* is also reputed to show oestrogenic activity.

The flower buds and occasionally also the pods are used for dyeing yellow or granite-grey. The dye was mainly used to dye silk. Mixed with indigo, it gives a green colour. *S. japonicum* is commonly cultivated as an ornamental. Its tough and durable wood is used for door and window frames and agricultural implements. The shoots seem to be a suitable fodder, but as the pods are poisonous they should be given with care. In China, an extract of the leaves and pods is used to adulterate opium. A gum similar to that from carob (*Ceratonia siliqua* L.) can be extracted from the seeds.

Properties The seeds and pods of *S. japonicum* contain various haemagglutinins (lectins). This probably explains the toxic effect of intravenous administration of a seed or pod extract. The lectin fraction, called *S. japonicum* agglutinin (SJA) can furthermore be separated into two more subfractions; a D-galactose/N-acetyl-D-galactosamine specific lectin (B-SJA-I) and a D-mannose/D-glucose specific lectin (B-SJA-II). In agglutination experiments, *S. japonicum* agglutinin (SJA) demonstrated blood group specificity for the B-group human erythrocytes. Binding experiments with frozen sections of human kidneys also showed specific binding to the endothelia in specimens from blood groups B or AB, thus indicating a D-galactose/N-acetyl-D-galactosamine receptor specificity. Furthermore, the *S. japonicum* agglutinin appears to be devoid of mitogenic and immuno-suppressive activity, in contrast to, for example, concanavalin A, which suppresses the T helper-dependent antibody response to sheep erythrocytes.

The flavonoid-glycoside rutin (also known as rutoside, quercetin-3-rutinoside or 3,3',4',5,7-pentahydroxyflavone-3-rutinoside) is found in high concentrations in the flower buds. Known as a 'capillary protectant', the substance is used to treat capillary and venous disorders. Alone, or in combination with other drugs it is a common ingredient of vascular protective agents and venous tonics, and of topical agents in phlebology. Evidence of its value, however, still remains somewhat inconclusive.

Using an activity-guided procedure, an anti-haemostatic principle in the flower buds has been identified as the flavonoid isorhamnetin-(2-(3-methoxy-4-hydroxyphenyl)-3,5,7-trihydroxy-4H-1-benzopyran-4-one).

HPLC analysis of commercially available samples of *S. japonicum* in Taiwan revealed the presence of the flavonoids rutin, quercetin, sophoricoside, sophorabioside and genistein. Flower buds contained a great deal of rutin, while the immature fruits contained sophoricoside and sophorabioside. When flower buds were stir-fried for short periods over low heat, the extracted rate of rutin and quercetin increased slightly, decreasing with longer cooking periods at higher temperatures. When stir-fried with vinegar, flower buds quickly blackened, but when cooked with honey, they changed very little. Immature fruits, however, exhibit less variation in their active constituents after processing. All processed samples of *S. japonicum* have a pronounced aroma and could be more easily extracted with water than the unprocessed samples.

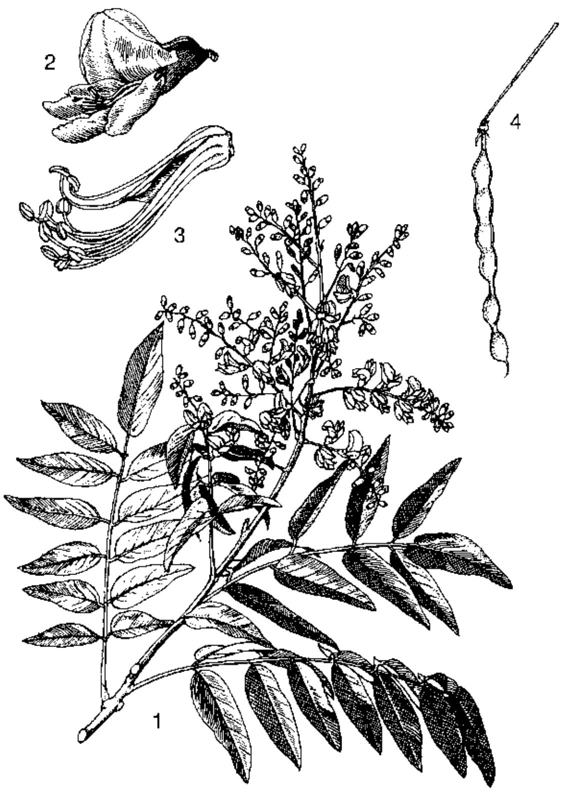
In a detailed study in Egypt on flavonoid contents of the various plant parts no qualitative changes were observed in the different development stages of leaves or flowers. The number and diversity of flavonoids gradually increase during transformation from flower to fruit. Sophorabioside, sophoraflavanoloside and genistein glucoside appeared at the beginning of fruit formation, while sophoricoside appeared only at maturity. The total rutin concentration was highest in flower buds (24%). The rutin content in leaves decreases from young to mature leaves.

An intragastrically administered aqueous extract of the flower buds showed strong anti-ulcer activity against ulcerations in rats induced by ethanol HCl. The mutagenic potential of a crude, freeze-dried hot-water extract was evaluated using the Ames test, and the micronucleus and chromosomal aberration assays in mice in vivo. *S. japonicum* (+/- S9) was found to significantly induce His^+-revertants in *Salmonella typhimurium* TA 98 and/or TA 100 strains. The extract was furthermore found positive in both in vivo assays.

Leaves contain 18.2% crude protein based on dry weight. The wet fractionation process was applied to twigs, leaves and pods. The leaf-protein concentrate obtained from the green juice after pressing contained 16% crude protein, which is very low and 69% total lipids, which is very high; both values were determined on a dry matter basis. Seeds contain 9.9% fatty oil which is rich in linoleic acid (52.8%), but is poor in drying properties. The seedcake contains 30% protein, but glycosides should be removed before using it as fodder.

Adulterations and substitutes Other sources for industrial extraction of rutin are the leaves of *Fagopyrum esculentum* Moench, a cereal especially from temperate zones, and the leaves of some *Eucalyptus* species e.g. *E. macrorhyncha* F. v. Mueller ex Benth. from Australia.

Description A deciduous, small to medium-sized tree up to 25(–30) m tall; bole generally short; bark surface corrugated, dark greenish-brown or dark grey-green, with paler lenticels; crown broad. Leaves arranged spirally, imparipin-



Styphnolobium japonicum (L.) Schott – 1, flowering twig; 2, flower; 3, stamens and ovary; 4, pod.

nate, 15–25 cm long; stipules early caducous; leaflets alternate to subopposite, 7–17, elliptical to ovate-lanceolate, 1.5–6 cm × 1–2.5 cm, acute or sometimes obtuse at apex, mucronate, glabrous or sparsely hairy above, short-haired below, shortly petiolulate; stipellae absent or small and setaceous. Flowers in a terminal, 15–35 cm long panicle, papilionaceous; bracteoles present; calyx 3–4 mm long, teeth shorter than the tube; corolla yellowish-white or greenish-white, standard 12–15 mm long; stamens 10, filaments joined near the base; ovary superior, pilose. Fruit an indehiscent pod, 3–12 cm × 7–12 mm, constricted between the seeds, stipitate, glabrous, beaked, 1–8-seeded. Seeds 8 mm × 4–5 mm, yellowish-brown. Seedling with epigeal germination; cotyledons emergent; first few leaves imparipinnate or sometimes 1- or 3-foliolate.

Growth and development Seeds of *S. japonicum* germinate quickly, usually within about 4 days. The tree starts flowering when about 3–4 years old, though sometimes only when about 30 years old. In Vietnam, trees flower from May to August and fruit from September to November. In China, flowering is in August–September, fruiting in October–November.

Other botanical information *Styphnolobium* is a small genus of 9 species occurring in North and Central America, with *S. japonicum* as the only Asian representative. The segregation of *Styphnolobium* from the closely related genus *Sophora* is supported by morphological characters (flowers with bracteoles, pods indehiscent), a different somatic chromosome number and the results of DNA studies. The DNA studies even indicate that the two genera are not closely related. Several varieties have been distinguished within *S. japonicum*, the status of which is still unclear, and several cultivars are grown as ornamentals.

Ecology *S. japonicum* is well adapted to dry weather conditions and to a great variety of soils, but thrives best in well-drained, sandy loam. Being native in temperate and subtropical regions, cultivation in the tropics is only possible in drier regions or at higher altitudes. Under temperate conditions *S. japonicum* is tolerant of heat and drought, whereas it also tolerates severe frost (up to –25°C) except when young.

Propagation and planting *S. japonicum* can be propagated by seed, which should be scarified or treated with hot water and soaked before sowing. Under temperate conditions the seed germinates well and within a few days. Grafting, layering, greenwood and root cuttings are used for ornamental cultivars. Trees can be coppiced successfully.

Diseases and pests Among the reported diseases and pests of *S. japonicum* are fungi such as *Uromyces truncicola* which cause a canker disease in seedlings, and leafminers such as *Odontota dorsalis*, and aphids (*Aphis* spp.).

Harvesting Flower buds, inflorescences and young fruits of *S. japonicum* are hand picked. Inflorescences are harvested when flowers begin to open. Young stems can simply be cut as routine under coppice management.

Yield Analyses of bark, leaves, flower buds, flowers and fruits of *S. japonicum* revealed that the highest rutin content (24–37%) was found in young flower buds and the lowest (1.5–3%) in the bark. In view of the total volume and weight of harvestable plant parts it is recommended to use the flower buds, flowers and young fruits as a source of rutin. In the temperate zones *S. japonicum* is considered fast-growing.

Handling after harvest After harvesting, the inflorescences of *S. japonicum* are dried, and rachises and pedicels discarded. Rutin is extracted by subsequent boiling in water and crystallization upon cooling, followed by recrystallization from ethanol.

Genetic resources and breeding Various ornamental cultivars of *S. japonicum* are available, mainly in western Europe, e.g. weeping, dwarf and variegated forms. Breeding efforts should be directed towards plants flowering at a relatively early age.

Prospects *S. japonicum* is an important industrial source of rutin. Research in further applications in the treatment of capillary and venous disorders deserves more attention.

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Other selected sources 193, 202, 287, 360, 710, 806, 871, 997, 1035, 1036, 1045, 1128, 1277, 1283, 1468, 1480, 1554, 1634.

Tran Cong Khanh

Taraxacum officinale Weber ex F.H. Wigg.

Prim. fl. holsat.: 56 (1780).

COMPOSITAE

$2n = 16, 24, 32, 40, 48$

Vernacular names Dandelion (En). Dent de lion, pissenlit (Fr). Indonesia: jombang (Java). Vietnam: b[oof] c[oo]ng anh.

Origin and geographic distribution Dandelion is native to Europe and continental temperate Asia south to the Himalayas, but now distributed almost all over the world. In the Malesian region it has been introduced and naturalized in Peninsular Malaysia, West Java and the Philippines (Benguet Province). It is sometimes cultivated as a vegetable or for medicinal applications.

Uses Infusions or decoctions of dried roots, leaves or simply the entire plant of dandelion are widely used as a general tonic, anti-inflammatory, depurative, cholagogue, diuretic, mild laxative, and for kidney and liver disorders. Infusions are also recommended in the treatment of skin problems, such as acne, eczema, psoriasis and even for arthritic and rheumatic complaints. Externally the latex is applied to boils and other skin infections or applied as a poultice on inflamed wounds. In South-East Asia, dandelion is a fairly recently introduced weed, so traditional uses are very limited. In Indo-China it is used as a diuretic and cholagogue. In India, the roots are applied as a tonic, diuretic, mild laxative, and chiefly used in kidney and liver disorders. In China, the leaves are prescribed internally as a bitter depurant, in the treatment of breast and lung tumours, mastitis, abscesses, jaundice, and urinary tract infections; and externally to treat snake bites. In Europe and North America, the leaves and roots, fresh or dried, are used as a mild laxative, a diuretic and for the treatment of high blood pressure by reducing the volume of fluid in the body. The roots accelerate steady elimination of toxins, by working principally on liver and gall bladder to help remove waste products, and simultaneously stimulating the kidneys to remove toxins in the urine. The leaves or roots may also help to prevent or even dissolve gallstones. A decoction of the roots is used as an antidiabetic.

The leaves are also eaten as a vegetable. When grown without light (artificially or when covered with earth) the pale leaves are more brittle and taste better. The young and unopened flower heads can be used as capers. In North Africa the leaves are used as a seasoning. The bitter leaves are also applied in wines, beers and non-alcoholic drinks. The ground roots are used as a substitute for coffee. In spring the flowers contain much nectar and are locally important for the production of honey. Formerly, dandelions were cultivated in Japan for ornamental purposes.

Production and international trade In Germany, France and the United States dandelion is comparatively often cultivated as a vegetable. It is also cultivated in India, where it is a popular remedy for liver complaints. However, no statistics are available on production and trade.

Properties Phytochemical analysis has revealed chicoric acid and monocaffeyltartaric acid to be the major phenolic constituents of flowers, roots, leaves and involucral bracts of *T. officinale.* These compounds are also the main phenolic constituents of some common dandelion preparations, e.g. dandelion tea, root coffee and root capsules. Furthermore, the presence of sesquiterpene lactones (germacranolide type, as glucosides), triterpenes (e.g. cycloartenol) and flavonoids (apigenin-7-glucoside, luteolin-7-glucoside) in the leaves is reported in literature.

As with many *Compositae*, the roots of dandelion also have a high content of inulin, a polysaccharide based on fructose. This compound serves as a food reserve and can reach levels as high as 25% in autumn in the temperate zones. Inulin can be used as a sugar substitute, which is of interest for diabetic patients. Furthermore, the hypoglycaemic activity of this compound is sometimes mentioned in literature, though many reports are not conclusive in this respect. On the other hand, hypoglycaemic activity of dandelion preparations have been observed in various animal models: the 50% ethanol-water extract of the entire plant at a dose of 250 mg/kg orally in rats, dried entire plants at doses of 1–2 g/kg administered intragastrically to rabbits and a water extract of dried roots at a dose of 25 mg/kg administered intragastrically to mice all showed hypoglycaemic activities.

The high potassium content of dandelion, especially in the leaves (up to 4.5% of the dry weight) is considered to be responsible for the well-known diuretic activity, which has been confirmed in various animal models. The ethanol (30%) extract of dandelion roots, administered orally at a dose of 0.1 ml/kg in male rats, shows diuretic activity. In experiments with mice and rats the diuretic and saluretic indices of a fluid extract of dandelion, corresponding to approximately 8 g dried aerial parts/kg body weight, were comparable to those of furosemide (80 mg/kg body weight) a well-known diuretic. The high potassium content ensures that potassium eliminated in the urine is replaced. Furthermore, in dogs, the volume of bile doubled when a decoction of fresh leaves (equivalent to 5 g of dried plant material) was administered intravenously. In rats, a choleretic effect was observed following administration of a 5% dandelion extract (2 ml) by means of a cannula, and in another experiment, an alcoholic extract of the whole plant administered to rats gave a 40% increase in bile secretion.

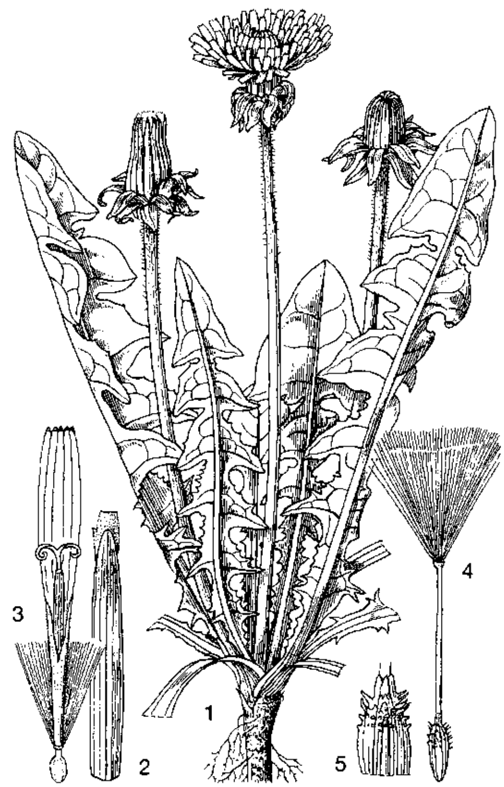
The anti-inflammatory activity of dandelion has been investigated in several animal models. A methanol extract of dandelion leaves, at a dose of 2.0 mg/ear applied externally, reduced swelling and inflammation in mice with 12-0-tetradecanoylphorbol-13-acetate (TPA)-induced ear inflammations. Furthermore, a 95% ethanol extract of dried dandelion leaves, administered intraperitoneally in rats with carrageenan-induced pedal oedema at a dose of 0.1 g/kg showed anti-inflammatory activity. Finally, the 80% ethanol extract of dried dandelion roots administered by gastric intubation at a dose of 100 mg/kg in male rats showed 25% inhibition of oedema in a carrageenan-induced pedal oedema model, in comparison with 45% inhibition of indomethacin (5 mg/kg) in the same experiment.

Other pharmacological activities include: a dose-dependent inhibition of the ADP-induced aggregation of human platelets by an ethanolic extract of the roots of *T. officinale.* A bioguided purification revealed activity in two fractions: one containing low-molecular weight polysaccharides, and one fraction characterized by the presence of triter-

penes/steroids. A 95% ethanol extract of dried dandelion leaves administered to mice intragastrically at a dose of 1.0 g/kg, and intraperitoneally at a dose of 0.1 g/kg, exhibited analgesic activity in both the phenylquinone-induced writhing and the hot plate models. The water extract of dandelion roots administered intragastrically at a dose of 2 g/kg in rats with ETOH-HCl-induced ulcerations showed a strong anti-ulcer activity. However, the methanol extract at the same dose shows only weak activity. The hot water extract of dried dandelion aerial parts given intraperitoneally at doses of 30–40 mg/kg exhibited antitumour activities against CA-C3H/HE-MM46 and fibrosarcoma METH-1 in mice.
The 70% ethanol extract of dried dandelion aerial parts at concentrations of 2, 10 and 50% showed acaricide activity against *Tetranychus urticae*, with percentages of inhibition being respectively 57, 90 and 100%. Both ether and methanol extracts of fresh aerial parts used at undiluted concentrations in the disk method showed antifungal activity against *Aspergillus flavus*. Furthermore, the tincture (10%) of dried leaves at a concentration of 0.1 ml/disk showed antibacterial activity against *Bacillus subtilis*.
Lettucenin A is a sesquiterpenoid phytoalexin produced by a number of *Compositae* including *T. officinale* to protect themselves against microorganisms. In a liquid cell culture 16.4 μg/g fresh weight inhibits the growth of the fungus *Cladosporium herbarum*; the lettucenin A production peaked only 2–6 hours after infection.
An analysis of leaves and flowers from Pakistan gave per 100 g edible portion: water 88.8 g, protein 3.6 g, ether extracts 1.6 g, total carbohydrates 3.7 g, fibre 0.4 g, and ash 2.3 g, phosphorus 59 mg, calcium 474 mg, iron 3.3 mg and vitamin C 73 mg. In vitro dry-matter digestibility is about 80%. The latex from dandelion may cause skin irritation. The sugar content of the nectar is around 50%. The sugars are mainly glucose and fructose, and a smaller proportion of sucrose. The pollen contains about 15% of protein.

Adulterations and substitutes Roots of *Cichorium intybus* L. are used as a substitute for the roots of dandelion. They are also rich in inulin, and bitter due to sesquiterpenoid lactones.

Description A perennial, stemless herb up to 30(–50) cm tall, with a long taproot and latex in all parts. Leaves arranged spirally in a radical rosette, oblanceolate to narrowly spathulate, 4–35 cm × 0.7–10 cm, very variably and irregularly pinnatilobed to pinnatipartite, variably hairy or rarely completely glabrous, almost distinctly petiolate or narrowly tapering into a winged petiole, petiole green or pink to purplish. Inflorescence an axillary head, 1–25 per plant, peduncle simple, hollow, leafless, (3–)3.5–5(–6.5) cm in diameter, outer involucral bracts many-seriate, patent to recurved, ovate to linear-lanceolate, unequal, without 'horns' (thickened and/or clawed apices), inner involucral bracts 1-seriate, erect, oblong, receptacle flat, naked. Flowers many, all ligulate; corolla yellow, but often with a purple line outside; stamens 5, anthers fused into a tube, sagittate at base; ovary inferior, with a single ovule; style 1, greenish or yellowish to black, stigmas 2, spreading. Fruit an achene, narrowly obovoid, about 3 mm long, ribbed, greenish to straw-coloured or brownish, the upper third minutely spiny, abruptly contracted into a 6–12 mm long beak which is crowned by spreading, scabrid, white pappus hairs. Seedling with epigeal germination; cotyledons free, leafy, obspathulate, sheathed at base; epicotyl absent; all leaves alternate.



Taraxacum officinale Weber ex F.H. Wigg. – *1, plant habit; 2, inner involucral bract; 3, flower; 4, fruit; 5, upper part of achene.*

Growth and development Both sexually and asexually reproducing populations of *T. officinale* exist. The sexually reproducing plants are generally obligate cross-pollinators, although exceptions have been reported. The self-compatibility is hereditary. The asexual reproduction is known as agamospermy, and functions only in polyploid plants. It may be obligatory or facultative, even within a single head.
The flowers produce nectar and pollen that attract insects, mainly bees, which pollinate the flowers. Most of the orange-coloured pollen is released between 10–12 h in the morning, and some 20–75% is sterile. Wind can disperse the seeds over long distances by means of their 'parachute'-like pappus.

Other botanical information *Taraxacum* is closely related to the genus *Crepis*, and belongs to the tribe *Lactuceae*. It has been subdivided into some 40 sections. *T. officinale* sensu lato forms a large and highly variable polyploid complex. The agamospermous reproduction results in a high number of uniform 'clones', which have often been described as microspecies or agamospecies. *T. officinale* sensu stricto belongs to section *Ruderalia* J. Kirschn., H. Ollg. & Stepanek (synonym: section *Vulgaria* Dahlst. p.p.) with about 1000 microspecies. Some authors prefer to distinguish many taxa at subspecific rank while recognizing only a few species within *Taraxacum*. The section *Ruderalia* is likely to be of recent origin, as it harbours the more advanced microspecies. These are often polyploid and tend to possess more satellite chromosomes than generally diploid primitive microspecies. The length of the beak on the achene generally increases with increasing ploidy level.
The microspecies *T. javanicum* v. Soest has been described from Java, and belongs to *T. officinale* sensu lato. Recently, another microspecies, *T. indonesicum* Sonck has been described from West Java. Although the two are clearly distinct to specialists, it is likely that both are used in a similar way by local people.

Ecology Being weedy in nature, *T. officinale* is most often found in ruderal places, along roads and fields and in grassland. In tropical regions it occurs only at higher elevations, in Malesia at 1200–1500 m altitude. It occurs on various soils, from sandy dunes to thick clay, and from dry to wet, sometimes even brackish habitats, though it seems to grow best on fertile sandy or loamy soils.

Propagation and planting Propagation of dandelion is by seed or by division. In Europe about 60% of all achenes germinate in the year of production; about 30% in the next year and about 5% in the year thereafter. A neglectable percentage germinates after 5 years. The viability of fresh achenes is 70–100%, but drops rapidly when stored dry at 20°C; cool and dry storage does not cause a rapid decrease in viability. Achenes germinate best at temperatures of 20–25°C, with a daily fluctuation of about 5°C. They should not be sown deeper than 1 cm as this will affect fast and uniform emergence.

In vitro production of active compounds Undifferentiated cultured cells of dandelion produce oleanolic and ursolic acids as major triterpenoids, in addition to triterpenols composed mainly of α- and β-amyrins. Regenerated and wild plants contain additional triterpenols (taraxasterol and lupeol), but negligible quantities of triterpene acids. Squalene synthase activity has been detected in the microsomal fractions of suspension-cultured cells of *T. officinale*, which produce cycloartane (involved in phytosterol biosynthesis) and other triterpenoids e.g. oleanane and ursane.

Husbandry Injured roots or small parts of roots of dandelion can regenerate and develop new rosettes. Therefore mechanical control of *T. officinale* as a weed is not effective. In Canada, ethalfluralin proved an effective herbicide for dandelion cultivation with no residues in the roots.

Diseases and pests Diseases observed in dandelion in the temperate zones include *Agrobacterium tumefaciens*, and fungi like *Synchytrium taraxaci*, *Bremia lactucae*, *Protomyces pachydermus*, *Sphaerotheca fuliginea*, *Puccinia* spp., *Ramularia taraxaci* and *Septoria taraxaci*. Pests include the nematodes *Ditylenchus dipsaci* and *Meloidogyne hapla* and the beetle *Ceutorhynchus punctiger*, whereas various other insects, spiders, snails, birds and mammals feed on dandelion in some way or another.

Harvesting Dandelion roots are harvested at the end of the growing season, when inulin contents are highest.

Yield In India, cultivated dandelion yields about 1650 kg of roots per ha. In Canada, the dry matter production of roots was about 2300 kg/ha, i.e. 19% higher when planted at a high density of over 114 000 plants/ha compared to a lower density of about 89 000 plants/ha. Average root production per dandelion plant with the flower buds removed was 40 g when grown in a nutrient solution and 30 g when grown on a peat substrate with organic fertilizer.

Handling after harvest In India, roots of dandelion are washed, dried and subsequently stored in containers to which a few drops of carbon tetrachloride have been added as preservative.

Genetic resources and breeding *T. officinale* is such a widespread weed that its genetic basis does not seem to be at risk; this is not the case for some of its microspecies. Breeding efforts have been directed to a more palatable crispy vegetable rather than to its medicinal properties.

Prospects As a result of the quite well investigated diuretic properties, dandelion preparations could be used as an adjunct to treatments where enhanced urinary output is desirable, for example, the prevention of renal gravel or frequently returning uncomplicated urinary tract infections. Other pharmacological actions (e.g. on the billary excretion) are also interesting, but merit further research.

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Wongsatit Chuakul

Tinospora Miers

Ann. Mag. Nat. Hist. ser. 2, 7: 35 (1851).
MENISPERMACEAE
x = unknown; *T. cordifolia*: $2n$ = 24, 26

Major species *Tinospora crispa* (L.) Hook.f. & Thomson, *T. glabra* (Burm.f.) Merr.

Vernacular names Philippines: makabuhay (general).

Origin and geographic distribution *Tinospora* consists of 33 species, which occur in the tropical and subtropical parts of the Old World: 7 species in tropical Africa, 2 in Madagascar, and 24 in Asia extending to Australia and the Pacific. In Malesia, 14 species have been found, but most of them are known from few collections; only *T. crispa* and *T. glabra* are widespread. *T. crispa* is also cultivated as a medicinal plant, e.g. in Thailand, Sri Lanka and India.

Uses Throughout most of South-East Asia, *Tinospora* species are a widely acclaimed source of remedies for many different complaints. Much of their reputation is probably due to influences from Chinese traditional medicine, where for instance stems and leaves of *T. crispa* are valued for their anti-inflammatory (antirheumatic), febrifugal, antimalarial and antibacterial properties. In Indonesia, Malaysia, Thailand and the Philippines, stems (infusions, decoctions) of *T. crispa* are considered to be effective in the treatment of skin complaints (external as antiseptic, antiparasitic, and for treating wounds and itches), stomach complaints (ulcers, as appetizer, tonic), diarrhoea, fevers (e.g. malaria, smallpox), diabetes mellitus, cholera (whole plant), jaundice, and as a vermifuge (also in children). In veterinary medicine, *T. crispa* is applied as veterinary tonic; powdered stems are used to fatten horses and cattle by stimulating their appetite.

T. glabra has similar uses as *T. crispa* although the latter is thought to be more effective, but is recommended particularly for dealing with wounds, scabies and tropical ulcers.

It is perhaps in the Indian subcontinent where the widest use is made of *Tinospora*. The main species is *T. cordifolia* (Willd.) Miers, which does not occur in Malesia. In present-day Ayurvedic medicine in India, all parts of the plant find wide use for their general tonic, anti-inflammatory, anti-arthritic, anti-allergic, antimalarial, antidiabetic, hepato-protective and aphrodisiac properties. Categorized as 'rasayana' in Ayurveda, it is also used for its general adaptogenic and pro-host immunomodulatory activity in fighting infections. *T. cordifolia* is thus claimed to be useful in e.g. skin diseases, jaundice, diabetes, anaemia, fever and rheumatism. In fact the plant is part of almost all decoctions mentioned in Ayurvedic textbooks for use in joint diseases. The starch from the stems and roots is used as a nutrient in chronic diarrhoea and dysentery. Juice of the fresh plant is a powerful diuretic (urinary diseases), and also used in gonorrhoea with advantage. Besides its antimalarial activity, the root is known for its anti-stress and antileprotic activities. Finally, *T. cordifolia* is also used as veterinary medicine.

A tincture from the stem of *T. sinensis* (Lour.) Merr. (synonyms: *T. malabarica* (Lamk.) Hook.f. & Thomson, *T. tomentosa* (Colebr.) Hook.f. & Thomson) has considerable reputation in Indo-China for treating arthritis and chronic rheumatism. There are also reports suggesting the efficacy of the roots, stems and leaves in conditions like cough, wound healing, malaria, skin complaints and allergic disorders.

Production and international trade Stem parts or powdered stems can be found frequently on local markets, but are not traded internationally.

Properties A number of chemical constituents have already been isolated from different parts of *T. crispa*, e.g. diterpenes, alkaloids and flavonoids. Most extensively investigated are a series of furano-diterpene (glycoside) compounds: tinotufolin A–F (leaves), borapetoside A–H (glycosides, stems), borapetol A, B (stems, aglycones of borapetoside A, B) and the bitter tinocrisposide (glycoside, stems). In addition to these furano-diterpenes, a series of clerodane-diterpene glycosides has also been isolated from the stems and named rumphioside A, B, C, C-1, Ac-D, E and F.

Amongst the alkaloids isolated from *T. crispa* are the well known protoberberine type alkaloids palmatine (stems), berberine (stems, aerial roots) and the aporphine type alkaloid tembetarine (stems, aerial roots). From the methanolic stem extract three further N-acyl-aporphine type alkaloids have been isolated and their structures elucidated: (–)-N-formyl-annonaine, (–)-N-formyl-nornuciferine (= tinocrispicine) and (–)-N-acetyl-nornuciferine. Of these isolated alkaloids, berberine and its salts are known to have spasmolytic, antibacterial and in some degree antifungal and antiprotozoal activity.

Further constituents from *T. crispa* include: N-trans and N-cis feruloyl tyramine (stems, phenolic acid amides), tinotuberide (stems, phenolic glucoside), and the flavone-O-glycosides (from stems): luteolin-4'-methylether-7-glucoside, genkwanin-7-glucoside, luteoline-4'-methylether-3'-glucoside, diosmetin and genkwanin.

An aqueous extract from *T. crispa* stems showed lowering of blood glucose levels and stimulated insulin release in moderate alloxan-diabetic rats. The dose administered orally (4 g/l in drinking water) and the method of preparation of the extract were comparable to those used by diabetics in Malaysia. After two weeks of treatment, the rats also showed an improvement in the glucose tolerance test; there were no effects in normal and severe alloxan-diabetic rats. These results suggest that the hypoglycaemic effect observed is due to stimulation of insulin release, rather than some extra-pancreatic action. This insulinotropic activity was also observed after intravenous injection of 50 mg/kg of the extract in normal rats.

Toxicity of *Tinospora* extracts proved to be low in tests with rats (LD_{50} values of over 5 g/kg orally, 3 g/kg dermally). *Tinospora* extracts in high concentrations can cause infection in the liver and follicular atresia in mice, but the kidneys are not much affected. Crude extracts showed protective effects in mice with experimental urinary tract infection caused by *Pseudomonas aeruginosa*.

A number of compounds have been isolated from the stems of *T. cordifolia*, including diterpenes and alkaloids. The diterpenes comprise the major group of components isolated: the norditerpene-furan-glycosides cordifoliside A–E, the clerodane-diterpenes tinosponone, tinosporaside (= tinosponone-glycoside) and tinocordioside (glycoside) and the clerodane-furano-diterpenes cordioside (glycoside), together with 4 other furano-diterpene compounds: colombin, one being an epimer of 6-hydroxy-arcangelisin, and two being a set of optical isomers (not yet named). The biosynthesis of the clerodane-furano-diterpene skeleton has also been investigated.

Amongst the alkaloids isolated from *T. cordifolia* are magnoflorine and tembetarine (stems, aporphine type alkaloids) and jatrorrhizine (roots, protoberberine type alkaloid). Syringin is a phenolic component, isolated from the fresh stems.

Considerable efforts have been made to investigate the biological effects of *T. cordifolia*. An aqueous, alcoholic and chloroform extract of the leaves after oral application exerted a significant hypoglycaemic effect in both normal and alloxan-diabetic rabbits. The reaction in alloxan-diabetic animals, in which almost all pancreatic β-cells have been destroyed, appears to be like a direct effect, probably by a mechanism similar to insulin. However, the stronger effect in normo-glycaemic rabbits suggests that the mechanism of action consists not only of this direct insulin-like effect, but that there is also an indirect action by stimulating the insulin release from pancreatic β-cells. Besides the hypoglycaemic activity, no effects were found on the blood lipid levels, and acute toxicity studies did not reveal visible signs and symptoms of toxicity. Further investigations in albino rats and different groups of rabbits confirm the hypoglycaemic effect and the proposed mechanism of action.

Several studies have focused on the immunotherapeutic effects. Pretreatment (oral) with an aqueous extract strongly reduced the mortality in a mouse model for *E. coli* peritonitis. This was associated with significantly improved bacterial clearance and improved phagocytic capacities of neutrophils in the group treated with *T. cordifolia*. *T. cordifolia* extract itself did not possess in vitro bactericidal activity. These results were confirmed in experiments with wistar rats in which abdominal sepsis was induced by caecal ligation. Both in rat and man, oral application of a *T. cordifolia* extract improved the surgical outcome in patients with obstructive jaundice, in which sepsis initiated by bacteria in the bile at the time of biliary tract surgery comprises a major risk. In the group receiving the extract, the phagocytic and killing capacities of neutrophils improved; thus *T. cordifolia* appears to act by strengthening host defences.

Further investigations included antileishmanial, anti-stress, antipyretic and diuretic effects. Leishmaniasis, commonly known as 'kala-azar', causes great mortality in tropical and subtropical regions of the world. The antileishmanial effect was evaluated in infected golden hamsters. A 50% ethanol extract of *T. cordifolia* stems showed significant inhibition of multiplication of parasites, and increased survival periods. The anti-stress activity was studied by investigating the effects of treatment on brain norepinephrine, dopamine and serotonine levels in stressed rats. The ethanol extract, prepared from roots previously extracted with petrol (60-80) and chloroform, and given orally after drying, was found to possess normalizing activity against stress-induced changes on brain neurotransmitter levels. The antipyretic effect was investigated in rats, and yeast-induced pyrexia was used to screen the extracts. The antipyretic action was clearly significant for a *T. cordifolia* ethanol extract (whole plant, given orally) and appeared to be comparable to that of the aspirin control. Finally, *T. cordifolia* extract showed mild diuresis and a significant increase in the excretion of electrolytes in rats after oral application.

Tinospora extracts are toxic to brown planthoppers (*Nilaparvata lugens*) and green leafhoppers (*Nephotettis virescens*), which are common pests in rice in the Philippines. Soaking the roots of rice seedlings in aqueous *Tinospora* extract in the field is effective in controlling the major rice pests, and broadcasting the ground stems on the seed-beds 10 days after sowing is also applied successfully. The extracts can control the diamondback moth (*Plutella xylostella*); the effectivity is comparable to malathion, and the extracts show antifeedant effects on the insect. In tests in Thailand, *T. crispa* extract showed mild repellency to the oviposition of the oriental fruit fly (*Darcus dorsalis*). It is also effective in controlling borers on maize, and bollworms (*Helicoverpa armigera*) in cotton. The extract showed high toxicity to fish in experiments in Malaysia. In vitro tests in the Philippines using mutant strains of *Bacillus subtilis* and *Salmonella typhimurium* showed that *Tinospora* extracts do not contain direct mutagens.

Adulterations and substitutes Other *Menispermaceae* (e.g. *Cyclea* and *Stephania* species) have similar or related alkaloids and have similar applications. Other insecticides of plant origin used in South-East Asia are present in the roots of *Derris* and *Lonchocarpus* spp., in seeds of *Croton tiglium* L., in leaves of *Azadirachta indica* A.H.L. Juss., *Nicotiana tabacum* L. and *Vitex negundo* L., in leaves, fruits and bark of *Melia azedarach* L., in whole plants of *Tanacetum cinerariifolium* (Trev.) Schultz-Bip., *Lantana* spp. and *Tagetes* spp., and in leaves, roots and seeds of *Annona squamosa* L.

Description Dioecious woody climbers up to 15 m long, sometimes scandent shrubs, usually entirely glabrous; stem woody, with bark often becoming detached on drying, striate when young, becoming tuberculate or warty with raised lenticels, usually glabrous but sometimes puberulous, sometimes producing very long filiform aerial roots. Leaves arranged spirally, simple and entire (occasionally dentate or 3-lobed), often cordate, palmately veined, sometimes domatia present in axils of veins beneath, petiole swollen and geniculate at base; stipules absent. Inflorescence axillary or cauliflorous, thyrsoid, pseudopaniculate, pseudoracemose or pseudospicate. Flowers unisexual, 6-merous; sepals usually free, outer 3 usually smaller, elliptical, imbricate; petals free, often broadly cuneate-ovate with the lateral edges inrolled, usually fleshy and often glandular-papillose externally towards the base; male flowers with 6 free stamens; female flowers with 3 curved-ellipsoid carpels having short-lobed, reflexed stigmas, and 6 subulate staminodes. Fruit a usually ellipsoidal drupe with terminal style scar, borne on a short or columnar carpophore; endocarp bony, dorsally convex and often verrucose or tuberculate, ventrally with central aperture or with shallow longitudinal groove. Seed with usually ruminate endosperm.

Growth and development *T. crispa* usually flowers when leafless, in Thailand in January to March. The scented flowers are pollinated by insects such as small flies and bees, and possibly also small beetles and moths. Female plants, with or without fruits, have rarely been collected.

Other botanical information *Tinospora* belongs to the tribe *Tinosporeae*, characterized by the drupe with terminal style scar, and embryo with foliaceous cotyledons, together with *Chlaenandra*, *Fibraurea*, *Parabaena* and *Tinomiscium*.
T. glabra has been much confused with *T. crispa*. Information on medicinal and chemical properties of *T. crispa* (or its synonym *T. rumphii*) given in literature for the Philippines partly refers to *T. glabra*.

Ecology *Tinospora* occurs in forest, thickets and hedges up to 1000 m altitude. It has a very strong capacity of regeneration and is often very abundant in secondary regrowth after disturbance of the natural forest. In primary forest it occurs much more scattered. *T. glabra* can also be common in littoral forest and on limestone.

Propagation and planting Stems of *T. crispa* remain viable when cut into pieces because the dried sap effectively seals the cut ends. If kept in a closed box they can still be viable after one year. Apparently *T. crispa* is mainly propagated vegetatively.

In vitro production of active compounds Experiments on the in vitro culture of *Tinospora* root segments showed promising results, with good callus formation and a high content of therapeutic substances.

Diseases and pests Larvae of the noctuid moth *Othreis fullonia* feed mainly on *Tinospora* leaves. The adult moth can cause considerable damage to commercial fruit tree plantations, especially of longan (*Dimocarpus longan* Lour.) and citrus in Thailand, by piercing the skin of the fruits. The destruction of natural forest and the increasing area of secondary vegetation, preferred by *Tinospora*, promote the spread of the pest.
In Pakistan, *T. cordifolia* showed effective resistance to the root-knot nematodes *Meloidogyne incognita* and *M. javanica*.

Handling after harvest Under ambient and refrigerated conditions stored crude stem extracts maintain their pesticidal activity during 3 months.

Genetic resources and breeding *T. crispa* and *T. glabra* are widely distributed and will not easily become endangered, since they prefer sites with secondary vegetation and show strong regeneration capacity. In India, *T. cordifolia* is a popular medicinal plant and is locally endangered because of extensive collecting from the wild.

Prospects *T. crispa* and the non-Malesian *T. cordifolia* are well investigated medicinal plants with numerous interesting properties which have been confirmed by modern research. It is expected that they will keep their important role in local medicine in South-East Asia, whereas they have good prospects to play a more prominent role in modern medicines in other parts of the world.
The need for safer pesticides lead to a revival of interest in pesticides of plant origin which can be used in integrated pest management. In the Philippines, *Tinospora* extracts have been evaluated in the field and proved effective.

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Selection of species

Tinospora crispa (L.) Hook.f. & Thomson

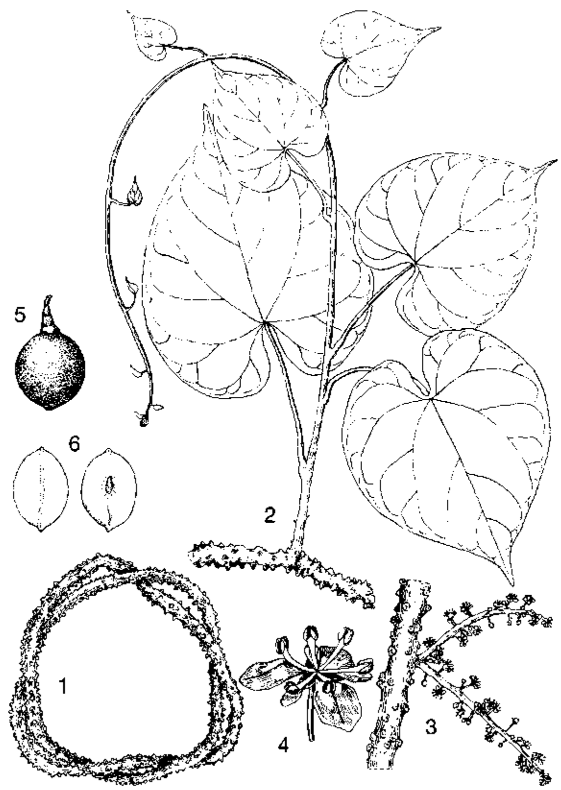
Fl. ind. 1: 183 (1855).

Synonyms *Tinospora rumphii* Boerl. (1901), *Tinospora tuberculata* (Lamk) Beumée ex K. Heyne (1927).

Vernacular names Indonesia: andawali (Sundanese), brotowali, putrowali (Javanese). Malaysia: akar putarwali, petawali (Peninsular), daun akar wali (Sarawak). Philippines: makabuhay, meliburigan (Mindanao), paliaban (Bisaya), panyawan vine (Visayas). Cambodia: bandaul pech. Laos: khua kao ho. Thailand: boraphet (central). Vietnam: d[aa]y th[aaf]n th[oo]ng, d[aa]y k[ys] ninh, d[aa]y c[os]c.

Distribution India, Burma (Myanmar), Cambodia, Laos, Vietnam, southern China (Yunnan), Thailand, Peninsular Malaysia, Singapore, Indonesia (Java, Sumbawa) and the Philippines (Luzon, Mindoro, Mindanao); cultivated as a medicinal plant, e.g. in Thailand, Sri Lanka and India.

Uses An infusion of the stem is drunk in Malaysia and Indonesia as a vermifuge and of the whole plant to treat cholera; it is also used to treat diabetes mellitus. Externally it is applied against scabies and to heal wounds. In Brunei, the plant is used in the treatment of high blood pressure, diabetes and to relieve abdominal pains. In Indo-



Tinospora crispa (L.) Hook. f. & Thomson – 1, part of stem as found in the market; 2, part of stem with leafy shoot; 3, part of stem with male inflorescence; 4, male flower; 5, fruit; 6, endocarp in dorsal and ventral view.

China, an infusion of the stem is drunk to treat fever (also when caused by malaria) and jaundice. Powdered stems are used to fatten horses and cattle by stimulating their appetite. *T. crispa* is a very commonly used medicinal plant in the Philippines. In Thailand, an infusion from the stem is used to treat jaundice, cholera, malaria, and against worms in children.

Observations A woody climber up to 15 m long, older stems very prominently tuberculate and producing very long filiform aerial roots; leaves broadly ovate to orbicular, 7–14(–25) cm × 6–12(–24) cm, without domatia; inflorescences appearing when plant is leafless; flowers usually with 3 petals; fruit ellipsoidal, about 2 cm long, orange. *T. crispa* occurs in primary rain forest and mixed deciduous forest, but can be very common in secondary vegetation after logging and in hedges, up to 1000 m altitude. The stem contains an exceedingly bitter milky sap.

Selected sources 6, 75, 123, 202, 213, 331, 332, 339, 350, 421, 423, 444, 445, 446, 447, 448, 580, 908, 965, 975, 1035, 1049, 1050, 1051, 1100, 1101, 1102, 1103, 1178, 1190, 1388, 1486, 1572.

Tinospora glabra (Burm.f.) Merr.

Journ. Arn. Arb. 19: 340 (1938).

Synonyms *Tinospora reticulata* Miers (1864), *Tinospora coriacea* (Blume) Beumée ex K. Heyne (1927).

Vernacular names Indonesia: pancasona (Sundanese), tajungan (Javanese), wase wages (Flores). Philippines: makabuhay (Luzon, Mindoro), papaitan (Palawan), sangawnaw (Mindanao).

Distribution The Andaman Islands, Hainan, throughout Malesia (possibly except Sulawesi) and the Solomon Islands.

Uses Burnt leaves are used in the Philippines to treat pinworms, and ground bark is applied to sore breasts of nursing mothers. *T. glabra* has much more medicinal applications, but the exact usage is unclear because of confusion with *T. crispa*; the latter is said to be more effective. *T. glabra* is also used for baiting wild pigs by mixing sliced roots with sweet potato (*Ipomoea batatas* (L.) Lamk).

Observations A woody climber, older stems becoming warty and finally developing a smooth, thin papery bark often becoming detached on drying; leaves oblong-ovate or narrowly to broadly ovate, 7–12(–15) cm × 5–9(–13) cm, domatia usually present in basal vein-axils; inflorescences appearing together with leaves; flowers with 6 petals; fruit ellipsoidal or subglobular, about 1 cm long, red. *T. glabra* often occurs in littoral rain forest and in forest dominated by *Casuarina equisetifolia* L., in mangrove vegetation and on sandy beaches, but also inland in disturbed forest and thickets, up to 500 m altitude. It is very frequently found on limestone and on black soils under seasonal conditions.

Selected sources 421, 580, 1178.

Umi Kalsom Yusuf, S.F.A.J. Horsten & R.H.M.J. Lemmens

Trichosanthes L.

Sp. pl. 2: 1008 (1753); Gen. pl. ed. 5: 439 (1754).

CUCURBITACEAE

$x = 11$; *T. cucumerina*: $2n = 22$, *T. tricuspidata*: $2n = 44$

Major species *Trichosanthes kirilowii* Maxim.

Vernacular names Malaysia: timun dendang, timun gagak (Peninsular).

Origin and geographic distribution *Trichosanthes* comprises some 40 species and is found from Pakistan, India and Sri Lanka to the Himalayas, Burma (Myanmar), Indo-China, China, Japan, Thailand, throughout Malesia, towards northern and eastern Australia and into the Pacific east to Fiji. Some 15 species are present within the Malesian region. Fossil evidence proves the presence of *Trichosanthes* in Eurasia during the Miocene and Eocene.

Uses Various *Trichosanthes* species are used for a wide array of medicinal purposes. The best known of these include application as a cooling agent, as diuretic, as galactagogue, as a hypoglycaemic, and in the treatment of various skin complaints. The fruits of several *Trichosanthes* species, e.g. those of *T. ovigera* and of cultivated forms of *T. cucumerina* are eaten as a vegetable.

Production and international trade Snake gourd (*T. cucumerina*) is mainly grown in home gardens for own consumption or for the local market. The wild *Trichosanthes* are collected and consumed locally only.

Properties The importance of *T. kirilowii* has increased due to the discovery of its activity against human immunodeficiency virus (HIV). The active proteins, trichosanthin (a mixture of 4–5 antigenic proteins), and TAP-29 (Trichosanthes anti-HIV protein, a 29 kDa protein), have been isolated from the roots. Both proteins exhibit anti-HIV activity in a similar way, as measured by assays for syncytium formation, p24 expression, and HIV reverse transcriptase activity. However, they differ significantly in cytotoxicity: trichosanthin demonstrates a dose-dependent toxic effect on host cells, but TAP-29 does not.

Furthermore, trichosanthin is reported to inactivate eukaryotic ribosomes via its N-glycosidase activity; it is also a potent inhibitor of protein synthesis in a reticulocyte-lysate assay. Two other proteins, karasurin-B and karasurin-C have also been isolated from the tubers of *T. kirilowii* var. *japonica*. Both karasurins had strong ribosome-inactivating activities, revealed by in vitro inhibition of translation in the rabbit reticulocyte system.

The traditional use of *T. kirilowii* as an abortifacient has led to extensive studies. In a study in which the water extract of the roots at a dose of 0.2 mg/person was administered intramuscular to 2500 pregnant patients, the percentage of labour-induction was 96% in late-term pregnancy, and 71% in mid-term pregnancy. Drug recipes containing whole roots of *T. kirilowii* were also found to be active. However, precautions are recommended, because of the risk of death as a complication. The compounds responsible for the abortifacient activity are trichosanthin, β-trichosanthin, α-kirilowin and β-kirilowin. Furthermore, β-trichosanthin isolated from the tubers of *T. ovigera*, was found to be about twice as potent as trichosanthin from *T. kirilowii* in inducing mid-term abortion in mice.

The proteins α-kirilowin and β-kirilowin, isolated from the seeds of *T. kirilowii*, have very similar biological activities as the other trichosanthins. They were found to inhibit protein synthesis in a cell-free system, to suppress [3H]-thymidine incorporation into mouse melanoma cells, and to induce abortion in mice. β-Kirilowin, with an ID_{50} of about 1.8 ng/ml, inhibits the cell-free translation system.

A type-1 ribosome-inactivation protein, designated as TK-35, has been purified from suspension cultures of stem sections of *T. kirilowii* transformed by *Agrobacterium rhizogenes*. In a protein translation inhibition assay, TK-35 had an IC_{50} value of 2.45 nM and was able to release the rRNA N-glycosidase diagnostic fragment from rabbit reticulocytes.

The polysaccharide fraction from the rhizomes of *T. kirilowii* showed marked anti-tumour and cytotoxic activities together with immunopotentiating effects. The latter effects were evidenced by an increase in the number of circulating leucocytes and peritoneal exudate cells, and recovery from reduced antibody formation in mice.

In vitro cytotoxicity tests with trichosanthin showed that it selectively injured choriocarcinoma and melanoma cells. Under experimental conditions, the marked decrease in secretion of human chorionic gonadotropin and progesterone by choriocarcinoma cells after treatment with the proteins could be mainly attributed to the loss of cells. A structural, electrophoretic, variant of karasurin isolated from *T. kirilowii* roots strongly inhibited the growth of BeWo cells (a human choriocarcinoma cell line) in vitro.

Furthermore, human peripheral blood-derived monocytes and macrophages were found highly sensitive to trichosanthin; the mixture suppressed lymphocyte proliferation (ID_{50} about 1.7 μg/ml). Human T and macrophage cell-lines were more sensitive (ID_{50} < 0.9 μg/ml) to trichosanthin compared with B and myeloid cell-lines. These findings suggest that this selective cytotoxicity towards human macrophages and/or monocytes may be implicated in trichosantin's anti-HIV activity and, furthermore, that the selective killing of leukaemia-lymphoma cells by trichosanthin merits evaluation for possible use to treat some forms of lymphoma and leukaemia.

At non-cytotoxic concentrations (10–1000 ng/ml for splenocytes, and 10–100 ng/ml for macrophages), karasurin-A from the roots of *T. kirilowii* inhibited the lymphocyte proliferation induced by lipopolysaccharide, concanavalin A or phytohaemagglutinin, and nitric oxide production induced by lipopolysaccharide. It has also been suggested that karasurin-A has immunosuppressive activity in vitro. Trichosanthin increased the secretion of the enzymes glutamate-pyruvate-transaminase, lactate dehydrogenase and isocitrate dehydrogenase by isolated rat hepatocytes into the culture medium. This hepatotoxic effect appeared to be concentration-dependent. Trichosanthin furthermore produced adverse effects on prenatal development of mice, both in vitro and in vivo.

α-Trichosanthin, isolated from fresh tubers of *T. kirilowii*, showed no lipogenic activity in rat cells, nor did it affect the fasting plasma-glucose levels in mice, or testosterone and corticosterone production in isolated rat cells.

The immunotoxin trichokirin conjugated to a monoclonal antibody directed against the Thy 1.2 antigen, selectively killed leukaemia cells expressing this Thy 1.2 antigen. In in vivo application it is reported to be more advantageous than ricin A-chain immunotoxins. 2-Iminothiolane-trichosanthin conjugated to Hepama-1, which is a monoclonal antibody directed against human hepatoma, proved to be a potent and quite specific agent against hepatoma.

Bryonolic acid isolated from transformed cultures of hairy roots of *T. kirilowii* var. *japonica* exhibited cytotoxic effects against human and animal tumour cell-lines in vitro, which were independent of the cell type. Normal cells, such as rat hepatocytes, were less sensitive to bryonolic acid than tumour cells. A so-called DNA ladder was detected in bryonolic acid-treated HL-60RG cells, indicating that apostosis may be the cause of cell death triggered by bryonolic acid.

Anti-inflammatory activity of *T. kirilowii* was investigated against ear inflammation in mice induced by tetradecanoylphorbol-13-acetate (TPA). The active constituents, isolated from the seeds, were identified as 3-epikarounidiol (= D:C-friedo-oleana-7,9(11)-diene-3β,29-diol), 7-oxoisomultiflorenol (= 7-oxo-D:C-friedo-olean-8-en-3β-ol), 3-epibryonolol (= D:C-friedo-olean-8-ene-3α,29-diol), and 7-oxo-10α-cucurbitadienol and its acetyl- and 24-dihydro-derivatives karounidiol (= D:C-friedo-oleana-7,9(11)-diene-3α,29-diol) and 7-oxodihydrokarounidiol (= 7-oxo-D:C-friedo-olean-8-ene-3α,29-diol) which are all triterpenes. Furthermore, at 2 mmol/mouse, karounidiol markedly suppressed the promoting effect of TPA (1 mg/mouse) on skin tumour formation in mice following initiation with 7,12-dimethylbenz[a]anthracene (50 mg/mouse).

The 50% ethanol extracts of the whole fruit, as well as of the seeds of *T. kirilowii* administered orally, exhibited anti-inflammatory and analgesic activity. The anti-inflammatory activity was investigated against vascular permeability in mice induced by acetic acid, carrageenin-induced oedema, and granuloma formation in rats induced by cotton pellets; the analgesic activity against writhing symptoms in mice.

Seed extracts of many *Trichosanthes* species show potent haemagglutinating activity. Data on haemagglutination inhibition show that Me-βD-galactose is the best monosaccharide inhibitor of the galactose-specific lectin present in the seeds of cultivated *T. cucumerina*. A lectin isolated from the root tuber of *T. kirilowii* agglutinated rabbit erythrocytes. Studies of carbohydrate-binding specificity demonstrated that agglutination was strongly inhibited by lactose and D-galactose. The galactose-binding lectin from root tubers of *T. kirilowii* stimulated the incorporation of D-(3-3H)-glucose into lipids in rat epididymal adipocytes, but did not inhibit lipolysis.

A decoction of dried tubers of *T. kirilowii* exhibited antihyperglycaemic activity. The ethanolic extract of *T. cucumerina*, when administered orally to rats in 250 mg/kg doses failed to lower blood sugar levels, or to depress the peak value after a glucose load. Five glycans, trichosans A, B, C, D and E, isolated from *T. kirilowii* roots, showed hypoglycaemic actions in normal mice. The main glycan, trichosan A, also exhibited activity in alloxan-induced hyperglycaemic mice.

The hypolipidemic activity of the pectin from cultivated *T. cucumerina* was investigated by feeding male Sprague-Dawley rats a diet containing 5% pectin. Levels of serum cholesterol, phospholipids in the liver and fatty acids in the blood fell significantly.

The chloroform extract of roots of *T. cucumerina* showed significant antibacterial activity against *Pseudomonas aeruginosa*; its activity against *Staphylococcus aureus*, however, was not significant. Seeds extracts of cultivated *T. cucumerina* resulted in high mortality of the nematodes *Meloidogyne incognita* and *Rotylenchulus reniformis*.

Adulterations and substitutes *Momordica* may be a potential substitute for *Trichosanthes*, due to quite similar properties, such as antihyperglycaemic and cytotoxic activities.

Description Annual or perennial, monoecious or dioecious, climbing or trailing herbs. Tendrils adjacent to the petiole insertion, simple or 2–5-fid. Leaves alternate, petiolate; blade simple and unlobed to palmately 3–9-lobed or rarely palmately compound; stipules absent. Flowers axillary, unisexual, actinomorphic; calyx with a long, narrow tube and 5 entire to dentate lobes; corolla funnel-shaped, white or greenish-white, deeply 5-lobed, lobes fimbriate with long hairs. Male flowers in usually bracteate racemes or rarely solitary; stamens 3, inserted on the corolla tube, filaments short, free, anthers free or united, one 1-locular and two 2-locular; pistillode 3-parted, filiform. Female flowers solitary or rarely in racemes; staminodes absent; ovary inferior, 3-carpellate but 1-celled with 3 placentas and many ovules, style 1, with 3, entire to bifid stigmas. Fruit a fleshy, indehiscent berry (pepo), globose to long spindle-shaped. Seeds often compressed and elongated.

Growth and development Flowering of *T. cucumerina* commences about 5 weeks after sowing. The flowers open in the evening or early morning. Anthers shed their pollen several days before complete flower anthesis; stigmas are receptive from a few hours before anthesis to a few hours after. *Trichosanthes* flowers are pollinated by insects. The often brightly coloured fruits are eaten by monkeys but especially by large crows which thus disperse the seeds.

Other botanical information Within the subfamily *Cucurbitoideae*, *Trichosanthes* belongs to the tribe *Trichosantheae*, an Old World tribe of 10 genera characterized by elongated hypanthia in both male and female flowers. *Trichosanthes* is still rather poorly known taxonomically, but a revision is in preparation. Reports from the Malesian region of *T. bracteata* (Lamk) Voigt are erroneous and may concern three widespread, related species: *T. pubera* Blume, *T. quinquangulata* and *T. tricuspidata*. True *T. bracteata* is from continental Asia.

Ecology Most *Trichosanthes* species are climbers of open forest, forest margins and thickets, at low to medium altitudes. They are fairly drought resistant, although *T. cucumerina* does not tolerate dry soil.

Propagation and planting *T. cucumerina* is propagated by seed, requiring 4–6 kg/ha. Seed can be sown in a nursery and seedlings transplanted at the 2-true-leaf stage but usually the seed is directly sown in planting holes or on ridges 1–1.5 m apart, with 60–75 cm between plants. Seeds are soaked in water to hasten germination; under favourable conditions germination takes place within a week. Tuber-bearing *Trichosanthes* has been propagated vegetatively, but no details are available.

In vitro production of active compounds In in vitro culture hairy roots of *T. kirilowii* were successfully induced by infection with *Agrobacterium rhizogenes* strain R1601, yielding 8.16 mg trichosanthin per g fresh weight. A recombinant *T. kirilowii* trypsin inhibitor analogue with the same activity as the natural one has been successfully synthesized, yielding 2 mg/l. Recombinant α-trichosanthin with concentration-dependent inhibition of protein synthesis in vitro has been synthesized.

Husbandry For fruit production (e.g. *T. cucumerina*) plants are trellised or otherwise supported so that the fruits can hang down.

Diseases and pests The most serious diseases of *T. cucumerina* are downy mildew (*Pseudoperonospora cubensis*) and anthracnose (*Colletotrichum lagenarium*). Repeated spraying with fungicides, e.g. maneb, can control both diseases. The major pests of *T. cucumerina* are leaf beetles (*Aulacophora vinula*, *Copa occidentalis* and *Lagria villosa*) and root-knot nematodes (*Meloidogyne* spp.).

Harvesting For consumption as vegetable, fruits are picked 12–20 days after fruit set. For seed production, fruits are harvested when fully ripe and have attained full size.

Yield From dried tubers of *T. kirilowii* 0.16% of pure trichosanthin has been obtained after cation-exchange perfusion chromatography for only 10 minutes.

Genetic resources and breeding Germplasm collections of *T. cucumerina* are available in the Philippines (NPGRL-IPB, Los Baños), India (Kerala Agricultural University, Trichur, Kerala), Nigeria (NACGRAB, Ibadan), Russia (the Vavilov Institute of Plant Industries, St Petersburg) and the United States (Department of Horticultural Sciences, Cornell University, New York).

Prospects Several compounds from *Trichosanthes* show interesting pharmacological activities, e.g. cytotoxic (anti-tumour), anti-inflammatory and anti-HIV. As lead-compounds, they may have potential in research and development of future medicines. Although extracts of the roots of *T. kirilowii* are reported to be abortifacient, this activity must be considered too toxic to be applied, as death may occur as a complication.

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Selection of species

Trichosanthes borneensis Cogn.

A. DC. & C. DC., Monogr. phan. 3: 369 (1881).

Synonyms *Trichosanthes grandibracteata* Kurz (1877), *Trichosanthes wallichiana* Ridley non (Ser.) Wight.

Vernacular names Malaysia: akar timun gagak, daun jari buaya, labu ayer hutan (Peninsular).

Distribution Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses In Peninsular Malaysia, crushed fruits have been applied to the head to relieve headache; they are reported to be poisonous. The leaves are applied to the abdomen after miscarriage.

Observations A vine with slightly grooved, subglabrous stem; leaves suborbicular, 3–5-lobed, 8–10 cm × 6–10 cm, base cordate, lobes oblong to triangular, acute, glabrous to sparsely hirsute above, glabrescent below; corolla about 7 cm in diameter; male inflorescence 15–35 cm long, bracts oblong-ovate, 2–3 cm long, laciniate; female flowers solitary; fruit ellipsoidal to ovoid, 5–8 cm long, red; seeds angular. *T. borneensis* is reported from forests.

Selected sources 202, 457, 1126, 1227.

Trichosanthes cucumerina L.

Sp. pl. 2: 1008 (1753).

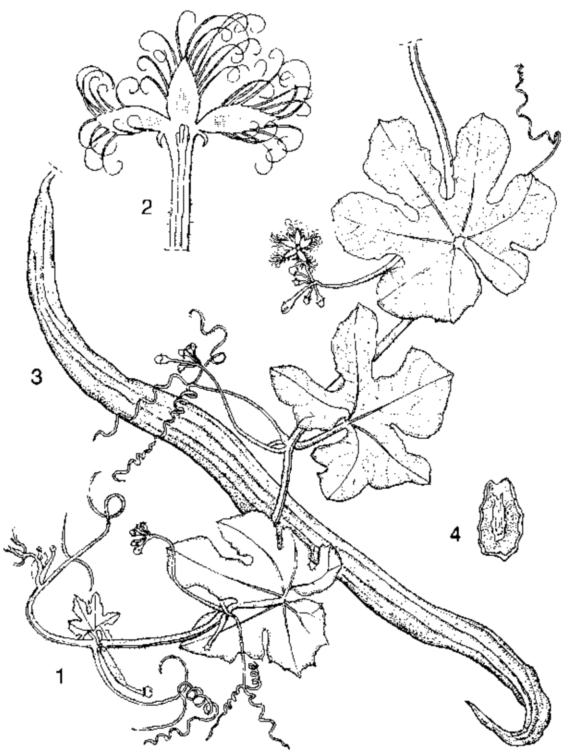
Synonyms *Trichosanthes anguina* L. (1753), *Trichosanthes pedatifolia* Miq. (1856), *Trichosanthes reniformis* Miq. (1856).

Vernacular names Snake gourd (En). Patole, serpent végétal (Fr). Indonesia: paria belut (general), petola ular (Malay, Moluccas), pare welut (Javanese). Malaysia: ketola ular, timun bengkok, petola ular (Peninsular). Philippines: melon-daga, pakupis, tabubok (Tagalog). Laos: ngoo ngèèwz. Thailand: buap ngu, nom phichit (central), ma noi (northern). Vietnam: d[aa]y na t[aa]y, d[uw]a n[us]i, m[uw] [ows]p t[aa]y.

Distribution From India and Sri Lanka to Indo-China, southern China, Thailand and throughout Malesia towards northern Australia; cultivated in this area and elsewhere.

Uses Fruits of wild plants are used as a purgative and a vermifuge. In Indonesia, the inner pulp of the fruit is made into a syrup to treat cough. Immature fruits of cultivated forms are eaten boiled as a vegetable or in curries. Young shoots and leaves are also edible. The fruits become inedible upon ripening. In West Africa, the red fruit pulp is used as a kind of cheap tomato paste. Fruits of the wild forms are very bitter and inedible.

Observations A monoecious, annual vine up to 6 m long, stem 4-angular, sparsely pubescent or glabrescent; leaves suborbicular or slightly kidney-shaped to broadly ovate, shallowly to deeply 3–7-lobed, 7–10 cm × 6–13 cm (in cultivated forms up to 25 cm across), base cordate, lobes rounded to obtuse, sparsely hirsute to almost glabrous on both sides; corolla about 3 cm in diameter; male flowers in lax, 3–25 cm long racemes, bracts small, up to 2 mm long; female flowers solitary or rarely in pairs; fruit ovoid, 4.5–7.5 cm × 3–4 cm, ripening to yellow or orange (in cultivated forms fruit linear, up to 100 cm long); seeds ovate-truncate, compressed. The cultivated forms are traditionally distinguished as a species (*T. anguina* L.), subspecies (subsp. *anguina* (L.) Greb.) or variety (var. *anguina* (L.) Haines), though it seems more appropriate to classify these in a cultivar group (e.g. cv. group Snake Gourd). Wild *T. cucumerina* is found in open forest, forest margins and scrub vegetation, up to 1000(–1500) m altitude.



Trichosanthes cucumerina L. – 1, flowering shoot; 2, top of female flower in longitudinal section; 3, fruit of cultivated plant; 4, seed.

Selected sources 97, 233, 486, 721, 759, 763, 792, 886, 1128, 1134, 1178, 1263, 1313, 1443.

Trichosanthes kirilowii Maxim.

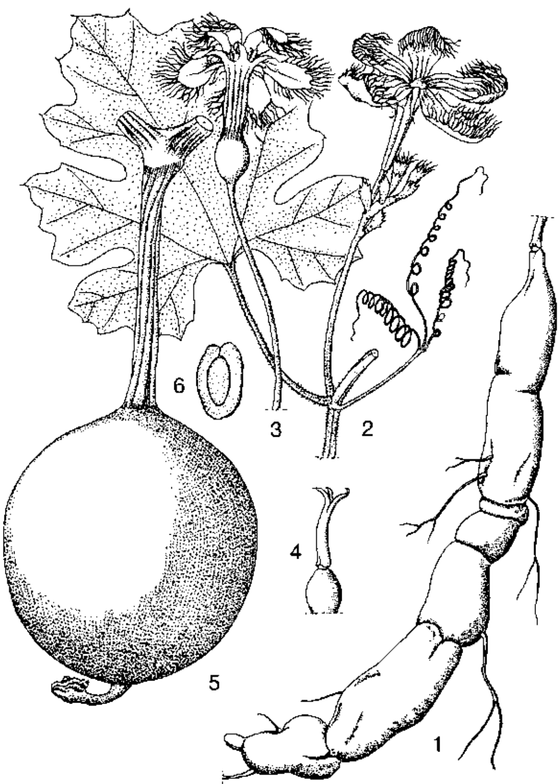
Prim. fl. amur.: 482 (1859).

Synonyms *Trichosanthes quadricirrha* Miq. (1865).

Vernacular names Vietnam: qua l[aa]u, qua l[aa]u nh[aa]n, thao ca.

Distribution Korea, China, Japan and Vietnam (especially the northern part); possibly also in Taiwan and Laos.

Uses *T. kirilowii* is a well-known medicinal plant. A decoction of its tuberous roots and seeds is administered as thirst-quenching, bechic, expectorant, febrifuge, diuretic and galactagogue. Starch from the roots is spread on ulcers, wounds, irritation from perspiration, chicken pox and other skin diseases. A decoction of the root, fruit rind and seeds is used as an anti-emetic and a diuretic to regulate the excretory system and to relieve constipation. Furthermore, the roots are reported as a cooling agent, a depurative, a sialagogue, and a maturative, useful in treating sunstroke, sore throat, jaundice and large boils. In Peninsular Malaysia, Chinese used to import seeds and fruit rind for use as a tonic and an astringent.



Trichosanthes kirilowii Maxim. – 1, main root; 2, twig with male inflorescence; 3, female flower; 4, ovary and styles; 5, fruit; 6, seed.

Observations A dioecious, perennial vine up to 10 m long, stem angular, sparsely pubescent; leaves broadly ovate to orbicular in outline, 3–5(–7)-lobed, 10–12 cm × 10–12 cm, base cordate, lobes mucronate, shortly pilose above, glabrescent below; corolla up to 7 cm in diameter; male flowers in 10–20 cm long racemes, bracts obovate-rhombic, about 1.5–2.5 cm long, coarsely toothed; female flowers solitary; fruit ovoid-globose to ellipsoidal, up to 10 cm long, yellow to orange-red; seeds oblong to ovate-orbicular, compressed. Plants from Japan have been distinguished as var. *japonica* (Miq.) Kitam (synonym: *Trichosanthes japonica* (Miq.) Regel).

The plants formerly identified as *T. kirilowii* from Taiwan have now been distinguished as a separate species: *T. rosthornii* Harms; whether this concerns a truly distinct species or a mere form of *T. kirilowii* remains as yet uncertain. *T. kirilowii* is found in open forest, scrub vegetation and grassy places, up to 2000 m altitude.

Selected sources 43, 44, 146, 202, 218, 230, 247, 267, 366, 367, 586, 626, 721, 764, 765, 789, 837, 870, 902, 939, 1024, 1025, 1027, 1028, 1035, 1099, 1173, 1325, 1331, 1332, 1441, 1445, 1472, 1479, 1546, 1592, 1599, 1625, 1628, 1630, 1656, 1657.

Trichosanthes ovigera Blume

Bijdr. fl. Ned. Ind.: 934 (1826).

Synonyms *Trichosanthes horsfieldii* Miq. (1856), *Trichosanthes cucumeroides* (Ser.) Maxim. ex Fr. & Sav. (1875), *Trichosanthes himalensis* C.B. Clarke (1879).

Vernacular names Indonesia: areuy tiwuk (Sundanese). Vietnam: hoa b[as]t.

Distribution From the Himalayas to China, Taiwan, Vietnam, Thailand, Sumatra, Java, the Lesser Sunda Islands and north-eastern Australia.

Uses In China, Japan and Taiwan the root is regarded as a good remedy for intestinal parasites, jaundice and bloody stools. It is also considered to be a diuretic and galactagogue. In eastern China, it is a substitute for *T. kirilowii*. In Taiwan, the root and seeds are applied to soothe the throat and lungs and to prevent inflammation, and are also considered to be a bechic, expectorant and thirst quenching. Boiled fruits are eaten as a side dish with rice. In China and Japan the starch of the tubers is sometimes extracted.

Observations A dioecious, perennial vine, stem angular, sparsely puberulous to glabrescent; leaves broadly ovate to suborbicular in outline, unlobed to deeply 3–5-lobed, 7–15 cm × 6–15 cm, base deeply cordate, lobes ovate to obovate, obtuse to acute, mucronate, denticulate, scabrid above, densely pubescent to velvety below; corolla up to 5 cm in diameter; male flowers in 6–20 cm long racemes, bracts narrowly obovate, 5–10 mm long, dentate; female flowers solitary; fruit ovoid to ellipsoidal, 8–10 cm × 2.5–3 cm, glabrous; seeds broadly ovate, cylindrical. *T. ovigera* is found in light forests, forest margins, thickets and roadsides, up to 1600 m altitude.

Selected sources 97, 486, 721, 870, 1024, 1126, 1263, 1443.

Trichosanthes quinquangulata A. Gray

U.S. Expl. Exped., Bot., Phan. 1: 645 (1854).

Vernacular names Indonesia: kalayar (Sundanese). Philippines: kalanum-uak (Bisaya), katimbau (Iloko), patolang-gubat (Tagalog).

Distribution Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines.

Uses In the Philippines, the cooked, powdered seeds are applied to itch and mixed with wine to treat stomach-ache. Some of the uses reported below for *T. tricuspidata* may actually refer to *T. quinquangulata*, due to the confusion of species.

Observations A largely monoecious, perennial vine up to 6 m long, stem angular, glabrous; leaves roundish in outline, shallowly or sometimes deeply 5–7-lobed, up to 20 cm in diameter, base cordate, lobes acute, glabrous or glabrescent; corolla 7–9 cm in diameter; male inflorescence 15–20 cm long, bracts elliptical to obovate-lanceolate, 15–20 mm long, subentire; female flowers solitary; fruit globose, 5–10 cm in diameter, red; seeds elliptical with obtusely acuminate apex, compressed. *T. quinquangulata* occurs in thickets, old clearings and rocky places up to 1500 m altitude.

Selected sources 190, 457, 721, 1126, 1178, 1263.

Trichosanthes tricuspidata Lour.

Fl. cochinch. 2: 588 (1790).

Synonyms *Trichosanthes tricuspis* Miq. (1856).

Vernacular names Indonesia: kalayar (Sundanese). Thailand: kradueng chang phueak (Prachuap Khitikhan), kheekaa khom (Phangnga), matuum kaa (Nakhon Ratchasima). Vietnam: l[aa]u s[as]c.

Distribution Indo-China, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines.

Uses The fruits are strongly purgative and emetic. In Peninsular Malaysia and Borneo, the leaves are used to poultice boils. In Indonesia, the leaf juice is drunk by children to treat diarrhoea. However, in Borneo leaves and shoots are reported strongly purgative and emetic. The crushed and fermented fruit is eaten as a condiment. Due to confusion with other species, some of these uses may actually refer to *T. quinquangulata*, *T. pubera* or even the extra-Malesian species *T. bracteata*.

Observations A dioecious, perennial vine up to 6 m long, stem sharply angular, almost glabrous; leaves broadly ovate in outline, 3(–5)-lobed or rarely entire, 10–12 cm in diameter, base deeply cordate, lobes acute, glabrescent; corolla about 8 cm in diameter; male inflorescence 10–18 cm long, bracts broadly elliptical to broadly elliptical-obovate, about 15 mm × 25 mm, dentate; female flowers solitary; fruit ovoid, red, 6–9 cm long; seeds obovate, compressed. *T. tricuspidata* is found in thickets and open places.

Selected sources 457, 580, 721, 829, 1126, 1263.

Trichosanthes villosa Blume

Bijdr. fl. Ned. Ind.: 934 (1826).

Synonyms *Trichosanthes kerrii* Craib (1914).

Vernacular names Indonesia: areuy baduyut, waluh leuweung (Sundanese). Philippines: kandolamo (Bukidnon). Laos: cho' tau quân. Vietnam: d[aa]y d[or] m[or].

Distribution Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines.

Uses Juice from the plant is drunk to treat diarrhoea when the stool is white. Crushed leaves have been smeared on the body to reduce fever, and also to alleviate the pain of swollen legs of women during pregnancy. Young fruits are edible when boiled.

Observations A dioecious, perennial vine of up to 10 m long, stem slightly grooved, velutinous; leaves broadly ovate, entire to slightly 3-lobed, 10–16 cm × 5–18 cm, base cordate, lobes acute, pubescent above, velutinous below; corolla about 6 cm in diameter; male inflorescence 10–20 cm long, bracts elliptical, 3–4 cm long, entire or nearly so, acute; female flowers solitary; fruit globose to ellipsoid-globose, 8–13 cm in diameter, bright yellow to reddish-brown or red; seeds obovate with a truncate apex, compressed. *T. villosa* is found in brushwood and forest edges up to 700 m altitude.

Selected sources 97, 457, 486, 580, 721, 935, 1263.

Trichosanthes wawrae Cogn.

A. DC. & C. DC., Monogr. phan. 3: 384 (1881).

Synonyms *Trichosanthes trifolia* auct. non (L.) Blume.

Vernacular names Malaysia: akar tiga chabang (Peninsular). Thailand: kheekaa din (peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra and Java: possibly also in peninsular Thailand.

Uses In Peninsular Malaysia, pounded leaves have been applied to the abdomen to relieve abdominal pains. In Indonesia, the leaf juice has been used to treat paralysis and oedema.

Observations A dioecious, perennial vine up to 10(–15) m long, stem angular, glabrous; leaves 3-foliolate with elliptical to ovate-elliptical, acuminate, serrate-dentate, glabrous leaflets, the central one 6–12.5 cm × 2–5 cm, lateral ones very unequal; corolla lobes about 1 cm long (excluding fringe); male inflorescence 10–16 cm long, bracts elliptical, distinctly dentate; female flowers solitary; fruit broadly ellipsoidal, 8–10 cm × 6–7 cm, red; seeds elliptical-obovate, truncate at base, compressed. *T. wawrae* is found in brushwood and forest, up to 1000 m altitude. It has often erroneously been treated as *T. trifolia* (L.) Blume, but that name actually refers to a *Momordica* species.

Selected sources 97, 202, 1126, 1227, 1263, 1380.

M.S.M. Sosef, E. Boer & N. Bunyapraphatsara

Verbena officinalis L.

Sp. pl. 1: 20 (1753).

VERBENACEAE

$2n = 12, 14$

Vernacular names Vervain, holy wort (En). Herbe sacrée, verveine officinale (Fr). Malaysia: marphin choo. Philippines: verbena. Thailand: nang dong laang. Vietnam: c[or] roi ng[uwj]a, m[ax] ti[ee]n th[ar]o.

Origin and geographic distribution *V. officinalis* is a species of temperate and subtropical regions, probably originating from the Mediterranean region. It is found at both low and higher elevations in South-East Asia, e.g. in Java, New Guinea, Luzon, northern Thailand and Vietnam. It was introduced for its ornamental value or traditional use in folk medicine in Europe. In general it has become a weed as a follower of cultivation.

Uses The aerial parts of *V. officinalis* are commonly used in European traditional medicine as digestive aid and mild diuretic, to stimulate the renal excretion of water. Furthermore, it is considered a tonic, galactagogue, emmenagogue, purgative, febrifugal, diaphoretic, astringent, anthelmintic, antihaemorrhagic, antispasmodic and antiscorbutic. Externally, it is applied as a gargle to treat throat problems and stomatitis, and as a compress or poultice against ulcers, cuts, contusions, piles and headache. Topical application as an emollient also includes the relief of itching in cases of skin disorders, sunburn and burns. In Europe, reported indications for its use are treatment of jaundice, chlorosis, dropsy, gout, kidney and bladder stones, rheumatism, haematuria, fever, neuralgia and ophthalmia.

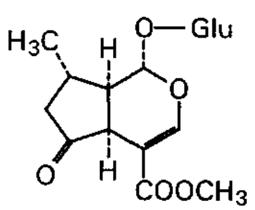
In Indo-China, China, Taiwan and Korea, *V. officinalis* is used internally against colds, fever, inflammations, digestive and intestinal complaints, uterine problems and disorders in the urinary tract. It is also taken after parturition, as a depurative and to help to remove the placenta, in cases of oedema, anaemia, tympanitis, congestion and as antidote after insect bites. Externally, it is used as a poultice or wash to treat skin diseases, wounds, abscesses and tumours. In Vietnam, a decoction of *V. officinalis* is used against dropsy and a poultice against tumours on the scrotum, whereas it is also considered to be useful to regulate menstruation. In Thailand, *V. officinalis* is used in the treatment of liver and gall bladder complaints, colds, fever, bronchitis and mental disorders, whereas the leaves are applied externally to treat rheumatism, wounds and eczemas. In India, the fresh leaves are used as a febrifuge, tonic and as a rubefacient to treat rheumatism or other diseases of the joints, whereas the root is believed to be useful in the treatment of scrofula and snake bite.

V. officinalis is applied as an insecticide. Other *Verbena* species like *V. laciniata* (L.) Briq., *V. rigida* Spreng. and *V. ×hybrida* Voss are cultivated in Java as ornamentals, but *V. bonariensis* L. is naturalized and found in fields, grassland, plantations and roadsides. Medicinal uses have been reported for *V. rigida* in Africa, where root decoctions are used against heartburn and colic and for

V. bonariensis in Brazil, where it is used to treat fevers and catarrh.

Properties *V. officinalis* has a bitter taste. It is known to contain iridoids and their glycosides, such as hastatoside, verbenalin (= verbanaloside, cornin) and verbenin (= aucubin), and phenylpropanoid glycosides e.g. verbascoside (= acetoside) and eukovoside (= leucosceptosid-A). Further phytochemical investigations have also revealed the presence of phytoestrogens and phytoprogestins, flavonoids, saponins, tannins, mucilage, adenosine and β-carotene. *V. officinalis* leaves from Morocco were found to yield an essential oil containing more than 40 compounds, the predominant ones being spathulenol (10.8%), limonene (7.5%), 1,8-cineole (7.5%), caryophyllene-epoxide (7.3%), ar-curcumene (6.0%), geranial (3.3%), neral (2.5%) and α-terpineol. Verbenalin (= verbanaloside), a monoglycoside of the iridoid verbenalol, is present in all plant parts. It has been shown that iridoid biosynthesis efficiency in *V. officinalis* decreases during the flowering period. Furthermore, verbenalin is identical to cornin, which has been isolated from *Cornus florida* L. Verbenalin is non-toxic and has parasympathomimetic properties. It stimulates the uterus in mammals, giving an increased tonus and stronger contractions. In dogs it slightly retards cardiac movements, reduces blood pressure and respiration, causes vasodilation in the kidneys and gives increased and more regular intestinal movements. In rabbits, it has shown antithermic activity, and it stimulates smooth muscle preparations of isolated rabbit intestines. In frogs, verbenalin in large doses is reported to stimulate the motoric activities of the central nervous system, causing stupor, convulsions and paralysis.

Verbenin (= aucubin), another iridoid glycoside, is known to have galactagogue properties. When given to lactating animals it increases milk secretion. The phenylpropanoid verbascoside (= acetoside) is reported to act as an agonist to the antitremor action of laevodopa, and furthermore as an antihypertensive and analgesic.

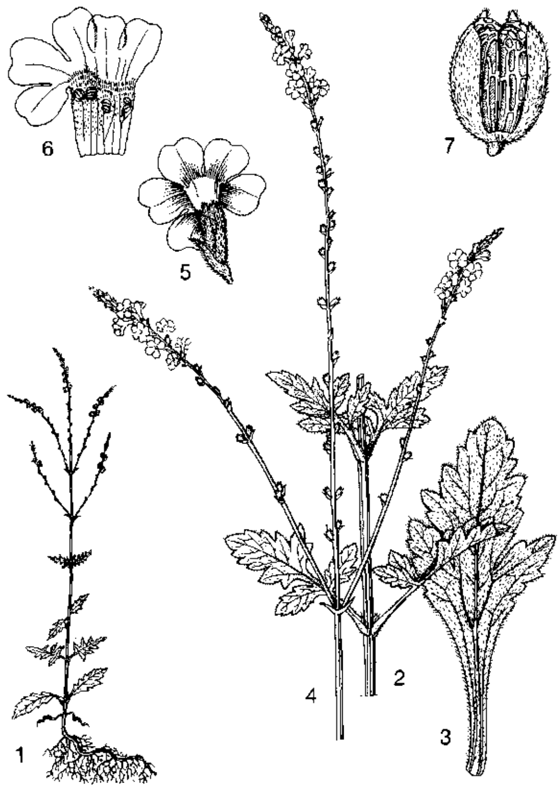


verbenalin (Glu = glucose)

Pharmacological properties attributed to the plant as a whole include anti-microbial activity and antiviral activity against the murine cytomegalovirus. Its usefulness in the prevention and treatment of kidney-stone formation might be attributed to its disinfectant action and perhaps to the presence of saponins.

Finally, *V. officinalis* is suspected of being poisonous to cattle, *V. rigida* of causing irritation in livestock and *V. bonariensis* of causing abortion in cows.

Description A perennial herb up to 100 cm tall; stem erect or decumbent at base, shallowly furrowed, glabrous or sparingly pubescent, tough. Leaves opposite, ovate-oblong in outline, pinnatifid to pinnately divided, 2.5–8 cm × 0.8–5 cm, base attenuate, apex acuminate, sessile by a narrowed base. Inflorescence a spike, lax at anthesis, 5–20 cm long, solitary or combined into a lax compound inflorescence. Flowers with a tubular calyx 2.5–3 mm long at anthesis, 5-toothed, densely glandular



Verbena officinalis L. – 1, plant habit; 2, part of stem; 3, leaf; 4, inflorescence; 5, back of flower with bracteole; 6, corolla opened out; 7, fruit with part of calyx removed.

pubescent, scarcely longer than the fruit; corolla tube 3–4 mm long, corolla limb 5-lobed, 3–5 mm in diameter, pale lilac; stamens 4, inserted on the corolla tube; ovary superior, 4-celled, cells 1-ovuled, style short. Fruit breaking up into 4 closed cocci; cocci about 2 mm long. Seedling with epigeal germination; cotyledons herbaceous, glabrous; hypocotyl elongated, epicotyl present.

Other botanical information *Verbena* consists of about 200(–450) species, almost exclusively originating from temperate and tropical regions of the Americas. Only 2 species can be considered as originating from Europe or the Near East. A considerable number have been introduced in other parts of the world, mostly as garden ornamentals, and sometimes have become naturalized or even weedy. In North America *V. hallei* Small, indigenous to the south-eastern United States, is now considered as a subspecies of *V. officinalis* (*V. officinalis* L. subsp. *hallei* (Small) Barber). However, *V. officinalis* L. subsp. *officinalis* has been introduced from Europe and is now common in the eastern Atlantic part of the United States. In East Africa, the morphological distinctness found is given a taxonomic rank as *V. officinalis* subsp. *africana* R. Fernandes & Verdcourt.

Ecology *V. officinalis* seeds germinate only when mean temperatures are above 14°C, with day temperatures higher than 19°C. Flowering is promoted at temperatures of 16°C or higher. *Verbena* spp. do not tolerate high relative humidity.

Propagation and planting *V. officinalis* can be propagated through seed, cuttings and rootstock division.

Harvesting Aerial parts are collected before anthesis.

Handling after harvest After collecting, aerial parts and roots can be dried for storage and future use.

Prospects Although *V. officinalis* is credited with a wide range of medicinal properties, most of these remain to be scientifically confirmed. It might be useful as a remedy for fever and common colds, and to prevent and treat urolithiasis, but more effective and equally innocuous substances are already available.

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Other selected sources 97, 124, 135, 151, 193, 195, 215, 258, 287, 309, 428, 504, 508, 548, 572, 646, 900, 950, 1035, 1217, 1233, 1476, 1554, 1583, 1596, 1645.

Wongsatit Chuakul, Noppamas Soonthornchareonnon & Promjit Saralamp

Vernonia Schreber

Gen. pl. 2: 541 (1791).

COMPOSITAE

$x = 9, 10$; *V. anthelmintica*: $2n = 20$, *V. cinerea*: $2n = 18$, *V. elaeagnifolia*: $2n = 40$

Major species *Vernonia cinerea* (L.) Less., *V. patula* (Dryander) Merr.

Origin and geographic distribution *Vernonia* comprises about 1000 species occurring in tropical, subtropical and temperate regions of America, Africa and Asia with its main centre of diversity in the Neotropics. About 35 species occur in the Malesian region, most of which are herbs, shrubs or climbers; only two species are trees.

Uses All *Vernonia* species have in common that bitter constituents can be found in almost all plant parts. A multitude of medicinal properties are ascribed to these bitter constituents in particular. Ground leaves or a poultice of leaves of *V. cinerea* are a remedy for headache and when mixed with a little lime they are also applied to dress wounds. The leaves, either ground or as a decoction, are also used against skin diseases. In Indo-China and the Philippines, a decoction of the root is administered against diarrhoea and stomach-ache. In the Philippines, an infusion of the plant is used in the treatment of cough. In the Moluccas, the root is applied as a cough medicine and the juice of the whole plant to promote parturition. In India the flowers are administered for conjunctivitis and the root is given in cases of dropsy, whereas the seeds are also employed as an anthelmintic and alexipharmic. A decoction of *V. patula* is used as a general tonic, febrifuge and to treat diarrhoea.

V. anthelmintica (L.) Willd., occurring in India, Burma (Myanmar) and Laos, but not in the Malesian region, is applied as a vermifuge, and has a reputation for curing leprosy and skin diseases. It is also used as insecticide and insect repellent. The seeds, with a high content of epoxy acid, have been traded to Java as 'kursani'; in high dosage they are claimed to be an abortivum. *V. elaeagnifolia* DC., from Burma (Myanmar), northern Thailand and Indo-China, is reported to be used in a mixture with tobacco. The dried and finely chopped wood is smoked in the form of cigarettes to treat ulcerations of the nose. It is also an ingredient of an infusion to relieve cough. *V. arborea* Buch.-Ham., a common tree of secondary forest, has some medicinal applications as well. An infusion of the root, or a decoction of the bark together with other ingredients, may be given against fever. In southern Sumatra, the bark was chewed at the first signs of sprue.

In Africa, the leaves and roots of *V. amygdalina* Delile are widely applied in folk medicine. A decoction is taken as a febrifuge and to relieve abdominal pains. In East Africa, the leaves or roots of various *Vernonia* species, either chewed or as a decoction, are used to cure stomach-ache. Another general application of the leaves, as an infusion or decoction, is in the treatment of coughs, and as a poultice on wounds and sores, either fresh, cooked or pounded.

The young shoots of *V. cinerea* and *V. patula* are consumed as a cooked vegetable in Java.

Properties As with many other *Compositae*, *Vernonia* is rich in sesquiterpene lactones. The presence of common compounds such as triterpenes, sterols and flavone glycosides in Old World *Vernonia* is reported in literature.

The methanol extract of the whole plant of *V. cinerea* showed significant diuretic activity in rats at doses of 300, 700 and 1000 mg/kg body weight. Activity could be concentrated in the water-soluble fraction of the extract: the freshly prepared water-soluble fraction, representing 300 mg/kg body weight of the dried methanol extract was found to be effective. The effect was not linked to a certain compound or group of compounds; general chemical analysis of this fraction showed the presence of tannins, sugars, flavonoids and glycosides. Furthermore, an aqueous ethanol (50%) extract of the whole plant showed anti-cancer activity against Sarcoma 180 in mice; the maximum tolerated dose was found to be 500 mg/kg body weight.

Vernonin is a triterpenoid isolated from *V. cinerea*. When injected intravenously in dogs it produces hypotension and an action on the heart comparable to that of digitalin, but in general the compound is much less toxic. Other triterpenes isolated from the roots of *V. cinerea* are 3β-acetoxy-urs-19-ene and lupeol acetate. When *V. cinerea* flowers were screened for insecticidal principles, six pyrethrins (pyrethrin I, cinerin I, jasmolin I, pyrethrin II, cinerin II and jasmolin II) were identified by thin layer chromatography.

The anti-inflammatory effect of the alcoholic extract of *V. cinerea* flowers was tested in adjuvant-induced athritic rats. It was concluded that the extract, administered orally at 100 mg/kg, contained as yet unidentified anti-inflammatory principles. The petroleum ether and chloroform extracts of *V. patula* showed significant in vitro activity against lymphoid leukaemia L1210 and lymphocytic P388 tumour cell lines. A partially purified fraction was obtained from the chloroform extract, which was significantly active against these tumour cells in in vitro and in vivo models. Preliminary investigations by column chromatography of both petroleum ether and chloroform extract yielded 4 terpenes (2 identified as α-amyrin and its acetate; both inactive in anti-cancer tests) and 1 sterol (β-sitosterol).

Vernolepin, a sesquiterpene dilactone isolated from *V. amygdalina*, shows platelet anti-aggregating properties. It has a stabilizing effect during freeze-thawing of platelets; it inhibits platelet aggregation induced by arachidonic acid, ADP and collagen, and interferes with ATP release. Electron microscopy shows protection of platelets against adhesion together with a disaggregating effect. All these activities are time-dependent; a steep dose-response relationship is seen. Furthermore, vernolepin has antitumour effects in vitro, just like vernodalin and vernomygdin, two more cytotoxic sesquiterpene lactones isolated from *V. amygdalina*.

Anti-leishmanial activity of chloroform and methanol extracts of *V. amygdalina* has been assessed in vitro on *Leishmania aethiopica*. Amastigotes were more sensitive to *V. amygdalina* than promastigotes. The chloroform extract had a stronger parasiticidal activity (with median effective doses (ED_{50}) of 18.5 μg/ml for promastigotes and 13.3 μg/ml for amastigotes), than the methanol extract (with ED_{50} of 74.4 μg/ml and 45.8 μg/ml, respectively). Cytotoxicity caused by *V. amygdalina* to host cells, the human leukaemia monocyte THP-1 cell line, as determined by the methyl tetrazolium assay, resulted in a median lethal dose (LD_{50}) of 19.6 μg/ml for the chloroform extract and 243.4 μg/ml for the methanol extract. In comparison, the ED_{50} and LD_{50} of pentamidine, a standard anti-leishmanial drug, were 0.5 μg/ml and 1.4 μg/ml respectively. These results indicate that *V. amygdalina* displays potent anti-leishmanial activities and warrants further investigation.

Organic solvent extracts of leaves of *V. amygdalina* have inhibitory activity for His^- to His^+ reverse-mutations induced by ethyl methane sulphonate acting on *Salmonella typhimurium* TA100. The concentrated ethyl acetate, methanol and petroleum ether extracts were heat-stable when dissolved in dimethyl sulphoxide.

Phytochemical investigations of *V. anthelmintica* revealed the presence of a novel 4α-methylsterol, being 4α-methyl-5α-stigmasta-8,14,24,24'-Z-trien-3β-ol (= 4α-methylvernosterol). The 4-demethylsterol and 4,4-dimethylsterol fractions from the seeds were also investigated. The 4-demethylsterol fraction contained vernosterol and avenasterol as the dominant sterols. 4α-Methylvernosterol is suggested to be the possible intermediate in the biosynthesis of vernosterol in *V. anthelmintica* seeds.

Clinical tests of the pollen antigens from *V. cinerea* revealed that they are common allergens causing respiratory tract allergy. The pollen showed allergic manifestations in very low concentrations, were heat stable and non-dialysable, but lost their allergenic property on incubation with trypsin and chymotrypsin.

Adulterations and substitutes Sesquiterpene lactones of the germacranoline type are also found in *Elephantopus*, a closely related genus belonging to the tribe *Vernonieae*.

Description Evergreen herbs, shrubs, climbers or rarely small to medium-sized trees up to 30(–40) m tall. Leaves arranged spirally, simple, margin entire, glandular below, petiolate, stipules absent. Inflorescence terminal or in the upper leaf axils, consisting of widely branched panicles of heads; head with many white, pinkish or purple flowers which are slightly to much longer than the turbinate to campanulate involucre; receptacle alveolate, naked. Flowers bisexual, 5-merous, pappus present, corolla tubular with a campanulate to funnel-shaped limb; anthers fused, with sagittate base; ovary inferior, 1-celled and 1-ovulate, style split into 2 stigmas. Fruit a faintly to prominently ribbed, cylindrical to many-angled achene; pappus hairs usually 2- or rarely 1-seriate, scabrous. Seedling with epigeal germination; cotyledons leafy, glabrous but upper surface glandular dotted, apex truncate to shallowly emarginate; hypocotyl up to 5 mm long, epicotyl very short; first two leaves opposite, subsequent ones alternate.

Growth and development Light enhances germination of *V. cinerea* and seeds germinate over a 30-day period at 25°C. Germination decreases gradually from about 60% on the soil surface to less than 10% at 4 cm depth, and seedlings do not emerge from a depth over 1 cm. The pappus on the fruits enhances dispersal by wind and animals.

Other botanical information The Old World *Vernonia* species are sometimes placed in the subgenus *Orbisvestus*, whereas the New World species are placed in the subgenus *Vernonia*. This subdivision is supported by differences in chromosome numbers and sesquiterpene lactones. Several attempts have been made to refine the genus *Vernonia* by segregating genera and delimiting sections. However, at present no consensus has been reached by those working on the genus.

Ecology *Vernonia* occurs mostly in sunny or slightly shaded habitats, in general corresponding with young secondary vegetation, wasteland and other anthropogenic habitats, from sea-level to 1400 m altitude.

Propagation and planting *Vernonia* can be easily propagated by seed.

Diseases and pests *V. cinerea* can be the host of tobacco leaf curl virus, powdery mildew (*Erysiphe cichoracearum*), root-knot nematodes, and cotton bollworm.

Harvesting When grown as a vegetable, *Ver-*

nonia is harvested when still young. For medicinal purposes the leaves are picked or the roots are collected.

Genetic resources and breeding The *Vernonia* species of medicinal importance have a wide distribution and are common weeds in anthropogenic habitats. Therefore the risk of genetic erosion seems limited.

Prospects Biological activities of extracts of *Vernonia*, and their isolated, purified compounds (e.g. the sesquiterpene lactones) show considerable potential in the treatment of e.g. tumours or leishmaniasis. The importance of these indications merits further research. Furthermore, the medicinal *Vernonia* have potential to be grown as a plantation crop.

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Selection of species

Vernonia cinerea (L.) Less.

Linnaea 4: 291 (1829).

Synonyms *Conyza cinerea* L. (1753), *Vernonia leptophylla* DC. (1836).

Vernacular names Vernonia (En). Little ironweed (Am). Indonesia: maryuna (Javanese), sasawi langit (Sundanese), buyung-buyung (Malay, Moluccas). Malaysia: rumput tahi babi, tambak-tambak (Peninsular). Philippines: kolong-kugon (Bisaya), agas-moro (Ilokano), bulak-manok (Tagalog). Thailand: kaan thuup (south-eastern), yaa dok khaao (central), yaa saam wan (northern). Vietnam: b[aa]c d[aaf]u, d[aj] h[uw][ow]ng ng[uw]u.

Distribution Originally from the Old World, but now a pantropical weed. In Malesia, it is common throughout the region.

Uses Ground leaves or a poultice of leaves is a well-known remedy for headache and, when mixed with a little lime, they are also used to dress wounds. The leaves, either ground or as a decoction, are also applied against skin diseases. In Indo-China and the Philippines, a decoction of the root is used against diarrhoea and stomach-ache. An infusion of the plant is administered in the treatment of cough. In Thailand, the leaves are used in the treatment of asthma and bronchitis. The young shoots are eaten as a cooked vegetable in Java.

Observations An erect herb, 15–80 cm tall, sometimes branched in the upper part, roots crowded, short; leaves variable, lower ones 3–9 cm × 1.5–3.5 cm, upper ones 1–7 cm × 0.3–1.5 cm; inflorescence a terminal panicle, compound and corymbose, 5–35 cm × 5–15 cm, consisting of numerous heads; head turbinate, 20–25-flowered, involucre 3–4-seriate, much shorter than the head, 4–5 mm long, tomentose, corolla 3.5–4.5 mm long, tubular; fruit 1.5–2(–2.5) mm long, cylindrical, faintly ribbed, appressed whitish pubescent, densely brownish glandular, pappus biseriate, outer elements shorter and broader than inner ones, inner setae 4–5 mm long, caducous, white. *V. cinerea* is very polymorphic, and may be divided into several varieties. It flowers throughout the year and grows on a wide range of soils in rather

Vernonia cinerea (L.) Less. – 1, flowering plant; 2, flower head; 3, flower; 4, achene without inner pappus row.

open habitats, from sea-level to 1300 m altitude.

Selected sources 92, 97, 202, 287, 332, 458, 531, 580, 613, 654, 741, 758, 774, 821, 953, 1085, 1126, 1128, 1178, 1386.

Vernonia patula (Dryander) Merr.

Philipp. Journ. Sci., Bot. 3: 439 (1908).

Synonyms *Vernonia chinensis* Less. (1831).

Vernacular names Indonesia: yawun (Javanese), sarap (Madurese). Malaysia: ruku gajah, perasi putih (Peninsular). Vietnam: b[aj]c d[aaf]u.

Distribution Common in north-east India, Burma (Myanmar), Indo-China, southern China, Japan and throughout Malesia.

Uses In Malaysia a decoction of roots and leaves is applied to treat colds and fevers. In Indo-China the plant is used as a tonic and against diarrhoea. The young shoots are consumed as a vegetable in Java.

Observations An almost shrubby herb, 20–70 cm tall, stem much branched, roots crowded; leaves very variable, lower ones 2.5–10.5 cm × 1–4.5 cm, upper ones up to 1.5 cm × 0.5 cm; inflorescence a widely branched panicle or corymb consisting of many heads; head campanulate, 75–100-flowered, involucre 4-seriate, almost as long as the head, 4–6 mm long, tomentose, corolla 6–7 mm long, tubular; fruit 1–1.5 mm long, 4–6-angular, with prominent ribs, glabrous, glandular, pappus uniseriate, 2 mm long, caducous, setaceous, white. *V. patula* is polymorphic, and may be divided into several varieties. It flowers throughout the year and grows on a wide range of soils in rather open habitats, from sea-level to 1400 m altitude.

Selected sources 92, 97, 202, 287, 458, 580, 774, 1126, 1128.

B. Ibnu Utomo & J.L.C.H. van Valkenburg

Vitex L.

Sp. pl. 2: 638 ('938'; 1753); Gen. pl. ed. 5: 285 (1754).

VERBENACEAE

$x = 6, 8$; *V. negundo*: $2n = 24, 26, 32, 34$, *V. trifolia*: $2n = 26, 32, 34$

Major species *Vitex negundo* L., *V. trifolia* L.

Vernacular names Vitex (En). Indonesia: legundi (general). Malaysia: laggundi (Peninsular), leban (Peninsular, Sarawak), kulim papa (Sabah). Papua New Guinea: garamut. Philippines: lagundi. Burma (Myanmar): kyetyo. Laos: 'sa 'khang[1], tin nok. Thailand: tinnok. Vietnam: b[if]nh linh.

Origin and geographic distribution *Vitex* comprises about 150 species and occurs throughout the tropics and subtropics with a few species extending to temperate regions. About 30 species occur in the Malesian region. The most important medicinal species, *V. negundo* and *V. trifolia*, are widely cultivated not only for their medicinal properties but also as ornamental and hedge plants, and have sometimes naturalized.

Uses The bark, leaves, flowers, fruits or roots of various *Vitex* species are used as a general tonic, anthelmintic and in the treatment of gastro-intestinal disorders. The therapeutical applications of *V. negundo* and *V. trifolia* are very similar, although in various countries different parts of the plant are used for the same ailments. General applications are as an anodyne, febrifuge, expectorant and diuretic. A poultice of the leaves is applied in rheumatic pains, inflammations and sprains. An infusion of the leaves is used in the treatment of dermatitis and eczema. The leaves are traditionally placed between books and clothes as well as in rice stores to ward off insects. *V. altissima* L.f., *V. parviflora* A.L. Juss. and *V. pinnata* L. are also used in traditional medicine in South-East Asia but their primary use is for their timber. In the Philippines *V. negundo* is applied in veterinary medicine to treat internal parasites.

Production and international trade In the Philippines *V. negundo* is grown as one of 3 major species on government plantations totalling 3 ha, with an annual yield of 600 kg of powdered drugs. Private plantations have been established alongside these projects.

Properties In experiments on cat trachea leaf extracts of *V. negundo* showed bronchial-relaxing properties. The active constituents are probably the flavonoids casticin, chrysoplenol D, luteolin and isoorientin, and p-hydroxybenzoic acid.

A double-blind placebo-controlled trial was carried out to investigate the effects of lagundi (*V. negundo*) tablets in the control of non-bacterial cough in children: the clinical response was assessed subjectively and objectively and the pulmonary function was also measured. It was found that the *V. negundo* tablets significantly improved the subjective assessments of frequency of cough and colour of sputum in children older than 7 years. In younger children, they were no better than the placebo in terms of the subjective clinical parameters used. No side-effects were reported and the tablet was acceptable in its taste and smell.

An ethanol extract (50%) of *V. trifolia* shows antispasmodic and antihistamine properties. The essential oil contains several terpenes, including cineol, terpineol and α-pinene.

An ethanol extract and a cold aqueous infusion of leaves of *V. leucoxylon* L.f., an Indian species, were evaluated in a battery of tests to define its activity profile. The cold aqueous solution depressed SMA, antagonized d-amphetamine stereotypy and oxotremorine tremors, shortened the duration of mice immobility in a behavioural 'despair' test and lowered serum total cholesterol level. The ethanol extract showed significant inhibition of carrageenin-induced paw oedema and granulation tissue formation in rats. Suppression of acetic acid writhing was observed with both the ethanol extract and the aqueous solution. The LD_{50} value of the ethanol extract was over 3000 mg/kg (intraperitoneal) and that of the aqueous solution 800–1200 mg/kg.

The antifungal properties of leaf extracts of *V. negundo* have been confirmed experimentally both in vitro and in vivo. Antiviral properties against several viral diseases in rice have also been experimentally confirmed.

The ability of the flavonoid-rich fraction (5,7,3'-trihydroxy,6,8,4'- trimethoxy flavones) of *V. negundo* seeds to antagonize the androgen action of exogenous testosterone propionate on the male reproductive system has been confirmed in experiments with castrated prepubertal and intact adult dogs. Similar effects were observed in experiments with male rats. An alcohol extract from *V. negundo* seeds obtained by cold maceration was found effective as a hepatoprotective against liver damage induced by carbon tetrachloride.

A crude drug extract of *V. trifolia* leaves mediated a significant increase in lifespan in mice bearing sarcoma 180 cells, indicating potential antitumour activity. Similarly, expressed leaf juice from *V. negundo* showed antitumour activity in mice. The incidence of skin tumours initiated by dimethylbenzanthracene and promoted by croton oil was reduced appreciably.

Ecdysteroids are found in the bark of several *Vitex* species, e.g. *V. glabrata* and *V. pinnata*. The bark of these species is used as an anthelmintic and a remedy for gastro-intestinal disorders.

Leaf extracts of *V. negundo* show promise as a pesticide for integrated pest management. The insecticidal properties include effects on *Culex* and *Anopheles*, well-known vectors of malaria. Furthermore, dried and pulverized leaves or leaf extracts can be successfully applied in pest management during storage of potatoes, cereals and pulses. Oils from the leaves of *V. negundo* and *V. trifolia* show considerable mosquito repellent activity. The active principle in the leaves of *V. trifolia* has been identified as rotundinal, a cycloterpene aldehyde.

Description Evergreen or deciduous shrubs or small to medium-sized trees, sometimes large, up to 45 m tall; bole crooked to straight, up to 125(–200) cm in diameter, usually without buttresses but sometimes with distinct buttresses, often deeply fluted; bark surface rather smooth to shallowly fissured or flaky, pale grey to pale yellowish-brown, inner bark pale yellow to bright orange; crown often spreading. Leaves opposite or in whorls of 3, palmately compound with 3–7(–9) leaflets, rarely reduced to 1 leaflet, without stipules; leaflets entire, dentate or lobed. Inflorescence terminal or axillary, cymose, the cymes sessile or pedunculate, solitary or arranged in racemes, thyrses or panicles. Flowers bisexual; calyx campanulate to tubular, 5-lobed to truncate; corolla usually with a short tube, 2-lipped, upper lip 2-fid, lower lip 3-fid, often pubescent outside, white to blue or violet or rarely yellowish; stamens 4, didynamous, inserted on the corolla tube, exserted; ovary superior, usually first 2-locular and later 4-locular with a single ovule in each cell, style 1, filiform, stigma bifid. Fruit a juicy or dry drupe, seated on the often enlarged calyx, generally with one 4-seeded pyrene. Seeds obovoid or oblong, without endosperm. Seedling with epigeal germination; cotyledons emergent, leafy; hypocotyl elongated; leaves opposite, conduplicate, first ones simple and with toothed margins.

Growth and development Young *Vitex* trees grow rather slowly. *V. glabrata* trees showed a mean annual diameter increment of 0.8 cm in Burma (Myanmar), and *V. quinata* trees 1.2 cm in Java. One-year-old seedlings of the latter may reach 2 m in height in Java, and the mean annual height increment for the first 15 years after planting is 1 m. Usually flowering is during the rainy season and fruits ripen within a few months. In Java, trees of *V. quinata* do not start flowering until 11–12 years old. In the Philippines, *V. negundo* and *V. trifolia* flower year-round. In India, *V. negundo* flowers twice a year, once in July–November and again in March–May. Its flowers open from 8.30–13.00 h and are visited by various insects, some of which puncture the unopened buds to collect nectar. The flowers last for only 24 hours.

Other botanical information *Vitex* is generally placed in the subfamily *Viticoideae* and is probably most closely related to *Premna* which has simple leaves and very small flowers. *Vitex* might be confused with *Teijsmanniodendron* which differs, however, in the swollen apex of petioles and petiolules and the 2-celled ovary and fruit. Numerous subspecific taxa that are mainly varieties and formae have been described within many species of *Vitex*, but the usefulness of distinguishing them is questionable. *V. negundo* closely resembles *V. trifolia* but can be distinguished by its long-petioluled median leaflet and 3–5 leaflets.

Ecology Most *Vitex* occur in comparatively dry regions with a prominent dry season, often in lowland deciduous forest on rocky ground, on grassy slopes and on dry limestone soils, but sometimes also in littoral rain forest or in hill forest, occasionally up to 2000 m altitude.

Propagation and planting *Vitex* can be propagated by seed, but germination of *V. trifolia* seed is reported to be difficult. *V. quinata* has 7800–8200 dry fruits per kg. *V. negundo* can be propagated by cuttings 20 cm long which had 60% rooting success without the use of growth hormones; soaking the cuttings in naphthalene acetic acid at a concentration of 0.1–1.0 mg/l increased rooting to almost 100%. In the Philippines lagundi (*V. negundo*) for medicinal purposes is planted at a spacing of 2 m × 4 m. When nursery stock is transplanted, 25 g of ammonium sulphate is applied directly to the planting hole. In India, *V. negundo* has been planted at an experimental scale for the production of firewood with 25 000 plants/ha. Planting should be done early in the rainy season. Generally *V. quinata* is planted at 1 m × 3 m in Java, occasionally at 1 m × 1–2 m on very fertile soils.

In vitro production of active compounds Tissue culture of *V. negundo* in the Philippines produced callus with a high content of therapeutic substances, in particular fats.

Husbandry *V. negundo* readily produces root suckers and for maximum biomass production can be managed as coppice. Its twigs are usually not browsed. It grows best in full sun and the content of therapeutically active essential oils is highest under these circumstances. Optimum growth is achieved by applying NPK 14-14-14 at a dosage of 20 g/plant.

Diseases and pests In the Philippines, circular leaf spot caused by *Corynespora* sp. severely damages *V. negundo* plantations locally, especially in the rainy season. *Cercospora* leaf spot and leaf blight caused by an unknown agent have also been observed. Thrips, lepidopterous defoliators and leaffolders are economically important pests of *V. negundo*. In Java, *Cromerus kalshoveni*, a top-sucking insect, has been observed on *V. quinata*.

Harvesting In the Philippines *V. negundo* is harvested 3–9 times a year. Leaves of flowering plants contain significantly more essential oil than those of non-flowering plants. Only mature and healthy leaves are harvested; diseased and senescent ones are discarded.

Yield Steam distillation of *V. negundo* leaves gave a yield of 0.4% of essential oil, principally α-pinene, camphene, caryophyllene and citral.

Handling after harvest The leaves of *V. negundo* may be dried and pulverized and as such applied in tablets and capsules, whereas the leaf extract is used in syrups. The fruits can also be dried and stored for longer periods. In the Philippines harvested leaves are air-dried and stirred constantly in containers with screened bottoms. The desired moisture content of 10% is attained within 3–4 days during the dry season and within 2 weeks during the wet season. Storing dried leaves for 2 months in sealed, clear polyethylene bags under ambient conditions does not significantly reduce essential oil content.

Genetic resources and breeding Most *Vitex* species do not seem to be liable to genetic erosion as they are widespread and generally regenerate easily and abundantly after disturbance of the forest. The medicinally important *V. negundo* and *V. trifolia* are widely planted in hedges and for ornamental purposes. *V. negundo* is most probably an outbreeding species.

Prospects The application of *V. negundo* as a general tonic in syrups and tablets deserves further attention. The antitumour activity as observed in vitro seems promising. *V. negundo* and *V. trifolia* show considerable potential as a botanical pesticide that may be applied both indoors and outdoors.

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Selection of species

Vitex glabrata R.Br.

Prodr.: 512 (1810).

Synonyms *Vitex minahassae* Koord. (1898), *Vitex helogiton* K. Schumann (1905), *Vitex pentaphylla* Merr. (1909).

Vernacular names Indonesia: bihbul (Sundanese), gentileng, ketileng (Javanese). Philippines: bongoog (general), ampapalut (Balabac), talang-pulo (Camarines). Cambodia: popoul ach, popoul tuk. Laos: 'khi^2 hen, 'khi^2 nok, tin nok. Thailand: khainao (general), khee hen (north-eastern), khom khwaan (central). Vietnam: ma, b[if]nh linh nh[awx]n.

Distribution India, Burma (Myanmar), Indo-China, Thailand, Peninsular Malaysia (rare), Java, the Philippines, Sulawesi, Timor, New Guinea and northern Australia.

Uses The root and bark are astringent. The bark is used as an anthelmintic and as a remedy for gastro-intestinal disorders. The fruit and bark are applied as a component of masticatories. The timber is used for house construction, furniture, cart-wheels and oars. The fruits are edible. In India (Assam), *V. glabrata* has been recommended for planting in tea plantations for shade and wood.

Observations A medium-sized tree up to 25 m tall, bole branchless for up to 15 m, up to 125 cm in diameter, bark surface smooth, ash-grey; leaflets 3–5(–6), elliptical-oblong to elliptical-obovate, glabrous above, except for the larger veins, glabrous to pubescent below, especially in the primary vein axils, petioluled, median leaflet 11–31 cm × 4–13.5 cm, with 12–17 pairs of lateral veins; cymes axillary, solitary, lax, 7–22 cm long; calyx 3–4 mm long, with 5 small teeth, corolla yellowish-white, tube villous inside, median segment of lower lip blue-violet; fruit ovoid or obovoid, 1.2–2.5 cm long, purplish-black when mature. *V. glabrata* occurs in mixed evergreen forest, often along forest edges, sometimes also in deciduous forest or grassland, up to 1000 m altitude. In Burma (Myanmar) it is often associated with teak (*Tectona grandis* L.f.).

Selected sources 97, 287, 580, 809, 810, 969, 1067, 1128, 1215, 1413, 1562.

Vitex negundo L.

Sp. pl. 2: 638 ('938'; 1753).

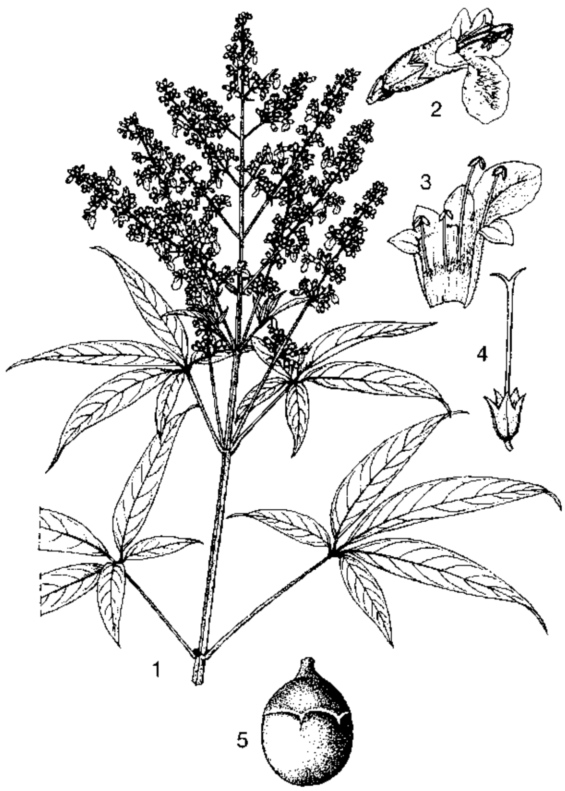
Synonyms *Vitex incisa* Lamk (1786), *Vitex paniculata* Lamk (1786), *Vitex leucoxylon* Blanco (1837).

Vernacular names Five-leaved chaste tree, horseshoe vitex (En). Indonesia: ai tuban (Ambon), lagundi laut laki-laki (Malay, Moluccas). Malaysia: lagundi, lemuning, lenggundi (Peninsular). Papua New Guinea: paparau (Kurtachi, Bougainville). Philippines: lagundi (Filipino), dangla (Iloko). Cambodia: trasiet. Thailand: khon thee khamoa (central), ku-no-kaa-mo (Malay, Pattani), kuuning (Malay, Narathiwat). Vietnam: ng[ux] tr[ar]o.

Distribution Eastern Africa and Madagascar to Iran, Afghanistan, Pakistan, India, Sri Lanka, Burma (Myanmar), Indo-China, China, Japan, Taiwan, Thailand, throughout the Malesian region, east to the Palau Islands, the Caroline Islands and the Mariana Islands. *V. negundo* is widely cultivated in Europe, Asia, North America and the West Indies, and has a tendency to escape and naturalize.

Uses Roots and leaves are applied in various manners as an anodyne, bitter tonic, expectorant and diuretic. As a febrifuge, the leaves can be employed as a poultice or in decoction. A decoction of the leaves is applied to wounds and ulcers, for aromatic baths, and internally as galactagogue, emmenagogue, antigastralgic, and against flatulence. In the Philippines the seeds are boiled in water and eaten, or the water is taken internally, to prevent the spread of toxins from poisonous bites of animals. Syrup, tablets and capsules prepared from leaves and flowering tops are given for coughs, colds, fever and asthma. In Papua New Guinea, sap from crushed heated leaves is diluted with water to treat coughs and sore throat. In India, the flowers are used in the treatment of diarrhoea, cholera and liver disorders, apparently for their astringent properties. *V. negundo* is often planted as a hedge or for ornamental purposes. The twigs are used for wattle-work and rough baskets.

Observations A deciduous shrub or small tree up to 8 m tall, bark surface slightly rough, peeling off in papery flakes, pale reddish-brown; leaflets 3–5, narrowly elliptical to ovate-lanceolate, minutely puberulous or glabrous above, densely tomentose or puberulent below, median leaflet 5–15 cm × 1–4 cm, with 2–12(–18) pairs of lateral veins, median leaflet on a 1–2.5 cm long petiolule, lateral ones sometimes subsessile; cymes arranged in



Vitex negundo L. – 1, flowering twig; 2, flower; 3, opened corolla; 4, calyx and style; 5, fruit.

panicles which are terminal and axillary in the upper leaf axils; calyx 1–2 mm long, shortly 5-toothed, corolla blue-violet, villous inside; fruit globose to broadly ovoid, 3–6 mm long, purple or black when mature. *V. negundo* is very variable and many varieties and formae have been distinguished. It is often found gregariously in humid places or along watercourses, in waste places, thickets and mixed open forest, up to 1700 m altitude.

Selected sources 35, 84, 97, 100, 110, 145, 190, 202, 206, 213, 284, 287, 307, 312, 325, 327, 332, 358, 415, 567, 580, 597, 709, 809, 810, 890, 894, 921, 942, 943, 970, 971, 972, 1035, 1126, 1128, 1171, 1176, 1178, 1195, 1287, 1307, 1380, 1478, 1524, 1525, 1564.

Vitex quinata (Lour.) F.N. Williams

Bull. Herb. Boiss. 2, 5: 431 (1905).

Synonyms *Vitex heterophylla* Roxb. (1832), *Vitex sumatrana* Miq. (1861), *Vitex celebica* Koord. (1898).

Vernacular names Orange-barked vitex (En).

Indonesia: ketileng (Javanese), ki bangbara (Sundanese), gofasa (Malay, northern Sulawesi). Malaysia: leban bunga, leban tandok, merboh (Peninsular). Philippines: kalipapa (general). Burma (Myanmar): kyetyo-po. Thailand: ee pae, makhang, maak lek maak noi (north-eastern). Vietnam: c[aa]y m[aj]n kinh.

Distribution India, the Andaman Islands, Burma (Myanmar), Indo-China, southern China, Thailand, Peninsular Malaysia, Sumatra, Java, the Philippines, Sulawesi, Timor and the Moluccas.

Uses The bark is used as a tonic and as a stomachic; an infusion of it is drunk to stimulate the appetite. The timber is used for house construction and boat building.

Observations A medium-sized to large tree up to 45 m tall, bole up to 100(–150) cm in diameter, often fluted, bark surface shallowly fissured, pale grey, inner bark bright orange; leaflets (3–)5, lanceolate to ovate, glabrous or pubescent on the veins only, petioluled, median leaflet 5–13 cm × 2.5–6 cm, with 9–12 pairs of lateral veins; cymes arranged in large panicles which are terminal or axillary in the upper leaf axils; calyx 3–4 mm long, almost truncate to minutely 5-toothed, corolla pale yellowish to purplish, glabrous to sparsely pubescent inside; fruit subglobose to pear-shaped, 6–12 mm long, blackish when mature. *V. quinata* occurs scattered in forest up to 1400 m altitude.

Selected sources 97, 284, 554, 580, 673, 809, 810, 992, 1035, 1067, 1128, 1413, 1564.

Vitex trifolia L.

Sp. pl. 2: 638 ('938'; 1753).

Synonyms *Vitex rotundifolia* L.f. (1781), *Vitex repens* Blanco (1837), *Vitex lagundi* Ridley (1906).

Vernacular names Common blue vitex, hand of Mary, three-leaved chaste tree (En). Indonesia: legundi (Javanese), galumi (Sumbawa), lagundi (Sumatra). Malaysia: lagundi, lenggundi, muning (Peninsular). Papua New Guinea: pitipitikoto (Gunantuna, New Britain). Philippines: lagunding-dagat (Filipino), dangla (Iloko), tigau (Sulu). Laos: kok pa pay, 'phi 'sua^2 noy^2. Thailand: khon dinso, khon thiso (central), phee suea noi (northern). Vietnam: d[ej]n ba l[as], m[aj]n kinh, quan [aa]m.

Distribution From southern Africa, Madagascar and Mauritius to Afghanistan, India, Sri Lanka, Burma (Myanmar), Indo-China, southern China, Japan, Thailand, throughout the Malesian region, south to northern Australia and east to New Caledonia.

Uses The uses of *V. trifolia* are very similar to *V. negundo*. A poultice of leaves is used to treat rheumatism, contusions, swollen testicles, and as a discutient in sprains. An infusion of the boiled roots is regarded as diaphoretic and diuretic, and is widely drunk in cases of fever and after childbirth. In Malaysia, various parts of the plants are considered a panacea for a wide variety of illnesses ranging from headache to tuberculosis. In Indonesia, the leaves are used in medicinal baths and a tincture or decoction of them for intestinal complaints, whereas the fruits are used as an anthelmintic. In the Bismarck Archipelago, the sap from crushed heated leaves is diluted with water and drunk to relieve headaches. In Vietnam, a decoction of dried fruits is given in the treatment of common cold, headache, watery eyes and mastitis. In Thailand, the fruits are used to treat asthmatic cough and haemorrhoids, and the root is applied in the treatment of liver diseases. *V. trifolia* is often used as a hedge plant, although it may trigger various allergic reactions (sneezing, respiratory problems, dizziness, headache, nausea) to people trimming or pruning such hedges.

Observations A shrub up to 6 m tall; leaflets (1–)3, glabrous above (except for the midrib), densely greyish puberulous below, median leaflet oblong-elliptical to obovate, 2.5–9.5 cm × 1.5–4 cm, with 6–13 pairs of lateral veins, on a 1–6 mm long petiolule, lateral leaflets sessile or subsessile; cymes terminal and axillary, arranged in panicles; calyx 3–5 mm long, obscurely 2-lipped, with 5 small teeth, corolla blue to purple or violet, throat villous inside; fruit globose to ovoid, 5–6 mm long, black or bluish-black when mature. *V. trifolia* is found in teak forest, secondary forest and thickets up to 1100 m altitude, but also in mangrove forest and along the shore. The phenotypical variation observed between these habitats is given specific or subspecific rank by various authors.

Selected sources 97, 190, 202, 284, 364, 580, 597, 809, 810, 921, 967, 972, 993, 1035, 1128, 1178, 1287, 1380, 1412, 1415, 1508, 1525, 1553, 1564, 1570.

E.P. Capareda

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Acronyms of organizations

- CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora (Lausanne, Switzerland).
- DGIS: Directorate-General for International Cooperation of the Netherlands Ministry of Foreign Affairs (Den Haag, the Netherlands).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- FRIM: Forest Research Institute Malaysia (Kepong, Malaysia).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- LIPI: Indonesian Institute of Sciences (Jakarta, Indonesia).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- RDCB: Research and Development Centre for Biology (Bogor, Indonesia).
- TISTR: Thailand Institute of Scientific and Technological Research (Bangkok, Thailand).
- UNITECH: Papua New Guinea University of Technology (Lae, Papua New Guinea).
- UPLB: University of the Philippines at Los Baños (Los Baños, the Philippines).
- WAU: Wageningen Agricultural University (Wageningen, the Netherlands).

Glossary

abaxial: on the side facing away from the axis or stem (dorsal)

abomasal: pertaining to the abomasum, the fourth stomach of a ruminant animal

abortifacient: causing abortion; an agent that causes abortion

abortive: imperfectly developed; effecting an abortion (abortifacient)

abortivum: agent inducing abortion

abscess: a swollen, inflamed area in body tissues, in which pus gathers

abstinence syndrome: withdrawal syndrome

acaricidal: destroying or controlling mites

accession: in germplasm collections: plant material of a particular collection, usually indicated with a number

accrescent: increasing in size with age

acetate pathway: the biosynthetical route which leads to acetate, see also acetates

acetates: a large group of secondary metabolites, in which acetylcoenzyme A ('acetate') is the building block; acetate itself is derived from primary metabolism carbohydrates via pyruvic acid

acetogenins: a group of long-chain aliphatic compounds, ending with a γ-lactone, most often unsaturated and cyclized into one or two tetrahydrofuran rings that may or may not be adjacent

achene: a small dry indehiscent one-seeded fruit

acne: inflammatory disease affecting hair follicles and glands of the skin; frequently used to designate acne vulgaris, with lesions on the face, chest and back

actinomorphic: radially symmetrical; applied to flowers which can be bisected in more than one vertical plane

aculeate: furnished with prickles; prickly

acumen: the point of an acuminate leaf; the drip-tip

acuminate: ending in a narrowed, tapering point with concave sides

acute: in botany: sharp; ending in a point with straight or slightly convex sides; in medicine: with a short and relatively severe course

acute toxicity: toxicity characterized by a sudden onset, sharp rise and short course

adaptogenic: strengthening the resisitance of the body to stress

adaxial: on the side facing the axis (ventral)

adenocarcinoma: carcinoma derived from glandular tissue or in which the tumour cells form recognizable glandular structures

adenovirus (AV): a virus belonging to the *Adenoviridae*, a family of DNA viruses

adnate: united with another part; with unlike parts fused, e.g. ovary and calyx tube

adpressed (appressed): lying flat for the whole length of the organ

adrenergic: activated by, characteristic of, or secreting epinephrine or related substances, particularly referring to the sympathetic nerve fibres that release norepinephrine when a nerve impulse passes

adrenoceptor, adrenoreceptor: adrenergic receptor, i.e. postulated site on effector organs innervated by adrenergic fibres of the sympathetic nervous system

adrenocortical hormone: = corticosteroid

adrenolytic: inhibiting the action of adrenergic nerves

adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems

aerial root: any root that grows above the ground

aetiology: the causes or origin of a disease or disorder

aflatoxin: a toxic factor produced by *Aspergillus flavus* and *A. parasiticus* and implicated as a cause of human hepatic carcinoma

agglutinin: antibody which aggregates a particular antigen; any other substance that is capable of agglutinating particles

aglycones: the non-sugar part of glycosides is called the aglycone part or simply the aglycone; aglycones and their glycosides may be present in the same plant; furthermore, the combination of aglycone and sugar will alter the properties of the molecule *agonist*: a drug that has affinity for and stimulates physiological activity at cell receptors normally stimulated by naturally occurring substances (see also antagonist)

agroforestry: land-use systems in which trees or shrubs are grown in association with crops (agricultural crops or pastures) in a spatial arrangement or a rotation and in which there are both ecological and economic interactions between the trees and the other components of the system

ague: a fever of malarial character marked by paroxysms of chills, fever, and sweating that recur at regular intervals

AIDS: acquired immune deficiency syndrome (acquired immunodeficiency syndrome), an epidemic, transmissible retroviral disease due to infection with HIV (human immunodeficiency virus), in severe cases manifested as a profound depression of cell-mediated immunity

ailment: any bodily or mental disorder; illness, especially one that is not severe

air layering: a form of layering in which soil (rooting medium) is brought to the branch to be layered; the ball of soil in a polyethene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated

albino: a person, animal or plant lacking normal pigmentation

albumen: the nutritive material stored within the seed, and in many cases surrounding the embryo (endosperm)

alexipharmac: an antidote or remedy for poisoning

alkaloids, pseudo-alkaloids: compounds, derived from plant sources, with basic properties, containing one or more nitrogen atoms (usually in a heterocyclic ring), they usually have a marked physiological action on man or animals

allelochemical: a plant compound inhibiting the growth of another plant species

allelopathy: the reputed baneful influence of one living plant upon another due to secretion of toxic substances

allergenic: acting as an allergen; inducing allergy

allergic: pertaining to, caused by, affected with, or of the nature of allergy

allergy: a state of hypersensitivity induced by exposure to a particular antigen (allergen) resulting in harmful immunological reactions on subsequent exposures

allopathic: pertaining to or characteristic of allopathy (a system of therapeutics in which diseases are treated by producing a condition incompatible with or antagonistic to the condition to be cured or alleviated; also called heteropathy)

alopecia: baldness; absence of the hair from skin areas where it is normally present

alterative: tending to change gradually the condition of the body to a normal state; a drug having this effect

alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled

alveolate: marked as though honeycombed

amastigote: any of the bodies representing the morphological (leishmanial) stage in the life cycle of trypanosomatid protozoa resembling the adult form of members of the genus *Leishmania*, with the oval or round cell having a nucleus, kinetoplast and basal body, and the flagellum being very small or absent (see also: promastigote)

amenorrhoea: abnormal absence or suppression of the menses

amoebiasis: the state of being affected by amoebae, especially with *Entamoeba histolytica*

amoebicidal: destroying amoebae

amplexicaul: stem-clasping, when the base of a sessile leaf or a stipule is dilated at the base, and embraces the stem

ampliate: enlarged

anabolic steroid: a (synthetic) derivative of testosterone, having pronounced anabolic and weak androgenic properties; clinically mainly used to promote growth and repair of body tissues in senility, debilitating illness and convalescence

anaemia: a condition in which the blood is deficient in red blood cells, in haemoglobin, or in total volume

anaesthesia: loss of the ability to feel pain, caused by administration of a drug or by other medical interventions

anaesthetic: producing loss of sensation; producing loss of the ability to feel pain; an agent used to abolish the sensation of pain

analeptic: restorative, especially a stimulant to the central nervous system

analgesia: absence of sensibility to pain; the relief of pain without loss of consciousness

analgesic: relieving pain; not sensitive to pain; an agent alleviating pain without causing loss of consciousness

anamorph: the asexual (imperfect) stage or state of a given fungus

anaphylaxis: a general term, originally applied to the situation in which exposure to a toxin resulted not in immunity (prophylaxis), but in hypersensitivity; extended to include all cases of systemic anaphylaxis in response to foreign antigens and to include a range of experimental models

anastomosis: cross connection of branches or roots; union of one vein or parenchyma band with another, the connection forming a reticulation

anatropous: of an ovule, reversed, with micropyle close to the side of the hilum and the chalaza at the opposite end

androdioecious: having male and bisexual flowers on different plants

androecium: the male element; the stamens as a unit of the flower

androgen: any substance that promotes masculinization

andromonoecious: having bisexual and male flowers, but no female flowers, on the same plant

aneuploid: with other than the exact multiple of the haploid chromosome complement

aneusomy: the condition in which an organism is made up of cells containing different numbers of chromosomes

angina pectoris: a paroxysmal thoracic pain, often radiating to the arms. It is most often due to deficiency of blood in the myocardium and precipitated by effort or excitement

angiogenic: inducing the growth of new blood vessels; arising in the vascular system

angioplasty: elimination of areas of narrowing in blood vessels

angiotensin: any of a family of polypeptide hormones formed by the catalytic action of renin on renin substrate and stimulating contraction of the muscular tissue of the capillaries and arteries

annual: a plant which completes its life cycle in one year

annular: used of any organs disposed in a circle

anodyne: relieving pain; a medicine that relieves pain

anorexia: lack or loss of the appetite for food

antagonist: a substance that tends to nullify the action of another, as a drug that binds to a cell receptor without eliciting a biological response (see also agonist)

antalgic: analgesic

anterior: of time, previous; of place, position in front, or turned away from the axis

anthelmintic: destructive to worms: a drug or agent that destroys worms

anther: the part of the stamen containing the pollen

anthesis: the time the flower is expanded, or, more strictly, the time when pollination may take place

anthocyanidins: the aglycone part of anthocyanins, compounds closely related to the flavonoids but derived from the 2-phenyl benzopyrylium cation

anthocyanins: glycosides of the anthocyanidins

anthracnose: a disease characterized by distinctive limited lesions on stem, leaf or fruit, often accompanied by dieback and usually caused by a *Gloeosporium* or a *Colletotrichum*, imperfect fungi. The perfect state of the fungus, when known, is *Gnomonia* or *Glomerella*

anthraquinones: a subgroup of the quinones, in which the dione is conjugated to the condensed polycyclic aromatic system of anthracene

anti-inflammatory: suppressing or counteracting inflammation; an agent that suppresses or counteracts the inflammatory process

antiarrhythmic: preventing or alleviating arrhythmia; an agent that prevents or alleviates arrhythmia

antibiotic: any of a large class of substances produced by various micro-organisms and fungi and having the power of arresting the growth of other micro-organisms or destroying them; a chemical, produced by plants, animals or synthetically, having similar properties

antibody: an immunoglobulin molecule formed in the body in response to a foreign substance (antigen) and serving to neutralize that substance

anticholinergic: blocking the passage of impulses through the parasympathetic nerves; an agent that blocks the parasympathetic nerves

anticomplementary: reducing or destroying the power of a complement (a complex system of heat-sensitive proteins present in serum and reacting with antibodies to destroy antigens)

antidote: anything counteracting the effects of a poison

antifeedant: preventing something from being eaten

antihepatotoxic: counteracting injuries to the liver

antimicrobial: killing micro-organisms, or suppressing their growth or multiplication; an agent acting so

antioxidant: a substance that opposes oxidation or inhibits reactions promoted by oxygen or peroxides; many of these substances are used as preservatives in various products

antiperiodic: remedial of periodic diseases, as qui-

nine for malaria; a remedy for such diseases
antiphlogistic: counteracting inflammation and fever; an agent counteracting inflammation and fever
antiplasmodial: destroying plasmodia
antipyretic: relieving or reducing fever; an agent that relieves or reduces fever
antiscorbutic: relieving or preventing scurvy; a remedy for scurvy
antiseptic: pertaining to asepsis (prevention of contact with micro-organisms); preventing decay or putrefaction; a substance inhibiting the growth and development of micro-organisms without necessarily killing them
antispasmodic: relieving spasm; an agent that relieves spasm
antitoxic: counteracting poison
antitussive: preventing or relieving cough; an agent that prevents or relieves cough
antrorse: directed upwards (opposed to retrorse)
anuria: complete suppression of urinary secretion by the kidneys
anxiolytic: reducing anxiety
aperient: a mild or gentle purgative; also called laxative
aperture: gap or mouth
apex (plural apices): the tip or summit of an organ
aphrodisiac: stimulating sexual desire; a drug arousing the sexual instinct
aphtha: small ulcer
aphthae: plural of aphtha; recurrent inflammation of the oral mucous membranes, characterized by the presence of small ulcers
apical: at the apex of any structure
apiculate: ending abruptly in a short point
apocarp: a fruit which is apocarpous
apocarpous: with the carpels free from each other
apomict: an organism reproducing by apomixis
apomixis: reproduction by seed formed without sexual fusion (apomictic)
apoplexy: sudden neurologic impairment due to a cerebrovascular disorder, either an arterial occlusion or an intracranial haemorrhage; copious extravasation of blood within any organ
apoptosis: fragmentation of a cell into membrane-bound particles, which are eliminated by phagocytosis
aporphine alkaloids: a subgroup of the alkaloids
appendage: a part added to another; attached secondary or subsidiary part, sometimes projecting or hanging
appressed (adpressed): lying flat for the whole length of the organ
aquaretic diuresis: diuresis without disturbing the electrolyte balance
arachnoid: like a cobweb
arboreal: of, relating to, or resembling a tree; inhabiting or frequenting trees
arborescent: attaining the size or character of a tree
areolate: with irregular squares or angular spaces marked out on a surface, e.g. of a fruit; with small cells or cavities
areole: an irregular square or angular space marked out on a surface, e.g. of a fruit; a small cell or cavity
aril: an expansion of the funicle enveloping the seed, arising from the placenta; sometimes occurring as a pulpy cover (arillus)
arillate: possessing an aril
armed: bearing some form of spines
arrhythmia: any variation from the normal rhythm of the heartbeat
arteriosclerosis: a group of diseases characterized by thickening and loss of elasticity of arterial walls
arthritis: inflammation of a joint or joints
article: a segment of a constricted pod or fruit, as in *Desmodium*
articulate: jointed, or with places where separation takes place naturally
articulation: a joint, popularly applied to nodes of grasses
ascariasis: infection by the roundworm *Ascaris lumbricoides*, which is found in the small intestine and causes colicky pains and diarrhoea, especially in children
ascendent, ascending: curving or sloping upwards
ascites: effusion and accumulation of serous fluid in the abdominal cavity
ascitic: pertaining to or characterized by ascites
asexual: sexless; not involving union of gametes
asphyxia: pathological changes caused by lack of oxygen in respired air, resulting in hypoxia and hypercapnia
asthma: a chronic disorder characterized by paroxysms of the bronchi, shortness of breath, wheezing, a suffocating feeling, and laboured coughing to remove tenacious mucus from the air passages
astringent: causing contraction; an agent or substance causing contraction of the skin, mucous membranes or raw or exposed tissues. As such, ethanol is used in skin-toning lotions and aluminium chlorohydrate in anti-perspirants
ataxia: failure of muscular coordination; irregularity of muscular action
atonic: lacking normal tone or strength

atony: lack of normal tone or strength
attenuate: gradually tapering
auct.: auctorum (Latin); of authors
auct. non: auctorum non (Latin); of authors not ... (author name); used after a scientific name when this name is erroneously applied by several authors to material actually belonging to a different species than the species described by the author mentioned
auricle: a small lobe or ear
auriculate: eared, having auricles
autotriploid: an autopolyploid with three similar sets of chromosomes
auxin: an organic substance characterized by its ability in low concentrations to promote growth of plant shoots and to produce other effects such as root formation and bud inhibition
awn: a bristle-like appendage, especially occurring on the glumes of grasses
axil: the upper angle between the leaf and the stem
axile: (placenta) belonging to or situated in an axis
axillary: arising from the axil
axis: the main or central line of development of a plant or organ
azoospermia: absence of spermatozoa in the semen or failure of formation of spermatozoa
bacillary dysentery: infectious disease caused by bacteria of the genus *Shigella*, and marked by intestinal pain, tenesmus, diarrhoea with mucus and blood in the stools, and variable toxaemia
bactericidal: destroying bacteria
bactericide: an agent that destroys bacteria
bacteriostatic: inhibiting the growth or multiplication of bacteria
barbiturate: any of a group of sedative-hypnotic agents derived from barbituric acid or thiobarbituric acid
bark: the tissue external to the vascular cambium collectively, being the secondary phloem, cortex and periderm
basifixed: attached or fixed by the base
basophil: granular leucocyte, from which vasoactive amines like histamine and serotonin are released on stimulation
batik: an Indonesian method of hand-printing textiles by coating parts of the fabric with wax to resist dye, dipping in a cold dye solution, boiling off the wax, and repeating the process for each colour used
beak: a long, prominent and substantial point, applied particularly to prolongations of fruits
beaked: used of fruits which end in a long point
bearded: awned; having tufts of hairs
bechic: a remedy or treatment of cough
benzoquinones: see quinones
beri-beri: a disease caused by a deficiency of thiamine (vitamin B1), marked by inflammatory or degenerative changes of the nerves and heart, and edema
berry: a juicy indehiscent fruit with the seeds immersed in pulp; usually several-seeded without a stony layer surrounding the seeds
biconvex: convex on both sides
bidentate: having two teeth; doubly dentate, as when the marginal teeth are also toothed
biennial: a plant which flowers, fruits and dies in its second year or season
bifid: forked, divided in two but not to the base
bilabiate: two-lipped
bilateral (botany): having 2, often opposite, sides
bilharzia: schistosomiasis
biliousness: a symptom complex with nausea, abdominal discomfort, headache and constipation, formerly attributed to excessive secretion of bile
bilocular: with two compartments or cells
biogenic: having origins in biological processes
biological half-life: the time rquired for a living tissue, organ or organism to eliminate one-half of a radioactive substance which has been introduced to it
biomimetic: imitative of biological processes
bipinnate: when the primary divisions (pinnae) of a pinnate leaf are themselves pinnate
bisbenzylisoquinoline alkaloids: a subgroup of the isoquinoline alkaloids
biseriate: arranged in two rows
bisexual: having both sexes present and functional in the same flower
blade: the expanded part, e.g. of a leaf or petal
blastogenic: pertaining to or characterized by blastogenesis, i.e. the transformation of small lymphocytes into larger cells resembling blast cells
blennorrhoea: an excessive discharge of mucus; former name for gonorrhoea
blight: a general term applied to any of a wide range of unrelated plant diseases
blotched: see variegated
bole: the main trunk of a tree, generally from the base up to the first main branch
bollworm: any of several genera of moths belonging to the *Noctuidae*
bract: a reduced leaf subtending a flower, flower stalk or the whole or part of an inflorescence
bracteole: a secondary bract on the pedicel or close under the flower
bradycardia: slowness of the heartbeat, as evi-

denced by a slowing of the pulse rate to less than 60 in an adult

bradykinin: a nonapeptide which is produced by activation of the kinin system in a range of inflammatory conditions; it is an extremely powerful vasodilator, which also increases vascular permeability, stimulates pain receptors and causes contraction of extravascular smooth muscles

bradypnea: abnormal slowness of breathing

bran: the husks or outer coats of ground corn, separated from the flour by bolting

breeding: the propagation of plants or animals to improve certain characteristics

bristle: a stiff hair or a hair-like stiff slender body

broadcast: to sow seed scattered, not in lines or pockets

bronchitis: inflammation of one or more bronchi

bronchoconstriction: the act or process of decreasing the diameter of a bronchus

bronchodilation: the act or process of increasing the diameter of a bronchus

bronchus (plural bronchi): any of the larger air passages of the lungs

bud: the nascent state of a flower or branch; often applied to those primordial vegetative or reproductive branches that are enclosed in a prophyllum and have a resting stage

budding: the process of inserting a scion, which consists of the bud in a leaf axil on a shield of rind, with or without a small piece of wood attached, into a plant (rootstock) with the intention that it will unite and grow there, usually in order to propagate a desired cultivar

bufadienolides: cardiac glycosides in which the side chain of the steroid aglycone is a 5-membered lactone ring

bulb: an underground storage organ with a much-shortened stem bearing fleshy leaf bases or scale leaves enclosing the next year's bud

bulbil: an aerial bulb or bud produced in a leaf axil or replacing the flower, which, on separation, is capable of propagating the plant

bullate: surface much blistered or puckered

bush: a low thick shrub without a distinct trunk

buttress: the enlargement of the base of trunks of tropical trees that ranges from a small spur or swelling to massive structures, partly root, partly stem, reaching as high as 10 m up the stem, thin and flat to thick, twisted or anastomose

cachexia: general ill health and malnutrition

caducous: falling off

calcareous: consisting of or containing chalk (calcium carbonate)

calculus: an abnormal concretion within the body and usually consisting of mineral salts; also called stone

callus: in plants, small hard outgrowth at the base of spikelets in some grasses, or tissue that forms over cut or damaged plant surface; in humans, localized hyperplasia of the horny layer of the epidermis due to pressure or friction, or an unorganized meshwork of woven bone which is formed after a fracture of a bone

calyx: the outer envelope of the flower, consisting of sepals, free or united

campanulate: bell-shaped

canaliculate: channelled, with a longitudinal groove

cancer: a malignant neoplasm or tumour, characterized by a morbid proliferation of epithelial cells in different parts of the body, resulting in progressive degeneration and often ending fatally

cancerous: of the nature of or pertaining to cancer

canker: a sunken, necrotic lesion of main root, stem or branch, due to disintegration of tissue outside the xylem cylinder, sometimes limited in extent because of host reactions resulting in overgrowth of surrounding tissues

canopy: the uppermost leafy layer of a tree, forest or crop

capillaroscopy: examination of the capillaries with the microscope

capitate: headed, like the head of a pin in some stigmas, or collected into compact headlike clusters as in some inflorescences

capitulate: with a capitulum

capituliform: shaped somewhat like a head

capitulum: a dense inflorescence of an aggregation of usually sessile flowers, as in *Compositae*

capsule: in botany: a dry dehiscent fruit composed of two or more carpels and either splitting when ripe into valves, or opening by slits or pores; in medicine: a structure in which something is enclosed, e.g. a hard or soft, soluble container enclosing a dose of medicine

carbohydrates: compounds formed from water and carbondioxide; they can be grouped into sugars and polysaccharides

carbuncle: a necrotizing infection of skin and subcutaneous tissue consisting of a cluster of boils, and with multiple formed or incipient drainage sinuses; it is usually caused by *Staphylococcus aureus*

carcinogenesis: the production of carcinoma

carcinogenic: producing carcinoma

carcinoma: a malignant new growth consisting of

epithelial cells, which tends to infiltrate surrounding tissues and give rise to metastases
cardenolides: cardiac glycosides in which the side chain of the steroid aglycone is a 5-membered lactone ring
cardiac: pertaining to, situated near, or affecting the heart; pertaining to the opening between the oesophagus and the stomach
cardiac glycosides: natural products characterized by a specific effect on myocardial contraction and atrioventricular conduction
cardioactive: having an effect on the heart
cardiotonic: having a tonic effect on the heart; an agent that has a tonic effect on the heart
cardiotropic: affecting, acting upon or attracted to the heart
cardiovascular: pertaining to the heart and blood vessels
carina: keel, the two inner united petals of a papilionaceous flower
carinate: keeled
cariogenic: leading to the production of caries
carminative: relieving flatulence; an agent relieving flatulence and assuaging pain
carotenoids: a subgroup of the terpenoids, containing 8 isoprene units (C_{40}) named after β-carotene
carpel: one of the foliar units of a compound pistil or ovary; a simple pistil has only one carpel
carpophore: the part of the receptacle which is prolonged between the carpels as a central axis
cartilaginous: hard and tough
caruncle: an outgrowth of a seed near the hilum
caryopsis: the fruit of a grass, in which the outer layer (testa) of the seed proper is fused to the ovary wall
castaneous: chestnut-coloured, dark brown
cataphyll: vestigial or scale-like leaf present in certain seedlings on the lower stem nodes and sometimes elsewhere on the seedling stem
cataplasm: poultice or soft external application
catarrh: inflammation of the lining tissue of various organs, particularly of the nose, throat, and air passages, and characterized by an outpouring of mucus
catch-cropping: a form of intercropping in which a perennial crop (e.g. cocoa) is interplanted in its juvenile phase with a secondary annual or short-perennial crop (e.g. banana) to obtain income during the interim period, to check weeds, to provide shade and to control the spread of insect pests; a form of sequential cropping in which, for instance, a green manure crop precedes the main crop
cathartic: causing evacuation of the bowels; an agent that causes evacuation of the bowels by increasing bulk, stimulating peristaltic action etc.; also called purgative
catkin: a close bracteate, often pendulous spike, usually with unisexual flowers
caudate: with a tail-like appendage
cauliflorous: with the flowers borne on the trunk
cauline: belonging to the stem or arising from it
cellulitis: acute, suppurative inflammation of the deep subcutaneous tissues and sometimes muscle, usually resulting from wound infection by bacteria such as group A streptococci and *Staphylococcus aureus*
cephalalgia: headache
cerebriform: having an irregular, brain-like appearance, like the kernel of a walnut
cerebrovascular: pertaining to the blood vessels of the cerebrum or brain
Chagas' disease: a form of trypanosomiasis, occurring widely in Central and South America and caused by *Trypanosoma cruzi*
chalcones: a subgroup of the flavonoids
channelled: grooved, hollowed out like a gutter
chartaceous: papery
chemiluminescence: luminescence resulting from the direct transformation of chemical energy into light energy
chemotype: taxon which is morphologically similar to another one but with different chemical content
chlorosis (in medicine): a disorder characterized by greenish-yellow discoloration of the skin and generally affecting adolescent females in the nineteenth century; believed to be associated with iron deficiency anaemia
cholagogue: an agent that promotes an increased flow of bile
cholangitis: inflammation of a bile duct
cholecystitis: inflammation of the gall bladder
cholekinesis: activation of the bile flow
cholera: acute, infectious inflammation of the intestine, caused by an enterotoxin elaborated by *Vibrio cholerae*, and characterized by severe, watery diarrhoea
choleragenic: producing cholera
choleresis: the secretion of bile by the liver
choleretic: stimulating the production of bile by the liver
cholestasis: suppression or stoppage of the bile flow
cholinergic: stimulated, activated or transmitted by acetylcholine; applied to the sympathetic and parasympathetic nerve fibres that liberate

acetylcholine at a synapse when a nerve impulse passes (see also: anticholinergic)

cholinesterase: enzyme that catalyses the cleavage of the acyl group from various esters of choline, including acetylcholine, and several related compounds, and which occurs primarily in the serum, liver and pancreas

choriocarcinoma: an epithelial malignancy, formed by abnormal proliferation of certain placental epithelium cells

chromophore: any chemical group whose presence gives a decided colour to a compound and which unites with certain other groups to form dyes

chromosome: a structural unit in the nucleus which carries the genes in a linear constant order; the number is typically constant in any species

chronic: persisting over a long period of time

ciliate: with a fringe of hairs along the edge

cincinnus: a monochasial cymose inflorescence with branches alternating from one side of the vertical axis to the other and normally curved to one side

circumscissile: dehiscing or falling off along a circular line

cirrhosis: liver disease characterized by diffuse, interlacing bands of fibrous tissue that divide the hepatic parenchyma into nodular areas

clavate: club-shaped or thickened towards the end

claw: the basal, narrow part of a petal or sepal

clawed: furnished with a basal, narrow part (the claw)

cleft: cut halfway down

cleistogamous: pollination and fertilization taking place within the unopened flower

clone: a group of plants originating by vegetative propagation from a single plant and therefore of the same genotype

clustered: compactly gathered together; with several stems

coccidial: pertaining to coccidia, i.e. organisms of a subclass (*Coccidia*) of parasitic protozoa, found in vertebrates and higher invertebrates

coherent: the incorporation of one part with another, as the petals to form a tubular corolla

cohobation: re-use of distillation waters for the purpose of recovering dissolved essential oil

colic: acute, spasmodic pain in the bowels; pertaining to the bowels

collagen: an insoluble fibrous protein that occurs in vertebrates as the chief constituent of the connective tissues, as in skin, cartilage, bone and hair

collar: the boundary between the above- and underground portions of the axis of a plant

colleter: a multicellular glandular hair

colliculate: covered with small round elevations

column (botany): a cylindrical body, e.g. a tube of connate stamen filaments or the central axis of a fruit

coma: in medicine: a state of unconsciousness from which the patient cannot be aroused; in botany: the hairs at the end of some seeds; a tuft of leafy bracts or leaves at the top of an inflorescence (e.g. pineapple)

compatibility: in floral biology: capable of cross- or self-fertilization; in plant propagation: stock-scion combinations resulting in a lasting union of the two parts

compound: of two or more similar parts in one organ, as in a compound leaf or compound fruit

concave: hollow

concolourous: similarly coloured on both sides or throughout; of the same colour as a specified structure

condensed tannins: see tannins

conduplicate: folded lengthwise

confluent: blended into one, passing by degrees from one into the other

congeneric: belonging to the same genus or forming a single genus

conical: having the shape of a cone (cone-shaped)

conjunctiva: the membrane that lines the eyelid and covers the anterior part of the eyeball

conjunctivitis: inflammation of the conjunctiva

connate: united or joined

connective (botany): tissue between the pollen sacs of an anther

connivent: having a gradually inward direction, as in many petals (convergent)

conspecific: belonging to the same species

constipation: a condition of the bowels in which the expulsion of waste matter is infrequent and difficult

contorted: twisted or bent

contraceptive: reducing the likelihood of or preventing conception; an agent that reduces the likelihood of or prevents conception

convalent bond: a chemical bond between two atoms or radicals formed by the sharing of one, two or three pairs of electrons

convex: having a more or less rounded surface

convulsion: a violent and involuntary contraction of the voluntary muscles

coppice: a small wood which is regularly cut at stated intervals, the new growth arising from the stools

coralline: pertaining to, composed of, or having

the structure of corals, as coralline limestone
cordate: heart-shaped, as seen at the base of a leaf, etc., which is deeply notched
coriaceous: of leathery texture
corm: in botany: a solid, short, swollen underground stem, usually erect and tunicated, of one year's duration, with that of the next year at the top or close to the old one
corolla: the inner envelope of the flower consisting of free or united petals
corrugate (corrugated): wrinkled
cortex: the bark or rind
corticosteroid: any of the 21-carbon steroids elaborated by the adrenal cortex (excluding sex hormones of adrenal origin) in response to the release of ACTH or angiotensin II; used clinically for hormone replacement therapy, for suppression of ACTH secretion, for suppression of immune responses and as antineoplastic, anti-allergic and anti-inflammatory agents
corymb: a flat-topped indeterminate inflorescence in which the branches or pedicels sprout from different points, but attain approximately the same level, with the outer flowers opening first
corymbose: flowers arranged to resemble a corymb
cotyledon: seed-leaf, the primary leaf; dicotylous embryos have two cotyledons and monocotylous embryos have one
coumarins: benzo-α-pyrone (α-chromone) derivatives
counterirritant: producing a counterirritation, i.e. a superficial irritation in one part of the body, intended to relieve an irritation in another part; an agent which causes counterirritation
cover crop: a close-growing crop primarily grown for the purpose of protecting and improving soil between periods of regular crop production or between trees or vines in orchards and plantations
crenate: the margin notched with blunt or rounded teeth
crenulate: slightly crenate, with small teeth
cross-incompatibility: not capable of cross fertilization
cross-pollination: the transfer of pollen from one flower to the stigma of a flower of another plant which is not of the same clone
crossing-over: the process of exchange of genetic material between homologous chromosomes during meiosis, consisting of the breakage of homologous chromatids at corresponding sites and their reunion with each other
crown: the aerial expanse of a tree, not including the trunk; corona; a short rootstock with leaves; the base of a tufted, herbaceous, perennial grass
crustaceous: of hard but brittle texture
cryopreservation: maintaining the viability of tissue or organs by storage at very low temperatures
crystalline: of the nature of or relating to a crystal or crystals
culm: the stem of grasses and sedges
cultigen: a plant species or race that has arisen or is known only in cultivation
cultivar (cv., plural cvs): an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety; a cultivar name should always be written with an initial capital letter and given single quotation marks (e.g. banana 'Gros Michel')
cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals
cupular: furnished with or subtended by a cupule
cupule: a small cup-like structure; the cup of such fruits as the acorn, consisting of an involucre composed of adherent bracts
cupuliform: cupule-shaped
cusp: a sharp, rigid but small point
cuspidate: abruptly tipped with a sharp rigid point
cutting: a portion of a plant, used for vegetative propagation
cyanogenic glycosides: a group of secondary metabolites that form hydrocyanic acid on hydrolysis
cymbiform: boat-shaped
cyme: a determinate inflorescence, often flat-topped, in which each growing point ends in a flower and the central flowers open first
cymose: bearing cymes or inflorescences related to cymes
cyst: a stage in the life cycle of certain parasites, during which they have a protective wall
cysticidal: destroying cysts, e.g. those of *Entamoeba histolytica*
cystitis: inflammation of the urinary bladder
cystolith (botany): mineral concretions, usually of calcium carbonate on a cellulose stalk
cytokine: generic term for nonantibody proteins released by a cell population on contact with a specific antigen and acting as intercellular mediators
cytokinin: any of a class of phytohormones having as main functions the induction of cell division and the regulation of tissue differentiation
cytoplasm: the protoplasm of a cell, excluding the nucleus

cytosol: the liquid medium of the cytoplasm
cytosolic: pertaining to or contained in the cytosol
cytotoxic: pertaining to or exhibiting a destructive effect on certain cells
damping-off: a disease of seeds or seedlings caused by fungi which cause various effects, from failure to germinate to the dying off of the seedling
deciduous: shedding, applied to leaves, petals, etc.
declinate: bent or curved downward or forward
decoction: a medicinal preparation or other substance made by boiling, especially in water
decompound: several times divided or compounded
decongestant: an agent that reduces congestion or swelling
decumbent: reclining or lying on the ground, but with the summit ascending
decurrent: extending down and adnate to the petiole or stem, as occurs in some leaves
decussate: of leaves, arranged in opposite pairs on the stem, with each pair perpendicular to the preceding pair
deflexed (reflexed): abruptly recurved; bent downwards or backwards
dehiscent: opening spontaneously when ripe, e.g. of capsules, anthers
deltoid: shaped like an equilateral triangle
demulcent: allaying the irritation of abraded or inflamed body surfaces, soothing; a soothing, mucilaginous or oily medicine or application
density: weight (kg) per volume (cubic m) at a certain moisture content
dentate: margin prominently toothed with the pointed teeth directed outwards
denticulate: minutely toothed
deobstruent: having the power to remove obstructions; an agent that removes obstructions
depilatory: having the power to remove the hair
depressant: diminishing functional activity; a medicine or drug which lowers functional activity and vital energy in general
depurative: tending to purify or cleanse
dermatitis: inflammation of the skin
dermatomycosis: superficial fungal infection of the skin or its appendages, with the term including dermatophytosis
dermatophyte: a fungus parasitic on the skin
dermatophytosis: any superficial fungal infection caused by a dermatophyte and involving the horny layer of skin, hair and nails
dermatosis: any skin disease, especially one without inflammation
determinate: of inflorescences, when the terminal or central flower of an inflorescence opens first and the prolongation of the axis is arrested; of shoot growth, when extension growth takes the form of a flush, i.e. only the previously formed leaf primordia unfold; for pulses also used to indicate bush-shaped plants with short duration flowering in one plane
diabetes: a general term referring to disorders characterized by the excretion of excessive amounts of urine. When used alone, usually referring to diabetes mellitus, i.e. a chronic syndrome of impaired carbohydrate, protein and fat metabolism owing to insufficient secretion of insulin or tissue insulin resistance
diadelphous: in two bundles
dialysable: capable of dialysis or of passing through a membrane
dialysis: the process of separating solutions of mixed substances of unequal diffusibility by means of membranes or septa
diapause: a state of inactivity and arrested development, accompanied by greatly reduced metabolism
diaphoretic: pertaining to, characterized by, or promoting (profuse) perspiration; an agent inducing sweating, having the power to increase perspiration
diarrhoea: a profuse, frequent, and loose discharge from the bowels
dichasium (plural dichasia): a cymose inflorescence with 2 equal or nearly equal lateral branches arising below the terminal flower, this pattern being repeated or not (compound and simple dichasium respectively)
dichotomous: forked, parted by pairs
dicotyledon: angiosperm with two cotyledons or seed-leaves
didynamous: with the stamens in two pairs, two long and two short ones
dieback: the dying off of parts of the aboveground structure of the plant, generally from the top downward
digestibility: the percentage of a foodstuff taken into the digestive tract that is absorbed into the body
digitate: a compound leaf whose leaflets diverge from the same point like the fingers of a hand
dilated (botany): expanded into a flat structure
dimer: a compound formed by combination of two identical simpler molecules
dimeric: showing the characteristics of a dimer
dimerous: with two members
dimorphic: of two forms, as may occur with branches, etc.

dimorphous: dimorphic
dioecious: with unisexual flowers and with the staminate and pistillate flowers on different plants (dioecy)
diosgenin: a complex steroid obtained from certain species of yam and which can be converted into 16-dehydropregnenolone, one of the main active ingredients in oral contraceptives
diploid: with two sets (genomes) of chromosomes, as occurs in somatic or body cells; usually written $2n$, having twice the basic chromosome number of the haploid germ cells
dipterocarp forest: woodland dominated by trees belonging to the family *Dipterocarpaceae*
disc: = disk
disciform: shaped like a disk
discoid: resembling a disk or discus, being flat and circular, e.g. of a leaf with a round thickened lamina and rounded margins
discutient: causing a disappearance; an agent which causes a disappearance
disk: a fleshy or elevated development of the receptacle within the calyx, corolla or stamens, often lobed and nectariferous
dispersal: the various ways by which seeds are scattered, e.g. by wind, water or animals
dissected: divided into many slender segments
distal: situated farthest from the place of attachment
distichous: regularly arranged in two opposite rows on either side of an axis
distillation: the process of transforming (fractions of) a liquid or solid into the vapour state, and condensing the vapour back to liquid or solid, named the distillate
distylous: referring to flowers of a species which possess one of two style types
diterpenes: a subgroup of the isoprenoids, formed by coupling of 4 C_5 units
diuresis: increased discharge of urine
diuretic: tending to increase the flow of urine; an agent that promotes the excretion of urine
divaricate: extremely divergent
domatium (plural domatia): a modified projection that provides shelter for other organisms
dormancy: a term used to denote the inability of a resting plant or plant part (e.g. the seed, bulb, tuber, or in tree crops usually the buds) to grow or to leaf out, even under favourable environmental conditions
dorsal: back; referring to the back or outer surface of a part or organ (abaxial)
dorsifixed: attached by the back, as in the case of the attachment of a filament to an anther
double blind: pertaining to a clinical trial or other experiment in which neither the subject nor the person administering treatment knows which treatment any particular subject is receiving
double-flowered: petals monstrously increased at the expense of other organs, especially the stamens
downy: covered with very short and weak soft hairs
dropsy: oedema
drupaceous: resembling a drupe, whether actually a drupe or not
drupe: a fleshy one-seeded indehiscent fruit with the seed enclosed in a strong endocarp
drupelet: a small drupe
dysentery: any of various diseases characterized by inflammation of the intestines, abdominal pain and frequent bloody, mucous faeces
dysmenorrhoea: painful menstruation
dyspepsia: a condition of disturbed digestion
dyspeptic: relating to or having dyspepsia
dysphoria: malaise, disquiet, restlessness; opposite of euphoria
dyspnoea (dyspnea): laboured or difficult breathing
dystonia: distorted or impaired movements resulting from disordered muscle tonicity
dystonic: pertaining to or characterized by dystonia
dysuria: difficult or painful urination
ebracteate: without bracts
EC_{50}: median effective concentration, i.e. the concentration that produces the desired effect in fifty percent of a test population
ecbolic: increasing uterine contractions and aiding in or hastening expulsion or delivery of child during birth; an agent acting so
ecotype: a biotype resulting from selection in a particular habitat
ecto-: in compositions, referring to the outside or the outer surface or part
ectoparasite: a parasite that lives on the outside of the hosts's body
eczema: a disease of the skin characterized by inflammation, redness, itching, and the formation of vesicles which exude a watery substance that evaporates and leaves the skin covered with crusts
ED_{50}: median effective dose, i.e. the dose that produces the desired effect in fifty percent of a population
edaphic: pertaining to or influenced by conditions of the soil
eglandular: without glands

elaiosome: a seed or fruit outgrowth in which oil is stored. Serves as food for ants
ellipsoid: a solid which is elliptical in outline
elliptical: oval in outline but widest about the middle
emarginate: notched at the extremity
embryo: in plants, the rudimentary plant within a seed, developed from a zygote (sexual) or from other nuclei in the embryo sac or cells of the nucellus or integuments (apomictic); in animals, those derivatives of the fertilized ovum that will become the offspring, during their period of most rapid development; in humans, the developing organism from the end of the 2nd week after fertilization to the end of the 8th week
emergent: of a tree, one of which the crown reaches distinctly above the forest canopy; of cotyledons, becoming free from the seed coat and other external tissues
emesis: vomiting
emetic: tending to induce or cause vomiting; an agent that induces or causes vomiting
emeto-cathartic: an agent that is both emetic and cathartic
emmenagogue: a substance or measure that induces menstruation
emollient: soothening and softening; an agent that soothes or softens the skin or soothes an irritated internal surface
emphysema: pathological accumulation of air in organs or tissues, especially applied to the lungs
encephalitis: inflammation of the brain
endemic: exclusively native to a specified or comparatively small region; also used as a noun for a taxon thus distributed
endo-: prefix, referring to the inside or the inner surface or part
endocarp: the innermost layer of the pericarp or fruit wall
endodermis: a sheath of one or more layers of modified parenchymatous cells between the cortex and the central zone of the stem or root
endogenous: originating from within the organism
endosperm: the starchy or oily nutritive material stored within some seeds, sometimes referred to as albumen; it is triploid, having arisen from the triple fusion of a sperm nucleus and the two polar nuclei of the embryo sac
enema: a liquid injected into the rectum
enfleurage: the process of transferring the volatile compounds responsible for the scent of picked flowers to a fixed oil or fat spread out on a glass plate. Enfleurage is successful only with flowers that continue to produce aroma compounds for several hours after picking, such as jasmine and tuberose
ensiform: sword-shaped
enterobiasis: infection with nematode worms of the genus *Enterobius*, especially *E. vermicularis* (seatworm, threadworm or pinworm)
entire (botany): with an even margin without teeth, lobes, etc.
epicotyl: the young stem above the cotyledons
epidermis: in plants, the true cellular skin or covering of a plant below the cuticle; in humans, the outermost and nonvascular layer of the skin
epidermoid: belonging to or resembling the epidermis
epididymal: pertaining to the epididymis
epididymis: the cordlike structure at the posterior part of the testis, whose coiled duct provides for storage, transit and maturation of spermatozoa
epigeal: above the ground; in epigeal germination the cotyledons are raised above the ground
epigynous: on the pistil, apparently above the ovary
epilepsy: any of a group of syndromes characterized by recurrent, transient disturbances of the brain function, with manifestations including unconsciousness and uncontrolled motion
epileptic: pertaining to epilepsy
epimer: either of two diastereomers that differ in the configuration around one asymmetrical carbon atom
epipetalous: borne upon or placed before the petals
epiphyte: a plant that grows on another plant but without deriving nourishment from it
epistaxis: nosebleed
epitepalous: borne upon or placed before the tepals
epithelium: in plants, the layer of secretory parenchymatous cells that surrounds an intercellular canal or cavity; in humans, the covering of internal and external body surfaces, including the lining of vessels and other small cavities
epithet: the second part of the scientific name of a species, the first part denoting the genus to which the species belongs
erect: directed towards summit, not decumbent
erecto-patent: between spreading and erect
erysipelas: an acute, superficial form of dermatitis, usually caused by group A streptococci and characterized by a spreading, red, hot plaque
erythema: name applied to skin redness produced by congestion of the capillaries
essential oil: a volatile product, obtained from a natural source, which agrees with that source in odour and name. In a narrow sense, only volatile products obtained by steam or water

distillation are called essential oils
eutrophic: providing adequate or with a large supply of nutrition
evergreen: bearing foliage all year long; a plant that changes its leaves gradually
ex situ: in an artificial environment or unnatural habitat
exalbuminous: lacking albumen
exanthem, exanthema: a skin eruption or rash; a disease in which skin eruptions or rashes are a prominent manifestation
exocarp: the outer layer of the pericarp or fruit wall
exocytosis: the discharge from a cell of particles which are too large to diffuse through the wall
expectorant: promoting the ejection of mucus or other fluids from the respiratory tract; an agent tending to promote discharge of mucus or other fluids from the respiratory tract
exsert, exserted: protrude beyond, as stamens beyond the tube of the corolla
exstipulate: without stipules
extra-axillary: beyond or outside the axil
extract: a concentrated preparation of a vegetal or animal drug obtained by removing the active constituents with a suitable solvent
extrafloral: of nectaries, beyond the flower
extrorse: directed outward, as the dehiscence of an anther
F_1, F_2, *etc.*: symbols used to designate the first generation, second generation, etc., after a cross
falcate: sickle-shaped
fallow: land resting from cropping, often covered by natural vegetation or planted with fast growing herbs, shrubs or trees (fallow crop)
fascicle: a cluster of flowers, leaves, etc., arising from the same point
fasciculate: connected or drawn into a fascicle
favus: type of ringworm, usually caused by *Trichophyton schoenleini*
febrifuge: an agent serving to reduce fever
fermentation: a chemical change accompanied by effervescence and suggestive of changes produced in organic materials by yeasts
fertile: in plants: capable of completing fertilization and producing seed; producing seed capable of germination; having functional sexual organs; in humans: having the capacity to reproduce; capable of developing into a new individual (said of ova)
fertilization (biology): union of the gametes (egg and sperm) to form a zygote
fibre: in plants: any long, narrow cell of wood or bark other than vessel or parenchyma elements; in humans: an elongated, threadlike structure
fibrinolytic: pertaining to, characterized by or causing fibrinolysis, i.e. the dissolution of fibrin by enzymatic action
fibroblast: connective tissue cell
fibroplasia: the formation of fibrous tissue, as occurs normally in the healing of wounds and abnormally in some tissues
fibrosarcoma: a malignant tumour consisting of cells and fibres derived from fibroblasts
fibrosis: the formation of fibrous tissue
fibrous: composed of or containing fibres
fig: the fleshy multiple fruit, derived from the inflorescence of *Ficus* spp. (syconium)
filament: thread; the stalk supporting the anther
filariasis: a diseased state due to the presence of nematode worms of the superfamily *Filarioideae* in the body
filiform: slender; threadlike
fimbriate: fringed
fissured: provided with fissures (cracks of considerable length and depth), e.g. in the bark of some trees
flaky: lamelliform, in the shape of a plate or scale
flatulence: the presence of excessive amounts of air or gases in the intestine
flavanoles: a subgroup of the flavonoids
flavanones: a subgroup of the flavonoids
flavones: a subgroup of the flavonoids
flavonoids: a group of natural products in which the basic structure is the 2-phenyl-chromane skeleton
flavonoles: a subgroup of the flavonoids
fleshy: succulent
floret: a small flower, one of a cluster as in grasses or *Compositae*; a grass floret typically consists of a lemma, palea, 2 lodicules, 3 stamens and a pistil with 2 plumose stigmas
flush: a brief period of rapid shoot growth, with unfolding of the leaf primordia which had accumulated during the previous quiescent period
fluted: of a bole, with rounded grooves and folds
fodder: something fed to domesticated animals, especially coarse, dried food from plants (hay, straw, leaves)
foliaceous: leaf-like
foliolate: 2-, 3-, 4- etc., with 2, 3, 4 leaflets
follicle: in plants: a dry, unicarpellate fruit, dehiscing by the ventral suture to which the seeds are attached; in humans: a sac or pouchlike depression or cavity, e.g. hair follicle
follicular atresia: the degeneration and resorption of an ovarian follicle before it reaches maturity and ruptures

fomentation: treatment by the application of warm, moist substances; the substance thus applied
forage: grassland and fodder plants suitable as feed for herbivores, usually with lower nutrient concentration and digestibility than concentrates such as grain
foveolate: with small pits
framboesia: see yaws
free: neither adhering nor united
free radical: a radical (a group of atoms which enters into and goes out of chemical combination without change and forms one of the fundamental constituents of a molecule) which is extremely reactive, has a very short half-life, and carries an unpaired electron
fringed: fimbriate; with hair-like appendages along the margin
frondose: frond-like
frugivorous: feeding on fruit
fruit: the ripened ovary with adnate parts
fugaceous: withering or falling off rapidly or early
fulminant hepatitis: massive hepatic necrosis, usually resulting from hepatitis B or non-A, non-B hepatitis
fulvous: yellow, tawny
fungicidal: destroying fungi
fungicide: an agent that destroys fungi or inhibits their growth
fungistatic: inhibiting the growth of fungi
fungitoxicity: the quality of having a toxic effect on fungi
funicle (funiculus): the little cord which attaches the ovule or seed to the placenta
furuncle: a painful nodule in the skin caused by inflammation of the dermis and subcutaneous tissue, enclosing a central core; it is caused by staphylococci which enter through hair follicles
fusiform: spindle-shaped; tapering towards each end from a swollen centre
galactagogue, galactogogue: promoting the flow of milk; an agent that promotes the flow of milk
galactophoritis: inflammation of the milk ducts
galenicals: medicines prepared according to the formulas of Galen; the term is now used to denote preparations containing one or more organic ingredients, as contrasted with pure chemical substances
gallery forest: fringing forest, forest growing along a watercourse in an otherwise non-forested area
gamete: either of two mature reproductive cells, an ovum or sperm, which in uniting produce a zygote; the malarial parasite in its sexual form
gametocidal: capable of destroying gametes or gametocytes
gametocyte: a cell capable of dividing to form gametes
gamopetalous: with united petals either throughout their length or at the base
gamophyllous: with leaves which are united by their edges
gargle: to rinse or medicate the throat and mouth with a liquid kept in motion by the slow expulsion of air from the lungs; a solution used for rinsing or medicating the throat and mouth
gastralgia: gastric colic
gastric: pertaining to, originating in, or affecting the stomach
gastritis: inflammation of the stomach
gastro-enteritis: acute inflammation of the lining of stomach and intestines, which may be caused by food poisoning, ingestion of irritating food or drinks, or psychological factors
gastropathy: any disease of the stomach
gene: the unit of inheritance located on the chromosome
genetic erosion: the decline or loss of genetic variability
geniculate: abruptly bent so as to resemble the knee-joint
genin: aglycone
genome: a set of chromosomes as contained within the gamete and corresponding to the haploid chromosome number of the species
genotype: the genetic makeup of an organism comprising the sum total of its genes, both dominant and recessive; a group of organisms with the same genetic makeup
genus (plural genera): the smallest natural group containing distinct species
geocarpic: having the fruits mature underground
germplasm: the genetic material that provides the physical basis of heredity
giardiasis: common infection of the small intestine with the flagellate protozoan *Giardia lamblia*
glabrescent: becoming glabrous or nearly so
glabrous: devoid of hairs
glandular: in botany: having or bearing secreting organs or glands; in medicine: pertaining to or of the nature of a gland
glaucoma: a group of eye diseases characterized by an increased intraocular pressure which causes pathological changes in the eye and impaired vision, and which may lead to blindness
glaucous: pale bluish-green, or with a whitish bloom which rubs off
glioma: a tumour composed of tissue representing

neuroglia (the supporting tissue of the nervous system); sometimes extended to include all primary, intrinsic neoplasms of the central nervous system

globose: spherical or nearly so

glomerule: a condensed head of almost sessile flowers; a cluster of heads in a common involucre

glossitis: inflammation of the tongue

glume (plural glumes): the chaffy or membranous two-ranked members of the inflorescence of grasses and similar plants; lower glume and upper glume, two sterile bracts at the base of a grass spikelet

glutinous: sticky

glycaemia: the presence of glucose in the blood

glycosides: see aglycones

goitre: an enlargement of the thyroid gland, resulting in a swelling in the front part of the neck

goitrogen: a goitre-producing compound

goitrogenic: producing goitre

gonadotrophic, gonadotropic: stimulating the gamete-producing glands

gonadotrophin, gonadotropin: any hormone that stimulates the gamete-producing glands (gonads), like ovary and testis

gonorrhoea: a venereal disease characterized by inflammation of the mucous membrane of the genitourinary tract and a discharge of mucus and pus

gout: a group of disorders of (purine) metabolism, characterized by inflammation of a joint, paroxysmal recurrent pain and an excess of uric acid in the blood

gouty: characterized by inflammation of a joint, paroxysmal recurrent pain and an excess of uric acid in the blood

graft: a union of different individuals by apposition, the rooted plant being termed the stock, the portion inserted the scion

grafting: the process of inserting a scion, which consists of a piece of stem and two or more buds of the plant to be propagated, into another plant (rootstock) with the intention that it will unite and grow

grain (botany): a general term for cereals, those grasses cultivated for food; the caryopsis or the fruit of cereals

gram-negative: losing the stain or decolorized by alcohol in Gram's staining method, which is a primary characteristic for bacteria with a cell wall consisting of a thin layer of peptidoglycan with an outer membrane of lipoprotein and lipopolysaccharide

gram-positive: retaining the stain or resisting decolorization by alcohol in Gram's staining method, which is a primary characteristic for bacteria with a cell wall consisting of a thick layer of peptidologlycan with attached teichoic acids

granulocyte: any cell containing granules, especially leucocytes containing cytoplasmic granules

granulocytopenia: a complex of symptoms characterized by a marked decrease in the number of granulocytes and by lesions of the throat and other mucous membranes, the gastro-intestinal tract and the skin; also known as agranulocytosis

granuloma: imprecise term, applied to aggregations of either mononuclear inflammatory cells or modified macrophages; granuloma formation represents a chronic inflammatory response

granulose (granular): composed of or covered with grain-like minute particles

green manure: green leafy material applied to and mostly worked into the soil to enrich the soil with nutrients and organic matter

greenwood cutting: a cutting of immature and still soft and pliable tissue

gregarious: growing in associated groups or clusters but not matted; at the same time; in bamboos gregarious flowering is used to indicate that a whole population flowers over a period of 2–3 years and then dies, although sometimes the rhizomes remain alive

gum: a colloidal polysaccharide substance that is gelatinous when moist but hardens on drying; gum is exuded by plants or extracted from them

gynobase: an elongated or enlarged receptacle on which the pistil is borne

gynobasic: of a style, attached to a prolongation upwards of the receptacle between the carpels

gynodioecious: having female and bisexual flowers on different plants

gynoecium: the female part or pistil of a flower, consisting, when complete, of one or more ovaries with their styles and stigmas

gynostemium: the androecium and gynoecium combined

habit (botany): external appearance or way of growth of a plant

habitat: the kind of locality in which a plant grows

haemagglutination: agglutination of erythrocytes

haematometra: an accumulation of blood in the uterus

haematopoietic: pertaining to or effecting the formation of blood cells; an agent that promotes

the formation of blood cells
haematotoxic: poisonous to the blood and the haematopoietic system
haematuria: the presence of blood in the urine
haemin: a porphyrin chelate of iron
haemolysis: disruption of the integrity of the red blood cell membrane, causing release of haemoglobin
haemolytic: pertaining to, characterized by, or producing haemolysis
haemoptysis: expectoration of blood or blood-stained sputum from some part of the respiratory tract
haemorrhage: bleeding; the escape of blood from blood vessels
haemorrhoid: a mass of dilated veins in swollen tissue situated near the anal sphincter
haemostasis: the arrest of bleeding
haemostatic: arresting the flow of blood; an agent that checks the flow of blood
haemostyptic: haemostatic
hallucinogenic: inducing hallucinations
hardwood cutting: a cutting consisting of mature woody tissue
head: a dense inflorescence of small crowded often stalkless flowers (a capitulum)
heartwood: wood from the inner portion of a tree in which the cells are dead and no longer engaged in sap conduction and food storage
hemi-: prefix, meaning half
hemiplegia: paralysis of one side of the body
hepatitis: inflammation of the liver
hepatocyte: liver cell
hepatomegaly: enlargement of the liver
hepatotoxic: having a toxic effect on liver cells
herb: any vascular plant which is not woody
herbaceous: with the texture, colour and properties of a herb; not woody
herbivore: a plant-eating animal
hermaphrodite: bisexual; in flowers, with stamens and pistil in the same flower
herpes: any of several inflammatory diseases of the skin caused by a herpesvirus and characterized by clusters of vesicles
herpes simplex: group of acute infections caused by herpes simplex virus type 1 or type 2, characterized by the development of one or more small fluid-filled vesicles on the skin or mucous membrane, and occurring as a primary infection or recurring because of reactivation of a latent infection
heterodistylous: with two kinds of plants, having either short or long styles
heteromorphic: varying in number or form
heterosis: exceptional vigour of organisms through crossbreeding between two different types
heterostylous: having styles of two or more distinct forms or of different lengths
heterotristylous: with three kinds of plants, having long, short or intermediate styles
hexaploid: having six sets of chromosomes ($6n$)
hilum: the scar left on a seed indicating its point of attachment
hirsute: with rather coarse stiff hairs
hispid: covered with long rigid hairs or bristles
hispidulous: minutely hispid
histiocytosis: a condition characterized by the abnormal appearance of macrophages in the blood
histochemical: pertaining to the chemical components or activities of cells and tissues
histopathological: pertaining to the histology of diseased tissues
HIV (human immunodeficiency virus): a virus that is the aetiological agent of acquired immunodeficiency syndrome (AIDS). Two serotypes are distinguished: HIV-1, with a worldwide distribution, and HIV-2, which is largely confined to West Africa
Hodgkin's disease: a form of malignant lymphoma characterized by painless, progressive enlargement of the lymph nodes, spleen and general lymphoid tissue
homeostasis: a tendency to stability in the normal body states of the organism
homogamous: bearing one kind of flowers
homostylous: having styles of the same length and/or shape
husk: the outer covering of certain fruits or seeds
hyaline: almost transparent
hybrid: the first generation offspring of a cross between two individuals of different species or taxa
hybridization: the crossing of individuals of different species or taxa
hydrolysable tannins: see tannins
hydrolysis: a chemical reaction of water in which a bond in the reactant other than water is split and hydrogen and hydroxyl are added
hydrophilic: having a strong affinity for water
hydrophobia: any morbid dread of water; rabies
hydrophobic: resistant to or avoiding wetting
hydrophyte: plant living in water or wet ground
hypanthium: a cup-like receptacle usually derived from the fusion of the floral envelopes and androecium on which are seemingly borne the calyx, corolla and stamens
hyperaemia: an excess of blood in a part of the body

hyperaesthesia: increased sensitivity, particularly a painful sensation from a normally painless touch stimulus
hyperbilirubinaemia: the presence of excessive concentrations of bilirubin in the blood, which may lead to jaundice
hypercalcaemia: an excess of calcium in the blood
hypercholesterolaemia: an excess of cholesterol in the blood
hypercholesterolaemic: pertaining to, characterized by, or tending to produce hypercholesterolaemia
hyperglycaemia: an abnormally increased glucose concentration in the blood
hyperglycaemic: pertaining to, characterized by, or causing hyperglycaemia
hyperlipemia: hyperlipidemia, a general term for elevated concentrations of any lipid or all lipids in the plasma
hyperphylloerythrinaemia: the presence of excessive concentrations of phylloerythrin in the blood
hypertension: high arterial blood pressure
hypertrophic: pertaining to or marked by hypertrophy, i.e. the enlargement of (part of) an organ due to an increased size of its cells
hypo-thyroidism: deficiency of thyroid activity; in adults characterized by a decreased basal metabolic rate, fatigue and lethargy, sensitivity to cold and menstrual disturbances; in children it may lead to arrested physical and mental development
hypocholesterolaemia: an abnormally diminished amount of cholesterol in the blood
hypocholesterolaemic: pertaining to, characterized by, or producing hypocholesterolaemia
hypocotyl: the young stem below the cotyledons
hypocrateriform: saucer-shaped, with a long and narrow tube and limbs at right angles to the tube
hypogeal: below ground; in hypogeal germination the cotyledons remain below ground within the testa
hypoglycaemic: pertaining to, characterized by, or producing an abnormally decreased glucose concentration in the blood (hypoglycaemia)
hypolipidaemic: promoting the reduction of lipid concentration in the serum
hypopodium: the basal portion of a leaf, including the stalk
hyposensitization: the act or process of reducing the ability to react to a specific allergen by applying repeated and gradually increasing doses of the offending substance
hypotension: an abnormally low blood pressure
ichthyotoxic: poisonous to fishes
imbricate: overlapping like tiles; in a flower bud when one sepal or petal is wholly external and one wholly internal and the others overlapping at the edges only
imidazole alkaloids: a subgroup of the alkaloids
imparipinnate: of leaves, pinnate with an unpaired terminal leaflet
impetigo: a contagious, purulent skin disease, caused by group A streptococci or *Staphylococcus aureus*, and mostly seen in children, usually on the face
implantation: the embedding of the fertilized egg in the uterus; the insertion or grafting of material into the body
impotence: lack of power, specifically lack of copulative power in the male due to failure to initiate or maintain an erection
in situ: in the natural environment; in medicine: in the natural or normal place
in vitro: outside the living body and in an artificial environment
inarching: grafting by approach, the scion remaining attached to its parent until union has taken place
incised: cut deeply
incompatibility: in floral biology: not capable of cross- or self-fertilization; in plant propagation: not capable of making stock–scion combinations resulting in a lasting union
indehiscent: not opening when ripe
indented: forced inward to form a depression
indeterminate: of inflorescences, a sequence in which the terminal flowers are the last to open, so that the floral axis may be prolonged indefinitely by the terminal meristem; of shoot growth: when the shoot apex forms and unfolds leaves during extension growth, so that shoot growth can continue indefinitely
indigenous: native to a particular area or region
indigestion: lack or failure of digestion
indole alkaloids: a subgroup of the alkaloids
indumentum: a covering, as of hairs, scales, etc.
induplicate: with the margins bent inwards and the external face of these edges applied to each other without twisting; V-shaped in cross section, trough-shaped
inequilateral: unequal-sided
inferior: beneath, lower, below; an inferior ovary is one which is situated below the sepals, petals and stamens
inflammation: a protective response of the body in response to injury, infection, irritation, etc.,

aimed at destroying or isolating the injurious agent and injured tissue, and characterized by redness, pain, heat, and swelling

inflexed: bent or curved inward toward the centre

inflorescence: the arrangement and mode of development of the flowers on the floral axis; the branch that bears the flowers, including all its bracts and branches

influenza: an acute highly contagious virus disease characterized by sudden onset, fever, prostration, severe aches and pains, and progressive inflammation of the respiratory mucous membrane

infrageneric: referring to any taxon below the genus level

infraspecific: referring to any taxon below the species level

infructescence: a ripened inflorescence in the fruiting stage

infundibular: funnel-shaped

infusion: a liquid extract obtained by steeping or soaking something in a liquid for the purpose of extracting its medicinal principles without boiling; the therapeutic introduction of a fluid, other than blood, into a vein

inner bark: the secondary phloem; the living part of the tissue outside the cambium

inoculation: grafting, more properly budding, a single bud only being inserted; introduction of microorganisms, infective material, serum and other substances into tissues of living plants and animals, or culture media promote growth

inoculum: material used for inoculation, e.g. rhizobia in soil to promote the growth of certain *Leguminosae*

inotropic: affecting the force or energy of muscular contractions (positive: increasing the force; negative: weakening the force)

insecticide: an agent that destroys insects

insomnia: sleeplessness

insulin: a protein hormone produced by β-cells of the islets of Langerhans in the pancreas, which is secreted in response to elevated glucose and amino acid levels in the blood and promotes their storage and utilization. Insulin deficiency is often the cause of diabetes, and exogenous insulin is used to control that disease

interacuminal: between acumens

intergeneric hybrid: hybrid between species of two or more genera

internode: the portion of the stem (culm) between two nodes

interpetiolar: of stipules placed between the petioles of opposite leaves

intracerebro ventricular: within one of the several cavities of the brain which are filled with cerebrospinal fluid

intragastric: within the stomach

intraluminal: within the lumen of a tube, e.g. of a blood vessel or intestine

intramarginal: placed within the margin near the edge; of a vein, running near and parallel with the margin

intrapetiolar: of stipules, positioned within the petiole axil

intraspecific: occurring within a species or involving members of one species

intrastaminal: within the stamens

introrse: turned inward, towards the axis, as the dehiscence of an anther

involucral: belonging to an involucre

involucre: a ring of bracts (involucral bracts) surrounding several flowers or their supports, as in the heads of *Compositae* or the umbels in *Umbelliferae*

involute: having the edges of the leaves rolled inwards

iridoids: monoterpenes (C_{10}) characterized by a cyclopentanotetrahydropyran ring system, also known as the iridane skeleton; seco-iridoids can be regarded as being formed from iridoids by opening of the cyclopentane ring between C_7 and C_8

ischias: pain in the inferior dorsal portion of the hip bone (ischium)

islets of Langerhans: irregular microscopic structures scattered throughout the pancreas and comprising its endocrine part

isoflavonoids: a subgroup of the flavonoids, in which the basic structure is the 3-phenyl chromane skeleton

isomer: a compound, radical or ion containing the same numbers of atoms of the same elements in the molecule as one or more others, and hence having the same molecular formula, but differing in the structural arrangement of the atoms and consequently in one or more properties

isoprenoids or terpenoids: a large group of secondary metabolites, in which isopentenyl pyrophosphate ('active isoprene' or 'C_5-unit') is the building block; isopentenyl pyrophosphate is derived via the mevalonic acid pathway; mevalonic acid itself is formed from 3 molecules of acetate, but the mevalonic acid pathway channels acetate into a different series of compounds than does the acetate pathway

isoquinoline alkaloids: a subgroup of the alkaloids

jaundice: a syndrome marked by hyperbilirubinaemia and deposition of bile pigments in the skin, mucous membranes and eyeball, resulting in yellowish pigmentation of these body parts

joint; jointed: an articulation, like a node in plants and a place of union of two bones in the human body; articulated

jugate: connected or yoked together; e.g. in leaves 1–n-jugate: with 1–n pairs of leaflets

karyology: the science of the nucleus and its development and vital history

karyotype: the full chromosome set of the nucleus of a cell

keel (carina): a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla; the principal vein of a sepal or glume

keeled (carinate): having a keel or carina

keloid: an overgrowth of scar tissue

keratinophilic: having an affinity for keratin, i.e. any of a family of scleroproteins which form the primary constituents of epidermis, hair, nails and horny tissues

kernel: the nucellus of an ovule or of a seed, that is, the whole body within the coats

labellum: lip; the lowest petal of an orchid; petaloid anterior staminode in *Zingiberaceae*

lac insect: a scale insect (*Laccifer lacca*, synonym *Kerria lacca*) that produces lac, a resinous gold-coloured substance used for lacquerware

laciniate: slashed, cut into narrow lobes

lactifuge: an agent that checks the secretion of milk

laevodopa: the laevorotatory isomer of dopa, used as an agent against parkinsonism

lamina: see blade

lanate: with woolly hairs

lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex

lanuginose: woolly or cottony

larvicidal: destroying insect larvae

larvicide: an agent destructive to insect larvae

laryngitis: inflammation of the larynx

lateral: on or at the side

laterite: a red soil that shows intensive weathering and chemical change and leaching away of bases and silica, leaving aluminium and iron oxides

latex: a juice, usually white and sometimes sticky, exuding from broken surfaces of some plants

laticiferous: latex-bearing

lax: loose, distant

laxative: aperient, mildly purgative; an agent that promotes evacuation of the bowel

layer: a branch caused to root while still connected to the parent and used for propagation (layering)

LC_{50}: median lethal concentration, i.e. the concentration of a chemical that kills fifty percent of the organisms in a test population

LD_{50}: median lethal dose, i.e. the amount of an agent that kills fifty percent of the organisms in a test population

leaflet: one part of a compound leaf

lecitins: glycerophosphoric acid derivatives, in which 2 free hydroxyl groups of the glycerol are esterified with fatty acids, while 1 of the 2 remaining groups of the phosphoric acid residue is esterified to an alcohol

lectins: proteins of glycoproteins, which are not antibodies or enzymes, but which have the ability to attach themselves to specific sugars; the binding is not covalent, and the sugar can either be free or constituent part of a larger molecule, which may be present, e.g. in a membrane

leishmanial: pertaining to or caused by leishmanias, i.e. protozoa of the genus *Leishmania*

Leishmaniasis ('kala azar'): infection caused by *Leishmania*, and classified into cutaneous, mucocutaneous and visceral leishmaniasis (kala-azar)

lemma: the lower of the two glumes which surround each floret in the spikelet of grasses

lenticel: lenticular masses of loose cells protruding through fissures in the periderm on stems, fruits and roots, usually arising beneath individual stomata; their main function is gaseous exchange

lenticellate: having lenticels

lenticular: shaped like a double-convex lens

leprosy: a chronic, infectious, slowly progressive disease, caused by *Mycobacterium leprae*, characterized by lesions in the skin, mucous membranes, nerves, bones and viscera, and manifested by a broad range of clinical symptoms

Letterer-Siwe disease: a specific form of histiocytosis, characterized by a haemorrhagic tendency, eczematoid skin eruption, enlargement of the liver, spleen and lymph nodes, and progressive anaemia

leucopaenia: reduction in the number of leucocytes (white blood cells) in the blood

leucopaenic: pertaining to, characterized by, or causing leucopaenia

leucorrhoea: a whitish, viscid discharge from the female genitals

leucotriens: see prostaglandins

leukaemia: a malignant, progressive disease of the blood-forming organs, with distorted proliferation and development of the white corpuscles (leucocytes) and their precursors

liana: a woody climbing vine

ligand: a molecule that binds to another molecule, used especially to refer to a small molecule that binds specifically to a larger molecule, e.g. an antigen binding to an antibody, or a hormone or neurotransmitter binding to a receptor

lignans: a group of natural products (dimers) derived from condensation of 2 phenylpropane units

lignins: see lignans

ligulate: possessing an elongated flattened strap-shaped structure or ligule

ligule: an elongated flattened strap-shaped structure; a membranous outgrowth on the upper surface of a grass leaf at the junction of the sheath and the blade which may be presented by a ridge or by a line of hairs; in palms it is a distal projection of the leaf sheath, often coriaceous

limb (botany): the expanded part of a tubular corolla, as distinct from the tube or throat; the lamina of a leaf or of a petal; the branch of a tree

line: used in plant breeding for a group of individuals from a common ancestry

linear: long and narrow with parallel sides

liniment: an oily liquid preparation to be used on the skin

lipolytic: pertaining to, characterized by, or causing the decomposition or splitting up of fat

lipomatosis: a condition characterized by abnormal localized, or tumour-like, accumulations of fat in the tissues

lipophilic: having an affinity to fat; dissolving in lipids

lithiasis: the formation of stones or calculi in the body

lithotriptic: pertaining to or producing lithotripsy, i.e. the destruction of a stone in the gallbladder or urinary system stone in the bladder or kidneys

lobe: any division of an organ or specially rounded division

lobed: divided, but not to the base

lochia: the vaginal discharge taking place during the first week or two after giving birth

locular: divided by internal partitions into compartments as in anthers and ovaries

locule: the cavity of an ovary or anther

loculicidal: the cavity of a pericarp dehiscent by the back, the dorsal suture

long-day plant: a plant which only reaches a certain development stage (usually flowering), or reaches it more rapidly, if there are more than a certain number of hours of light in each 24 h period

longitudinal: lengthwise

lotion: a liquid suspension or dispersion for external application to the body

lumbago: pain in the lumbar region of the back (loins); lumbar rheumatism

lupus: name originally given to localized destruction or degeneration of the skin caused by various cutaneous diseases; formerly the term was used to designate lupus vulgaris and lupus erythematosus, nowadays it is only used with modifier

lymphadenopathy: disease of the lymph nodes

lymphoma: any neoplastic disorder of the lymphoid tissue; the term is often used alone to denote malignant lymphoma

lyophilization: the creation of a stable preparation of a biological substance (e.g. blood plasma, serum) by rapid freezing and dehydration of the frozen product under high vacuum

lysosome: an intracellular body containing various hydrolytic enzymes and normally involved in the process of intracellular digestion. Injury to a lysosome is followed by release into the cell, which may damage the cell and give rise to wasting and other pathological aspects of certain diseases

lysozyme: an enzyme of the hydrolase class, occurring in saliva, tears, egg white and many animal fluids, and catalysing the breakdown of some bacterial cell walls

macerate: to reduce to a soft mass by soaking

maceration: a method of extract preparation in which the matter to be extracted is mixed with the prescribed extraction solvent, and allowed to stand in a closed container for an appropriate time; the residue is separated from the extraction solvent, and if necessary, pressed out; in the latter case, the two liquids obtained are combined; see also percolation

macrophage: any of the many forms of mononuclear phagocytes (cells capable of ingesting particulate matter) found in tissues

Malesia: the biogeographical region including Malaysia, Indonesia, the Philippines, Singapore, Brunei and Papua New Guinea

mangrove: a brackish-water coastal swamp of tropical and subtropical areas that is partly inundated by tidal flow

margin: the edge or boundary line of a body

mast cell: a connective tissue cell whose specific

physiological function remains unknown
masticatory: used for chewing (mastication)
mastitis: inflammation of the mammary gland or breast
median: belonging to the middle
medifixed: attached or fixed by the middle
melanoma: a tumour arising from the melanocytic system of the skin and other organs; when used alone, the term refers to malignant melanoma
membranous: thin and semi-transparent, like a fine membrane
meniscoid: thin and concavo-convex
menorrhagia: excessive uterine bleeding, occurring at regular intervals, with the period of flow being of usual duration; also called hypermenorrhoea
mericarp: one of the separate halves or parts of a fruit, as in *Umbelliferae*
meristem: undifferentiated tissue of the growing point whose cells are capable of dividing and developing into various organs and tissues
merous: 4-, 5- etc., with 4, 5 etc. parts or numbers of sepals, petals etc.
merozoite: a stage in the life cycle of certain sporozoan protozoa, resulting from asexual reproduction
mesocarp: the middle layer of the pericarp or fruit wall which is often fleshy or succulent
mesophyte: plant requiring medium moisture conditions; intermediate between hydrophyte and xerophyte
metabolic acidosis: a disturbance in which the acid-base status of the body shifts towards acidity as a result of the loss of bases or the retention of acids
metabolism: the sum of all the physical and chemical processes by which living organized substance is produced and maintained, and also the transformation by which energy is made available for the uses of the organism; biotransformation
metabolite: any substance produced by metabolism or by a particular metabolic process
metastasis (plural metastases): growth of abnormal cells or pathogenic microorganisms distant from the site which was primarily involved by the morbid process
metritis: inflammation of the uterus
metrorrhagia: uterine bleeding, usually of variable amount, occurring at completely irregular but frequent intervals, the period of flow sometimes being prolonged
mevalonic acid pathway: the biosynthetical pathway which leads to isoprenoids; see also isoprenoids
midrib: the main vein of a leaf which is a continuation of the petiole
mildew: a superficial, usually whitish growth on living plants produced by fungi
miliaria: a syndrome of cutaneous changes associated with the retention of sweat and the extravasation of sweat at different levels in the skin
mistletoe: any of numerous hemiparasitic plants of the family *Loranthaceae*
mitogen: a substance that induces blast transformation, the synthesis of DNA, RNA and proteins, and the proliferation of lymphocytes
mitogenic: causing or inducing mitosis or cell proliferation
mitosis: a method of indirect division of a cell, consisting of a complex of various processes, through which the two daughter nuclei normally receive identical complements of the chromosomes
module: shoot unit with determinate growth either by apical abortion or conversion of the apex to an inflorescence
molluscicide: an agent that destroys snails and other molluscs; also called molluscacide
monadelphous: of stamens, united into one group by their filaments
monochasium: a cymose inflorescence where a pattern of a single lateral branch arising below the terminal flower is repeated
monocotyledon: angiosperm having a single cotyledon or seed-leaf
monoecious: with unisexual flowers, but male and female flowers borne on the same plant
monomer: the simple unpolymerized form of a chemical compound having relatively low molecular weight
monomerous: formed of a single member, e.g. a fruit of one carpel
monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches; in bamboos used to designate a type of rhizome (see leptomorph)
monoterpenes: a subgroup of the isoprenoids, formed by coupling of 2 C_5 units
monotherapy: treatment by means of a single drug
monotypic: consisting of a single element, e.g. of a genus consisting of only one species
monsoon forest: a deciduous tropical woodland experiencing periodic drought
morphogenetic: relating to the development of normal organic form

mucilage (mucilaginous): a gelatinous substance that is similar to gum but that swells in water without dissolving and forms a slimy mass
mucolytic: an agent that destroys or dissolves mucin
mucous: pertaining to, resembling, producing, containing or covered with mucus
mucronate: ending abruptly in a short stiff point
mucronulate: diminutive of mucronate
mulch: plant or non-living materials used to cover the soil surface with the object of protecting it from the impact of rainfall, controlling weeds, temperature and evaporation
multiple sclerosis (MS): disease caused by sclerosis occurring in patches in the brain and/or spinal cord, leading to tremors, failure of coordination and various nervous and mental symptoms
musculotropic: affecting, acting upon, or attracted to muscular tissue
mutagen: an agent inducing or increasing genetic mutations by causing changes in DNA
mutagenesis: the induction of genetic mutation
mutagenic: capable of inducing genetic mutation
myalgia: pain in a muscle
mycoherbicide: a fungus deliberately used to cause disease in weeds or undesired crops
mycotoxigenic: producing or elaborating fungal toxins (mycotoxins)
mydriasis: physiological, morbid or drug-induced dilation of the pupil
myelogenic: produced in the bone marrow
myelosuppression: suppression of bone marrow activity, resulting in reduction in the number of platelets, red cells and white cells
myocardial ischemia: deficiency of blood supply to the heart muscle, due to constriction or obstruction of the coronary arteries
myocardium: the middle and thickest layer of the heart wall, composed of cardiac muscle
myorelaxant: an agent that aids in reducing muscle tension
myosis: contraction of the pupil
naphthaquinones: a subgroup of the quinones, in which the dione is conjugated to the condensed polycyclic aromatic system of naphthalene
narcotic: pertaining to or producing narcosis or stupor; an agent that in moderate doses dulls the senses, relieves pain and induces sleep, but in excessive doses may cause stupor, coma, convulsions and death
nasopharynx: the upper part of the alimentary canal continuous with the nasal passages
naturalized: introduced into a new area and established there, giving the impression of wild growth
nausea (nauseous): an uncomfortable feeling in and about the stomach associated with aversion to food and a need to vomit
necrobiosis: swelling, basophilia (abnormal accumulation of basophilic blood cells in the blood) and distortion of collagen bundles in the dermis, sometimes with obliteration of the normal structure, but short of actual necrosis
necrosis: in plants, death of a portion of tissue often characterized by a brown or black discoloration; in humans, the sum of morphological changes indicative of cell death and affecting groups of cells, parts of structures, or organs
nectar: a sweet fluid exuded from various parts of the plant (e.g. by the flower to attract pollinators)
nectary: a group of modified subepidermal cells in flowers or leaves (extrafloral) secreting nectar
nematicide: an agent that destroys nematodes
nematode: small elongated cylindrical worm-like micro-organism, free-living in soil or water, or parasitic in animals or plants
neolignans: see lignans
nephritis: inflammation of the kidney
nephroblastoma: a rapidly developing malignant mixed tumour of the kidneys, usually affecting children less than five years old; also called Wilms' tumour
nephrotic syndrome: general name for a group of diseases involving defective kidney glomeruli
nephrotoxicity: the quality of being toxic or destructive to kidney cells
nerve: in botany: a strand of strengthening and/or conducting tissue running through a leaf, which starts from the midrib and diverges or branches throughout the blade; in medicine: a cordlike structure consisting of nerve fibres, which convey impulses between the central nervous system and other body parts
neuralgia: pain radiating along the course of one or more nerves
neurasthenia: a syndrome of chronic mental and physical weakness and fatigue, which was thought to be caused by exhaustion of the nervous system
neuroblastoma: sarcoma consisting of malignant neuroblasts (immature nerve cells)
neurohypophysial: pertaining to the neurohypophysis, i.e. the posterior lobe of the pituitary gland
neurolathyrism: a morbid condition resulting from excessive ingestion of *Lathyrus* seeds
neuroleptic: term referring to effects of antipsy-

chotic drugs, such as producing a state of apathy, lack of initiative, limited range of emotion, and, in psychotic patients, normalization of psychomotor activity and reduced confusion and agitation

neuropathy: a functional disturbance or pathological change in the peripheral nervous system

neurotrophic: pertaining to neurotrophy, i.e. the nutrition and maintenance of nervous tissue

neutrophil: a granular leucocyte, having the properties of chemotaxis, adherence to immune complexes and phagocytosis

nidation: implantation of the fertilized egg in the uterus

nociception: sensation of pain

node: the point on the stem or branch at which a leaf or lateral shoot is borne

nodulation: formation of root-nodules

nodule: a small knot or rounded body, often in roots of leguminous plants, where bacteria of the genus *Rhizobium* are active in the fixation of nitrogen from the air

norlignans: see lignans

norlupinane alkaloids: a subgroup of the alkaloids

nut: a one- to many-seeded indehiscent fruit with a hard dry pericarp or shell

nutlet: a little nut

ob-: prefix, indication inverse or opposite condition (obtriangular, obcordate, etc.)

oblanceolate: reverse of lanceolate

oblate: more or less spherical but flattened at the poles

oblique: slanting; of unequal sides

oblong: longer than broad, with the sides parallel or almost so

obovate: reverse of ovate

obstructive jaundice: jaundice which is due to an impediment to the bile flow from the liver cells to the duodenum

obtuse: blunt or rounded at the end

octoploid: having eight times the basic number of chromosomes ($8n$)

odontalgic: pertaining to or characterized by toothache (odontalgia)

oedema: the presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body

oestrogen: a sex hormone produced especially in the ovaries

oliguria: reduced urine excretion

ombrophilous: rain-loving

oncogenic: giving rise to tumours (either benign or malignant) or causing tumour formation

oncolytic: pertaining to, characterized by, or causing the lysis or destruction of tumour cells

ophthalmia: severe inflammation of the eye, or of the conjunctiva or deeper structures of the eye

opposite: of leaves and branches when two are borne at the same node on opposite sides of the stem

optical activity: in organic chemistry, the property of a compound, containing an asymmetrical carbon atom, of rotating the plane of polarized light, clockwise in the case of dextrorotatory (abbreviated d-) compounds, and counterclockwise in the case of laevorotatory (abbreviated l-) compounds. In perfumery d- and l-compounds may have different odours, e.g. d- and l-limonene

optical isomerism: isomerism in which the molecular structures of the molecules are mirror-images of one another. Optical isomers have the same structural formula, but their molecules cannot be superimposed

orbicular: flat with a more or less circular outline

orchitis: inflammation of a testis

organoleptic: of or pertaining to sensations and their evaluation

orthotropic: having a more or less vertical direction of growth

osmolality: the concentration of osmotically active particles in solution

ostalgia: pain in a bone or in the bones

osteolathyrism: a skeletal disorder produced by diets containing *Lathyris* spp. or their active principles

osteosarcoma: a malignant primary tumour of bone

outcross: cross-pollination, usually by natural means, with plants differing in genetic constitution

outer bark: the periderm or rhytidome; the non-living layer of fibrous or corky tissue outside the cambium in woody plants which may be shed or retained

oval: see ovate

ovary: in plants, that part of the pistil, usually the enlarged base, which contains the ovules and eventually becomes the fruit; in humans, one of the two sexual glands in which the female reproductive cells (ova) are formed

ovate: egg-shaped in outline or in section; a flat surface which is scarcely twice as long as broad with the widest portion below the middle

ovicidal: destructive to the eggs of certain organisms

ovoid: a solid object which is egg-shaped (ovate in section)

ovule (botany): the immature seed (egg) in the ovary before fertilization
oxidation: the processes of combining a compound with oxygen, dehydrogenating, or increasing the proportion of the electro-negative part
palmate: of leaflets, leaf-lobes or veins, with the different elements arising from the same point
palsy: paralysis
palynology: a branch of science studying pollen
panacea: a universal remedy; a herb credited with remarkable healing properties
pancreas: a compound glandular organ associated with the gut in most vertebrates, and secreting the hormones insulin and glucagon from the endocrine part (the islets of Langerhans) and pancreatic juice with digestive enzymes from the exocrine part
panelling: to furnish or decorate with panels (rectangular boards)
panicle: an indeterminate branched racemose inflorescence
paniculate: resembling a panicle
pantropical: distributed throughout the tropics
papilionaceous flower: a butterfly-like, pea-like flower, with standard, wings and keel
papillate: having minute nipple-like protuberances
papilloma: a benign epithelial tumour producing finger-like or warty projections
papillomatosis: the development of multiple papillomas
papillose: covered with minute nipple-like protuberances
pappus: the various tufts of hairs on achenes or fruits; the limb of the calyx of *Compositae* florets
parasympatholytic: producing effects which resemble those of interruption of the parasympathetic nerve supply to a body part; an agent that opposes the effects of parasympathetic nerve impulses; also called anticholinergic
parasympathomimetic: producing effects resembling those of stimulation of the parasympathetic nerve supply to a part
parenchyma: in plants: ground tissue composed of thin-walled, relatively undifferentiated cells, e.g. the pith and mesophyll; in humans: the soft cellular substance of glandular and other organs, or the essential elements of an organ
paresthesia: an abnormal touch sensation, e.g. burning, itching or prickling, often without an external stimulus
parietal: placentation type, when the ovules are attached to the wall of a one-celled ovary
paripinnate: a pinnate leaf with all leaflets in pairs
parkinsonism: a group of neurological disorders marked by abnormally decreased motor function (hypokinesia), tremor and muscular rigidity
partite (parted): cleft, but not quite to the base
patent (botany): spreading out widely
pathophysiology: the physiology of disordered function
pectin: a substance yielding viscous solutions with water and, in combination with acid and sugar, forming a gel constituting the base of fruit jellies
pectinate: pinnately cleft with narrow segments set close like the teeth of a comb
pectoral: of, or pertaining to, the chest or thorax; relieving disorders of the respiratory tract; any medicine against ailments of the chest
pedicel: the stalk of an individual flower
pedicellate: furnished with a pedicel
peduncle: the stalk of an inflorescence or partial inflorescence
pedunculate: furnished with a peduncle
pellucid: translucent
peltate: of a leaf, with the stalk attached to the lower surface, not at the edge
pendent, pendulous: drooping; hanging down from its support
pentagonal: with five angles
pentamerous: having five parts in a flower-whorl
percolate: a liquid that has been submitted to percolation
percolation: a method of extract preparation in which the matter to be extracted is mixed with a portion of the prescribed extraction solvent, and allowed to stand for an appropriate time; the mass is then transferred to a percolator and the remaining extraction solvent is allowed to flow slowly, making sure that the matter to be extracted is always covered with liquid; the residue may be pressed out and the expressed fluid combined with the percolate; see also maceration
perennial: a plant living for many years and usually flowering each year
perianth: the floral leaves as a whole, including both sepals and petals if both are present
pericarp: the wall of the ripened ovary or fruit whose layers may be fused into one, or may be more or less divisible into exocarp, mesocarp and endocarp
peristalsis: the movement by which the digestive tract and other tubular organs with both longi-

tudinal and circular muscle fibres propel their contents

peritonitis: inflammation of the peritoneum, i.e. the serous membrane that lines the abdominal cavity

persistent: remaining attached; not falling off, not deciduous; applies to organs that remain in place after they have fulfilled their natural functions

petal: a member of the inner series of perianth segments (corolla) which are often brightly coloured

petiolar: borne on, or pertaining to a petiole

petiolate: having a petiole

petiole: the stalk of a leaf

petiolulate: having a petiolule

petiolule: the stalk of a leaflet

phagocytosis: endocytosis (uptake by a cell of material by invagination of its plasma membrane) of particulate material, such as microorganisms and cell fragments

pharmacokinetics: the activity or fate of drugs in the body over a period of time, including the processes of absorption, distribution, localization in tissues, biotransformation and excretion

pharmacopoeia: an authorative treatise on drugs and their preparations; a book containing a list of products used in medicine, with descriptions, chemical tests for determining identity and purity, formulas for certain mixtures of these substances, and generally also statements of average dosage

pharyngitis: inflammation of the pharynx

pharyngolaryngeal: pertaining to the pharynx (the passage between the mouth and the larynx and oesophagus) and the larynx (the structure connected to the upper part of the trachea and to the pharynx, guarding the entrance into the trachea and functioning as the organ of voice)

phenolics: phenols are compounds which have an aromatic ring with an alcoholic group attached to it

phenotype: the physical or external appearance of an organism as distinguished from its genetic constitution (genotype); a group of organisms with similar physical or external make-up

pheromone: a substance which is secreted to the outside of the body by an individual and which is perceived (e.g. by smell) by another individual of the same species, leading to a specific reaction of behaviour in the percipient

phlebitis: inflammation of a vein

phlebology: the study of the veins and their diseases

phlegm: a viscid, stringy mucous secretion, like that produced by the mucous membranes of the respiratory tract, as during a cold

phloroglucinols: derivatives of 1,3,5-trihydroxybenzene

photodermatitis: an abnormal state of the skin in which light is an important causative factor

photoperiod: the relative duration of illumination in a cycle of light and darkness, whether occurring naturally (day and night) or imposed in an artificial way

photosensitization: the development of abnormally heightened reactivity of the skin to sunlight

phototoxicity: a nonimmunological, chemically induced type of photosensitivity

phthisis: wasting away of (a part of) the body; tuberculosis, especially of the lungs

phyllody: transformation of flower parts into leaves

phylogenetic: based on natural evolutionary and genealogical relationships

phytophotodermatitis: dermatitis induced by the sequential exposure to certain plants containing psoralen-type photosensitizers and then to sunlight

phytosterins: see phytosterols

phytosterols: a group name for the widespread plant sterols sitosterol, campesterol and stigmasterol

phytotherapy: treatment by use of plants

pickle: steep or soak in a solution for preservation, conditioning etc.; a preserving, flavouring liquid; an object preserved in a pickle

pilose: hairy with rather long soft hairs

pinna (plural pinnae): a primary division or leaflet of a pinnate leaf

pinnate: arranged in pairs along each side of a common axis

pinnatifid: pinnately divided about halfway to the midrib

pinnatilobed: pinnately divided to about half-way to the midrib

pinnatipartite: pinnately parted

pinnatisect: pinnately divided down to the midrib

pioneer species: a species able to establish itself on bare ground, starting primary succession, often showing rapid growth and producing large amounts of diaspores

piperidine alkaloids: a subgroup of the alkaloids

piscicidal: poisonous to or controlling fish

pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of one or more ovaries, styles and stigmas

pistillate: a unisexual flower with pistil, but no stamens

pistillode: a sterile, often reduced pistil

pith: the soft core occurring in the structural centre of a log; the tissue, sometimes soft, in the centre of the stem of a non-woody dicotyledon

placenta: in plants, the part of the ovary to which the ovules are attached; in higher mammals, the vascular, spongy organ of interlocking maternal and foetal tissue by which the foetus is nourished in the uterus

placentation (botany): the way in which the placentae are arranged in the ovary

plagiotropic: having an oblique or horizontal direction of growth

plano-convex: flat on one side and convex on the other

platelet activating factor: a substance released by basophils and mast cells in immediate hypersensitivity reactions and macrophages and neutrophils in other inflammatory reactions. It is an extremely potent mediator of bronchoconstriction and of the platelet aggregation and release reactions

pleurisy, pleuritis: inflammation of the pleura (the membrane between thorax and lung), which may be acute or chronic

pleuritis: pleurisy

plicate: folded to and fro, like a fan

ploidy: degree or repetition of the basic number of chromosomes

plumule: the primary bud of an embryo or germinating seed

plywood: a panel material consisting of wood veneers glued together with the grains of adjacent layers arranged at right angles or at a wide angle

pneumonia: inflammation of the lungs, with the lungs becoming firm following the filling of air spaces with exudate

pod: a dry fruit composed of a single carpel and dehiscing by sutures, as in legumes; a general term for a dry dehiscent fruit

pollarding: cutting a tree back to the trunk to promote the growth of a dense head of foliage

pollen: spores or grains borne by the anthers containing the male element (gametophyte)

pollination: the transfer of pollen from the dehiscing anther to the receptive stigma

polygamous: with unisexual and bisexual flowers in the same plant

polymorphic, polymorphous: with several or various forms; variable as to habit

polyploidy: the state of having more than two full sets of homologous chromosomes

polyuria: the passage of a large volume of urine in a given period, a characteristic of diabetes

posology: the science of dosage

postphlebitic syndrome: the different complications associated with deep vein thrombosis

postsynaptic membrane: the area of the plasma membrane of postsynaptic cells (cells situated beyond or distal to a synapse), either a muscle fibre or a neuron, which is within the synapse and has areas specifically adapted for receiving neurotransmitters

poultice: a soft, moist, usually heated and sometimes medicated mass spread on cloth and applied to sores or other lesions to create moist local heat or counterirritation

prickle: a sharp, relatively stout outgrowth from the outer layers

primary immunization: first contact with an antigen

primary vegetation: the original, undisturbed plant cover

proanthocyanidins: see tannins

procumbent: lying along the ground; in wood anatomy also of ray parenchyma cells with their longest dimension in radial direction

progeny: offspring

progestational: promoting gestation

progestogen: a term applied to any substance which possesses progestational activity

promastigote: any of the bodies representing the morphological (leptomonad) stage in the life cycle of certain trypanosomatid protozoa resembling the adult form of members of the genus *Leptomonas*, with the elongate or pear-shaped cell having a central nucleus, and at the anterior end a kinetoplast and a basal body from which arises a long, slender flagellum (see also: amastigote)

prop roots: aerial roots

propagule: a part of a plant that becomes detached and grows into a new plant

prophyll: the first bract borne on the inflorescence; the bracteole at the base of an individual flower

prostaglandins: the prostaglandins, leucotriens and thromboxanes are a large group of modified C_{20} fatty acids; they are known to occur widely in animal tissues, but only in tiny amounts, and they have been found to exert a wide variety of pharmacological effects (e.g. mediators of inflammation, platelet aggregation) on humans and animals

prostrate: lying flat on the ground

protandrous: of flowers, shedding pollen before

the stigma is receptive
proteolytic: pertaining to, characterized by, or promoting proteolysis
proto-alkaloids: see alkaloids (Introduction)
protogynous, proterogynous: of flowers, the stigma is receptive before the pollen is shed; of inflorescences, the female flowers mature before the male ones
provenance: origin; a collection of pollen, seed or propagules from a certain restricted locality
proximal: in botany: the part nearest the axis (as opposed to distal); in human anatomy: relatively nearer to the central part of the body or point of origin
pruning: cutting off the superfluous branches or shoots of a plant for better shape or more fruitful growth; M-shaped pruning in bamboos: pruning a clump by removing culms so that the culm-less part looks like a letter M
pruritic: pertaining to or characterized by pruritus
pruritus: itching; any of various conditions marked by itching
pseudo-alkaloids: see alkaloids (Introduction)
pseudopetiole: a structure resembling a petiole, but not being one
pseudoraceme: raceme-like inflorescence but not a true raceme
pseudostem: an axis with the appearance of a stem but made up of other organs, e.g. leaf sheaths in *Musa* and *Curcuma*
psoriasis: a common chronic, scaly dermatosis with polygenic inheritance and a fluctuating course
psychomotor: pertaining to motor effects of cerebral or psychic activity
psychosis: a mental disorder marked by gross impairment in reality testing, reflected in delusions, hallucinations, incoherent speech or disorganized and agitated behaviour; also used in a more general sense for mental disorders in which impairment of mental functioning interferes with the capacity to meet the ordinary demands of life
psychotomimetic: pertaining to, characterized by, or producing manifestations resembling those of a psychosis,, e.g. hallucinations, distortion of perception and schizophrenia-like behaviour
psychotropic: affecting the mind
psyllid: belonging to the homopterous insect family *Psyllidae*, which includes the jumping plant lice
puberulent: covered with down or fine hairs
puberulous: minutely pubescent
pubescent: covered with soft short hairs
pulp: the soft fleshy part of the fruit; mechanically ground or chemically digested wood used in manufacturing paper and allied products
pulses: dry edible seeds of legumes
pulvinate: cushion-shaped
punctate: marked with dots or translucent glands
pungent: bearing a sharp point; causing a sharp or irritating sensation
purgative: causing evacuation of the bowels; an agent causing evacuation of the bowels, especially through stimulating peristaltic action; also called cathartic
purine alkaloids: a subgroup of the alkaloids
pustular, pustulate: with blister-like prominences
pyloric: pertaining to the pylorus (the opening between the stomach and the small intestine) or to the pyloric part of the stomach
pyrene: a nutlet or kernel; the stone of a drupe or similar fruit
pyrethrins: pyrethrins are esters of the monoterpenens pyrethic acid and chrysanthemic acid, with a cyclopentenolone bearing an unsaturated side chain; often these compounds are toxic to cold-blooded animals (e.g. fish, insects) but are harmless to man and other warm-blooded animals
pyrexia: fever; an abnormal elevation of the body temperature
pyridine alkaloids: a subgroup of the alkaloids
pyriform: resembling a pear in shape
pyrrole alkaloids: a subgroup of the alkaloids
pyrrolidine alkaloids: a subgroup of the alkaloids
pyrrolizidine alkaloids: a subgroup of the alkaloids
Q-fever: an acute rickettsial infection, caused by *Coxiella burnietti* and characterized by fever, chills, headache, myalgia, malaise and, rarely, rash
quadrangular: four-cornered or four-edged
quadrate: approximately square or cubical
quassinoids: a subgroup of the saponins; the aglycone is a modified triterpene which has lost 10 carbons, and thus could be misinterpreted as a diterpene; most quassinoid structures also include a lactone function in the molecule
quincuncial: in aestivation partially imbricated of five parts, two being exterior, two interior and the fifth having one margin exterior, the other interior
quinoline alkaloids: a subgroup of the alkaloids
quinones: a group of oxygen-containing homologues of aromatic derivatives, characterized by a diketo pattern (dione-structure)

raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards

racemic: made up of two enantiomorphic isomers (stereoisomers which have molecules which are mirror images of each other) and therefore optically inactive

racemose: raceme-like

rachilla: a diminutive or secondary axis, e.g. the branch that bears a flower or the stalk of the spikelet in grasses

rachis (plural rachides): the principal axis of an inflorescence or a compound leaf beyond the peduncle or petiole

radial: lengthwise, in a plane that passes through the pith; radiating, as from a centre (cf. tangential)

radical: arising from the root, or its crown

radicle: the first root of an embryo or germinating seed

ramentum (plural ramenta): thin, chaffy scale of the epidermis

ramification: branching

ramified: branched

ramiflorous: bearing flowers on the branches

raphe: a ridge on a seed, formed by a portion of the funicle that is adnate to the ovule, as in an anatropous ovule

rash: a temporary eruption on the skin, as in urticaria

ratoon: shoots in perennial crops such as the pineapple, left on the plants after harvest to produce the subsequent crop (ratoon crop)

ray: the radiating branch of an umbel; the outer floret of an inflorescence of the *Compositae* with straplike perianth which differs from those in the centre or disk

receptacle (botany): the flat, concave or convex part of the axis from which the parts of the flower arise

recombination: new gene combination as a result of cross-fertilization between individuals differing in genotype

recurved: bent or curved downward or backward

reduced: subnormal in size; connotes also either a failure to fulfil a normal function, or a diminution the expected number of parts in a set (of stamens, for example)

reflexed: abruptly bent or turned downward or backward

reforestation: the planting of a formerly forested area with forest trees

refrigerant: in medicine: an agent that relieves fever and thirst

regular: of a radially symmetrical flower; actinomorphic

renal calculi: kidney-stones

reniform: kidney-shaped

repand: with an undulating margin

resin: solid to soft semisolid amorphous fusible flammable substance obtained as exudate or as an extract of plants

resolvent: promoting resolution or the dissipation of a pathological growth

restenosis: recurrent stenosis, especially of a valve of the heart, after surgical correction of the primary condition

restorative: capable of restoring health, strength, consciousness; an agent having this capability

reticulate: netted, as when the smallest veins of a leaf are connected together like the meshes of a net

reticuloendothelium: the tissue of the reticuloendothelial system (a group of cells, e.g. in liver, spleen and bone marrow, which are able to take up and sequester inert particles and dyes)

retinaculum (plural retinacula): the funicle in most *Acanthaceae*, which is curved like a hook and retains the seed until maturity

retrorse: turned or directed backward or downward (opposed to antrorse)

retrovirus: any virus belonging to the family of the *Retroviridae*, a family of RNA viruses, most of which are oncogenic

retuse: with a shallow notch at a rounded apex

revolute: of leaves with the margins, rolled downwards towards the midrib

rhabdomyosarcoma: a highly malignant tumour of striated muscle

rheumatism: any of various disorders, characterized by inflammation, degeneration, or metabolic derangement of the connective tissue structures of the body, especially the joints and related structures, and accompanied by pain, stiffness or limited mobility of these parts

rhinitis: inflammation of the mucous membrane of the nose

rhizome: an underground stem which is distinguished from a root by the presence of nodes, buds, and leaves or scales

rhizosphere: the area of soil which immediately surrounds plant roots and is influenced by them

rhombic: shaped like a rhomb, an equilateral oblique-angled figure

rhomboid (botany): quadrangular, diamond-shaped with the lateral angles obtuse

ringworm: popular name for tinea, which is a term used to describe various fungal skin infections;

the name refers to the ring-shaped lesions
riparian: growing on the banks of streams or rivers
riverine forest: = riparian forest
root sucker: a shoot originating from adventitious buds on the roots
rootstock: see rhizome; a stock for grafting consisting of a root and part of the main axis
rosette: a cluster of leaves or other organs in a circular form
rosulate: collected in a rosette
rot: disintegration of tissue due to the action of invading organisms, usually bacteria or fungi; a disease so characterized
rotate: wheel-shaped; circular and flat
rotund: rounded in outline, somewhat orbicular, but a little inclined towards oblong
rubefacient: reddening the skin by causing hyperaemia (an excess of blood); an agent that reddens the skin
rudimentary: of organs, imperfectly developed and non-functional
rufous: reddish
rugose: wrinkled
ruminant: an animal that chews again what has been swallowed (e.g. sheep, cows, camels, goats)
ruminate: of endosperm, mottled in appearance, due to the infolding of a dark inner layer of the seed-coat into the paler coloured endosperm
runner: a specialized stem that develops from a leaf axil at the crown of a plant, grows horizontally along the ground, and forms a new plant at one of the nodes, usually at or near the tip (as in strawberry)
rust: a disease caused by, and a species in, the class *Urediniomycetes*, order *Uredinales*; so called because of the yellowish to orange brown colour of the spores
sagittate: shaped like an arrowhead; of a leaf base with two acute straight lobes directed downwards
saluretic: pertaining to, characterized by or promoting the excretion of sodium and chloride ions in the urine (saluresis)
sapling: a young tree of more than 1.5 m tall and with a bole of less than 10 cm in diameter
saponin: a glycoside with soap properties
saponins: the term is applied to a group of glycosides which have the ability to lower the surface tension of aqueous solutions
sapwood: the outer layers of wood adjacent to the bark which in the living tree contain living cells and reserve materials
sarcoma: any of a group of tumours usually arising from connective tissue, most of which are malignant
sarcotesta: the fleshy outer seed-coat
scaberulous: somewhat rough
scabies: a contagious dermatitis caused by the itch mite (*Sarcoptes scabiei*) that burrows under the skin and deposit eggs, causing intense itching
scabrid, scabrous: rough to the touch
scabridulous: slightly rough
scalariform: ladder-like, having markings or perforations suggestive of a ladder
scale: a thin scarious body, often a degenerate leaf or a trichome of epidermal origin
scandent: climbing
scape: a leafless floral axis or peduncle arising from the ground
scarification: scratching or making incisions, e.g. to harvest latex from *Papaver somniferum*; of seed, the cutting or softening of the wall of a hard seed to hasten germination
scarify: to treat a hard-coated seed by mechanical abrasion or with acid to facilitate germination
schistosomiasis: infection with flukes of the genus *Schistosoma*; sometimes called bilharzia
schizocarpous: in the form of a schizocarp
schizontocide: an agent that destroys schizonts, i.e. specific development stages or forms of certain protozoa
sciatica: pain in the lower back, buttocks, hips or adjacent parts of the body
scion: the plant being propagated vegetatively in grafting; the part of the plant above the graft union
scleroderma: chronic hardening and thickening of the skin, which may be a finding in several different diseases
scorpioid: circinate; coiled as to resemble a scorpion
scrofula: tuberculosis of the lymph nodes of the neck
scrub: vegetation whose growth is stunted because of lack of water coupled with strong transpiration
scurf: abnormal skin condition in which small flakes or scales become detached
scurvy: a disease resulting from a deficiency of vitamin C in the body, characterized by weakness, anaemia, spongy gums, bleeding from mucous membrane, etc.
scutelliform: platter-shaped
seborrhoea: excessive secretion of an oily substance (sebum) from certain glands of the skin (sebaceous glands), which are abundant on the scalp, face, chest, back, armpit and groin

seco-iridoids: see iridoids
secondary immunization: second contact with the same antigen
secondary vegetation: a plant cover that has been disturbed by natural causes or by man
section (botany): a taxonomic rank between the genus and the species accommodating a single or several related species
sedative: allaying activity and excitement; an agent that allays excitement
seed: the reproductive unit formed from a fertilized ovule, consisting of embryo and seed-coat, and, in some cases, also endosperm
seedling: a plant produced from seed; a juvenile plant, grown from a seed
segment: one of the divisions into which a plant organ, as a leaf or a calyx, may be cleft; the division of a palmate or costapalmate leaf
self-compatible: capable of fertilization and setting seed after self-pollination
self-fertile: capable of fertilization and setting seed after self-pollination
self-incompatible: self-sterile, i.e. not capable of producing seed without cross-pollination
self-pollination: pollination with pollen from the same flower or from other flowers of plants of the same clone
selfing: fertilization of female gametes with male gametes from the same individual
semi-: prefix, meaning half or incompletely, e.g. semi-inferior
seminal vesicle: either of the paired, sacculated pouches attached to the posterior part of the urinary bladder
senescence: advancing in age
sensu lato (s.l.): in the broad sense
sensu stricto (s.s.): in the strict sense
sepal: a member of the outer series of perianth segments
sepsis: the presence of pathogens or their toxins in the blood or other tissues
septate: divided by one or more partitions
septicidal: dehiscing along the septa of the ovary
septum (plural septa): a partition or cross-wall
seriate: serial, disposed in series of rows
sericeous: silky
serotonergic, serotoninergic: containing or activated by serotonin
serrate: toothed like a saw, with regular pointed teeth pointing forwards
sesquiterpenes: a subgroup of the isoprenoids, formed by coupling of 3 C_5 units
sessile: without a stalk
setose: set with bristles or bristle-like elements
setulose: set with small bristles or bristle-like elements
sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses
sheathing organ: any sheathing structure inserted at a node of any vegetative or reproductive axis in a gramineous plant; among the bamboos, distinguishable types of sheathing organs are rhizome sheaths, neck sheaths, culm sheaths, branch sheaths, leaf sheaths, prophylla, bracts, empty glumes, lemmas, and paleas
Shikimic acid pathway: shikimic acid is formed from the primary metabolism intermediates phosphoenolpyruvate and erythrose-4-phosphate; the shikimic acid pathway leads to a variety of secondary metabolites e.g. phenols, cinnamic acids and other phenylpropane derivatives, tannins and coumarins
shingles: an acute, infectious skin disease, characterized by neuralgia and eruptions sometimes extending half round the body like a girdle; also called herpes zoster
shoot: the ascending axis, when segmented into dissimilar members it becomes a stem; a young growing branch or twig
shrub: a woody plant which branches from the base, all branches being equivalent (see also tree)
sialagogue: an agent promoting the flow of saliva
side graft: a graft made by any of various methods in which the scion is inserted into the side of the stock, which is not beheaded until the union is complete
sigmoid, sigmoidal: doubly curved in opposite directions, like the letter s
silicosis: a pulmonary disease due to the inhalation of the dust of stone, sand or flint containing silicon dioxide
simple (botany): not compound, as in leaves with a single blade
sinuate: with a deep wavy margin
sinuous: wavy
sinusitis: inflammation of a sinus (cavity)
solitary: single stemmed, not clustering
somatic embryogenesis: the production of embryo-like structures (embryoids) from sporophytic or somatic cells of the plant, as opposed to gametophytic or germ cells (zygotic embryogenesis)
sooty mould: saprophytic fungus of the family *Capnodiaceae* or other families of the order *Dothideales*, which forms superficial, brown to black colonies on living plants, is often associated with insect secretion, and can be detrimental

to the plant
soporific: a drug or other agent that induces sleep
sore: popular term for almost any lesion of the skin or mucous membranes
spadix: a flower spike with a fleshy or thickened axis, as in aroids and some palms
spasmodic: of the nature of a spasm, i.e. a sudden, violent, involuntary contraction of a muscle or of a group of muscles
spasmolytic: checking spasms; antispasmodic
spastic: of the nature of or characterized by spasms
spat(h)ulate: spoon-shaped
spathaceous: resembling a spathe
spathe: a large bract enclosing a spadix, or two or more bracts enclosing a flower cluster
spectroscopy: examination by means of a spectroscope, i.e. an optical instrument for forming and analysing spectra emitted by substances or bodies
spermatogenesis: the process of formation of spermatozoa
spermatorrhoea: involuntary, abnormally frequent, and excessive emission of semen without copulation
spherical: globular
spicate: spike-like
spiciform: with the form of a spike
spike: a simple indeterminate inflorescence with sessile flowers along a single axis
spikelet: a secondary spike, one of the units of which the inflorescence is made in grasses, consisting of one or more florets on a thin axis, subtended by a common pair of glumes
spine (botany): a short, stiff, straight, sharp-pointed, hard structure usually arising from the wood of a stem
spinose, spinous: having spines
spiral: as though wound round an axis
splenocyte: the monocyte (mononuclear phagocytic leucocyte) characteristic of the spleen
spore: in cryptogams a cell which becomes free and capable of direct development into a new bion; the analogue of seed in phanerogams
sporozoite: the elongate, nucleated, motile infective stage of certain protozoa, like *Plasmodium* spp.
sprue: a chronic deficiency syndrome due to subnormal absorption of dietary constituents
stain: discoloration or variation from natural colour due to fungi, chemical action or other causes
stamen: one of the male reproductive organs of a flower; a unit of the androecium
staminode: an abortive or rudimentary stamen without or with an imperfect anther
standard (botany): the fifth, posterior or upper petal of a papilionaceous corolla
starch: polysaccharide made up of a long chain of glucose units joined by α-1,4 linkages, either unbranched (amylose) or branched (amylopectin) at a α-1,6 linkage, and which is the storage carbohydrate in plants, occurring as starch granules in amyloplasts, and which is hydrolysed by animals during digestion by amylases, maltase and dextrinases to glucose via dextrins and maltose
stellate: star-shaped, as of hairs with radiating branches, or of petals arranged in the form of a star
stem: the main ascending axis of a plant; in bamboos usually named culm, in other plant groups occasionally
stenocardia: angina pectoris
stenosis: narrowing or stricture of a duct or canal
stereoisomer: one of two or more isomers that have the same structure (linkages between atoms) but different configurations (spatial arrangements)
steric: of or pertaining to the 3-dimensional arrangement of the atoms in a molecule
sterile: unable to produce offspring; in plants: failing to complete fertilization and produce seed as a result of defective pollen or ovules; not producing seed capable of germination; lacking functional sexual organs (sterility)
steroid saponins: a subgroup of the saponins
steroidal alkaloids: a subgroup of the alkaloids
steroids: a group of modified triterpenes which contain a ring system of three 6-membered and one 5-membered rings
stigma: the portion of the pistil which receives the pollen
stilt root: an oblique adventitious root as in mangrove trees and similar forms
stimulant: producing a temporary increase of the functional activity or efficiency of an organism or any of its parts; an agent acting so
stipe: the stalk supporting a carpel or gynoecium
stipel: small secondary stipule at the base of a leaflet
stipitate: borne on a stipe or short stalk
stipulate: with or bearing stipules
stipule: a scale-like or leaf-like appendage at the base of a petiole
stolon: a trailing stem usually above the ground which is capable of producing roots and shoots at its nodes

stoloniferous: bearing a stolon or stolons
stoma (plural stomata): a breathing pore or aperture in the epidermis
stomachic: pertaining to the stomach; a medicine stimulating the action of the stomach
straggling: extremely divergent, spreading very far apart; irregular, bushy
strain: a group of individuals of a common origin, usually a more narrowly defined group than a cultivar
strangury: slow and painful urination
stratification: a moist, cold treatment of seed to overcome physiological dormancy
striate: marked with fine longitudinal parallel lines, as grooves or ridges
strigose: with short stiff hairs lying close along the surface
strongyloidiasis: infection with *Strongyloides stercoralis*, a roundworm which occurs widely in the tropics and subtropics and causes diarrhoea and ulceration of the small intestine
stump: seedling with trimmed roots and shoot and used as planting stock; the part of anything that remains after the main part has been removed, e.g. the part of a tree remaining attached to the root after the trunk is cut
style: the part of the pistil connecting the ovary with the stigma
styptic: astringent, tending to check bleeding through astringent properties; a remedy which is astringent and arrests bleeding
sub-: prefix, meaning somewhat or slightly (e.g. subacute), or below (e.g. subterranean) or less than, imperfectly
subfamily: a taxonomic rank between the family and the tribe denoting a part of a family
subglobose: nearly globular
subshrub: a small shrub which may have partially herbaceous stems
subspecies: a subdivision of a species, in rank between a variety and a species
subulate: awl-shaped, sharply pointed
succulent: juicy, fleshy
sucker: a shoot, usually originating from adventitious buds on the roots or basal stem parts, which does not fit in the architectural model, but is capable of repeating the model
sudorific: causing or promoting the flow of sweat; an agent causing sweating
suffrutescent: obscurely shrubby
superior: of an ovary, with the perianth inserted below or around its base, the ovary being attached at its base only
supraventricular: above the ventricles (lower heart chambers), especially applied to rhythms originating from centres proximal to the ventricles
suture: the line of junction of two carpels; the line or mark of splitting open
syconium: a multiple, hollow fruit, like a fig
symbiosis: the intimate living together of two dissimilar organisms in a mutually beneficial relationship
sympatholytic: opposing the effects of impulses conveyed by adrenergic postganglionic fibres of the sympathetic nervous system
sympathomimetic: mimicking the effects of impulses conveyed by adrenergic postganglionic fibres of the sympathetic nervous system
sympatrically: occupying an area together with another species
sympodial: of a stem in which the growing point either terminates in an inflorescence or dies, growth being continued by a new lateral growing point; in bamboos also used to designate the branching habit of a rhizome (see pachymorph)
synandrium: the cohesion of the anthers of each male flower, e.g. in certain *Araceae*
synapse: the site of functional apposition between neurons or between neurons and effector organs, at which an impulse is transmitted, usually by a chemical neurotransmitter
syncarp: a multiple or fleshy aggregate fruit, including fruit produced from a more or less entire inflorescence (as in *Artocarpus*, *Ananas*, *Morus*)
synergistic effect: the phenomenon of a mutually cooperating activity of substances, which in a mixture produce a greater effect than when taken alone
syphilis: a disease usually communicated by sexual contact, or via the blood or bite of an infected person, caused by a spirochete (*Treponema pallidum*) and characterized by a clinical course in 3 stages continued over many years
tachycardia: excessive rapidity of the heartbeat, usually applied to a pulse rate of more than 100 in an adult
tachypnea: excessive rapidity of respiration
taeniacide: an agent that destroys tapeworms
taeniafuge: an agent expelling tapeworms
tannins: a large group of plant-derived phenolic compounds
taproot: the primary descending root, forming a direct continuation of the radicle
taxon (plural taxa): a term applied to any taxonomic unit irrespective of its classification level, e.g. variety, species, genus, etc.
taxonomy: the study of principles and practice of

classifying living organisms (systematics)

tendril: a thread-like climbing organ formed from the whole or part of a stem, leaf or petiole

tepal: a segment of a perianth, applied when no distinction between sepals and petals can be made

teratogenic: tending to produce anomalies of formation or development

teratological: pertaining to teratology, i.e. that division of embryology and pathology which deals with abnormal development and congenital anomalies

terete: cylindrical; circular in transverse section

terminal: placed at the end or apex; a termination, end or extremity

termite: ant-like organism of the order *Isoptera* damaging wood by characteristic irregular honeycombing or wide channels with dry bore-dust or dust cemented together

ternate: in threes

terpenes: see isoprenoids

terpenoids: see isoprenoids

terrestrial: on or in the ground

tertiary venation: generally the collection of the smallest veins of a leaf blade

testa: the outer coat of the seed

tetanic spasm: physiological tetanus; a state of sustained muscular contraction without periods of relaxation

tetanus: an acute, often fatal, infectious disease characterized by muscular contractions and abnormal reflexes, and caused by a toxin produced by *Clostridium tetani*, a bacillus which is usually introduced through a wound

tetraploid: having four times ($4n$) the basic number of chromosomes or twice the diploid number ($2n$)

theca (plural thecae): a spore- or pollen-case

theileriasis: a group of diseases due to protozoa of the genus *Theileria*, which cause an infection with fever

thinning: removing trees, stems or plants from immature or mature stands in order to stimulate the growth of the remaining trees, stems or plants

thorn: a woody sharp-pointed structure formed from a modified branch

throat (botany): of a corolla, the orifice of a gamopetalous corolla

thrombocyte: a blood platelet

thrombocytopaenia: a decrease in the number of blood platelets

thrombosis: the formation, development or presence of an aggregation of blood factors (thrombus), often causing vascular obstruction

thrombotic: pertaining to or affected with thrombosis

thromboxanes: see prostaglandins

thrombus: an aggregation of blood factors, frequently causing vascular obstruction at the point of its formation

thrush: infection of the mucous membrane of the mouth with a fungus of the genus *Candida*, especially *C. albicans*, and characterized by the formation of creamy, white, somewhat elevated lesions

thyrse (thyrsus): a compound inflorescence composed of a panicle (indeterminate axis) with the secondary and ultimate axes cymose (determinate)

thyrsoid: like a thyrse

tiller: a shoot from the axils of the lower leaves, e.g. in some grasses and palms (making such shoots: tillering)

timber: any wood other than fuelwood

tincture: an alcoholic or hydroalcoholic solution of some principle used in medicine

tinnitus: a noise in the ears, like ringing, buzzing, roaring or clicking

tissue culture: a body of tissue growing in a culture medium outside the organism

tomentose: densely covered with short soft hairs

tomentulose: slightly tomentose

tongue graft: a graft in which a tongue cut on the scion is fitted into a slit cut slopingly in the stock

tonic: restoring or producing the normal tone (degree of vigour and tension) of tissue or organs; characterized by continuous tension (e.g. tonic spasm); medicinal preparation believed to have the power of restoring normal tone to tissue or organs

tonsillitis: inflammation of the tonsils

topical: pertaining to a particular surface area, as a topical anti-infective applied to a certain area of the skin and affecting only the area to which it is applied

tortuous: bent or twisted in different directions

toxigenic, toxicogenic: producing or elaborating toxins

trailing: prostrate, but not rooting

tranquillizer: a drug with a calming, soothing effect

transgenic: pertaining to the experimental splicing of a segment of DNA from one genome to DNA of a different genome

transverse: straight across; of tertiary veins, connecting the secondary veins, not necessarily in a

perpendicular way
trapezoid: like a trapezium, a figure of four unequal sides
trauma: a wound or injury, whether physical or psychic
tree: a perennial woody plant with a single evident trunk (see also shrub)
trematodiasis: infection with trematodes, i.e. parasitic animal organisms belonging to the *Trematoda*, a class of *Platyhelminthes* including the flukes
tribe (plural tribae): a taxonomic rank between the family and the genus
trifid: cleft in three parts
trigonous: three-angled, with plane faces
triploid: having three times the basic number of chromosomes, usually written $3n$
triquetrous: three-edged, with three salient angles
tristichous: in 3 vertical ranks
triterpene saponins: a subgroup of the saponins
triterpenes: a subgroup of the isoprenoids, formed by coupling of 6 C_5 units
tropane alkaloids: a subgroup of the alkaloids
trophozoite: the active, motile, feeding stage of a protozoan organism, as contrasted with the non-motile encysted stage
truncate: cut off more or less squarely at the end
trunk: the main stem of a tree apart from its limbs and roots
trypanosomiasis: the state of being infected with protozoa of the genus *Trypanosoma* (trypanosomes), which destroy the red corpuscles and cause serious and even fatal diseases, as the sleeping sickness
tuber: the swollen portion of an underground stem or root which acts as a storage organ and propagule; it is usually of one year's duration, those of successive years not arising directly from the old ones nor bearing any constant relation to them
tubercle: a small tuber-like excrescence
tuberculate: covered with warty protuberances
tuberculosis: any of the diseases in man and animals caused by *Mycobacterium* spp, characterized by the formation of lesions (tubercles) and necrosis in the tissue of the lung or other organs and having a tendency to great chronicity
tuberculostatic: inhibiting the growth of *Mycobacterium tuberculosis*, the causative agent of tuberculosis
tuberous: producing tubers or resembling a tuber
tufted: growing in tufts (caespitose)
tumorigenic: giving rise to either benign or malignant tumours
tumour necrosis factor: a substance (lymphokine) produced by macrophages, capable of causing in vivo haemorrhagic necrosis of certain tumour cells, but not affecting normal cells
tunic: the coat of a bulb
turbinate: top-shaped
turgid: swollen, but not with air
twining: winding spirally
tympanites: swelling of the abdomen, due to the accumulation of gas or air in the intestine or in the peritoneal cavity
tympanitis: inflammation of the lining membrane of the tympanum (middle ear)
ulcer: an open sore on an external or internal body surface, usually accompanied by disintegration of tissue and formation of pus
umbel: an indeterminate, often flat-topped inflorescence whose divergent peduncles (rays) and pedicels arise from a common point; in a compound umbel each ray itself bears an umbellule (small umbel)
umbelliform: umbrella-shaped
umbellule: diminutive of umbel
unarmed: devoid of thorns, spines or prickles
undershrub: any low shrub; partially herbaceous shrub, the ends of the branches perishing during the winter
undulate: wavy, said for instance of a leaf margin if the waves run in a plane at right angles to the plane of the leaf blade
unifoliolate: with one leaflet only, but in origin a compound leaf
unilateral: one-sided
unilocular: one-celled
uniparous: bearing one, as a cyme giving forth one axis at each branching
unisexual: of one sex, having stamens or pistils only
urceolate: urn-shaped
urticaria: a vascular reaction, acute or chronic, which can have various causes and is characterized by the development of weals on the skin
uterotonic: giving muscular tone to the uterus
utricle: a small bladdery pericarp
uveitis: inflammation of the uvea, the vascular middle coat of the eye
vagotomy: interruption of the impulses carried by the vagus nerve or nerves
valvate: of perianth segments, with their edges in contact, but not overlapping in the bud
valve: one of the parts produced by a dehiscing capsule
variegated: irregularly coloured in patches, blotched

variety: a botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar

vas deferens: the excretory duct of the testis, which unites with the excretory duct of the seminal vesicle to form the ejaculatory duct; also called ductus deferens (deferent duct)

vasoconstriction: diminution of the calibre of vessels, especially of arterioles

vasodilatation: a state of increased calibre of the blood vessels

vasodilation: dilation of a vessel, especially dilation of arterioles leading to increased blood flow to a part

vasomotor centres: centres in the central nervous system that regulate the calibre of the blood vessels and increase or decrease the heart rate and contractility

vein (botany): a strand of vascular tissue in a flat organ, such as a leaf

velutinous: see velvety

velvety: with a coating of fine soft hairs; the same as tomentose but denser so that the surface resembles (and feels like) velvet

venation (botany): the arrangement of the veins in a leaf

venereal: pertaining or related to or transmitted by sexual contact

venereal disease: any of a diverse group of contagious diseases (as gonorrhoea or syphilis) that are typically transmitted by sexual contact

venous: of or pertaining to the veins

ventral: in botany: facing the central axis (adaxial), opposed to dorsal (abaxial); in human anatomy: pertaining to the abdomen, or denoting a position more toward the belly surface than some reference object

ventricose: with a swelling or inflation on one side

ventricular: pertaining to a ventricle, i.e. a small cavity, such as one of the several cavities of the brain, or one of the lower chambers of the heart

vermiculite: lightweight highly water-absorbent material, usually resulting from expansion of the granules of mica at high temperature

vermifuge: an agent expelling worms or intestinal animal parasites; an anthelminthic

verrucose: warty

verruculose: very warty, much covered with warts

verticillaster: a false whorl, composed of a pair of opposed cymes, as in *Labiatae*

verticillate: in a whorl with several elements arising at the same node

vertigo: an illusory sense that the surroundings or one's own body are revolving

vesicant: causing blisters; an agent that induces blistering

vesicle (botany): a small bladder or cavity

vesicular arbuscular mycorrhiza: a common endomycorrhizal association characterized by 2 types of fungal structures: small structures within root cells known as arbuscules, and storage organs between root cells known as vesicles

vesicular stomatitis: a vesicular eruption caused by a virus and affecting pigs, cattle and horses

vestigial: small and imperfectly developed

vexillum: see standard

viability: ability to live, grow and develop

villose (villous): with long weak hairs

vine: a plant having a stem that is too slender to hold itself erect and therefore supports itself by climbing over an object; the stem itself

viricidal: capable of neutralizing or destroying a virus

virion: complete, individual virus particle, found extracelluarly and capable of surviving in crystalline form and infecting a living cell

vitiligo: a chronic, usually progressive, pigmentary anomaly of the skin, manifested by depigmented white patches that may be surrounded by a hyperpigmented border

volatile: a volatile substance is one that evaporates at room temperature. It is an essential property of odorous materials

volatile oils: see essential oils

vulnerary: pertaining to wounds or the healing of wounds; an agent promoting the healing of wounds

wart (in medicine): a small, usually hard and nonmalignant, excrescence on the skin

warty: covered with firm roundish excrescences

waterlogged: flooded with water, generally for a period of at least a few weeks

whipworm: *Trichuris trichiura*, an intestinal nematode parasite

whorl: arrangement with more than two organs of the same kind arising at the same level

wilt: loss of turgidity, usually in leaves, typically caused by pathogens which colonize the vascular system

wing: any membraneous expansion attached to an organ; a lateral petal of a papilionaceous corolla

withdrawal syndrome: a substance-specific organic mental syndrome that follows the cessation of use or reduction of intake of a psychoactive substance that had been regularly used to induce a state of intoxication

wood: the hard, compact, fibrous substance between pith and bark *woolly*: clothed with long and tortuous or matted hairs

wormicidal: destroying worms

xenobiotic: a chemical foreign to the biological system

xerophthalmia: dryness of the conjunctiva and cornea (the transparent anterior part of the eyeball) due to vitamin A deficiency

xerophytic: relating to a plant structurally adapted for life and growth with a limited water supply

xerosis: abnormal dryness, as of the eye, mouth or skin

xerostomia: dryness of the mouth due to malfunction of salivary glands

yaws: an infectious, tropical disease caused by a spirochete (*Treponema pertenue*), usually affecting children under 15, and marked by skin elevations (papules) and papilloma, with later manifestations including deformation of skin, bone and joints (also called framboesia)

zooflagellate: an animal-like flagellate protozoan of the class *Zoomastigophorea*

zygomorphic: irregular and divisible into equal halves in one plane only

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Arcangelisia flava: Westphal, E. & Jansen, P.C.M. (Editors): Plant Resources of South-East Asia. A selection. Pudoc, Wageningen, The Netherlands. p. 49 (intertwining flowering and fruiting stems, closed male flower, opened male flower, part of woody stem, detail of stem in cross and longitudinal section).

Aristolochia tagala: Beijing Botanical Research Institute, 1972. Iconographia Cormophytorum Sinicorum [Line drawings of Chinese vascular plants]. Vol. 1. Beijing, China. p. 548, pl. 1096 (flowering stem, fruiting stem); Phuphathanaphong, L., 1987. Aristolochiaceae. In: Smitinand, T. & Larsen, K. (Editors): Flora of Thailand. Vol. 5, Part 1. The Forest Herbarium, Royal Forest Department, Bangkok, Thailand. p. 16, fig. 10 (dehisced fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Artemisia annua: Hess, H.E., Landolt, E. & Hirzel, R., 1972. Flora der Schweiz un angrenzender Gebiete [Flora of Switserland and neighbouring regions]. Band 3. Birkhäuser Verlag, Basel & Stuttgart, Switserland & Germany. p. 580 (flowering stem, stem base and roots); Hegi, G., 1929. Illustrierte Flora von Mittel Europa. VI. Band, 2. Hälfte [Illustrated flora of Central Europe, 6st Volume, 2nd half]. J.F. Lehmanns Verlag, München, Germany. p. 630, fig. 341 (flower head). Redrawn and adapted by Achmad Satiri Nurhaman.

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Bidens pilosa: Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 65, fig. 4.18 (flowering and fruiting plant, flowering head, ray floret, disk floret, achenes).

Blumea lacera: Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 67, fig. 4.19 (plant habit, capitulum, marginal flower, disk flower, achene with pappus removed). Redrawn and adapted by Iskak Syamsudin.

Brucea javanica: Nooteboom, H.P., 1962. Simaroubaceae. In: van Steenis, C.G.G.J. (General editor): Flora Malesiana. Ser. I. Vol. 6. Wolters-Noordhoff Publishing, Groningen, The Netherlands. p. 210, fig. 12 (twig with flowers and fruits, female flower, male flower, fruit). Redrawn and adapted by Iskak Syamsudin.

Bryophyllum pinnatum: Liu, T.-S. & Chung, N.-J., 1993. Bryophyllum Salisb. In: Huang, T.-C. (Editor in Chief): Flora of Taiwan. 2nd edition. Vol. 3. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan, Republic of China. p. 12, pl. 5 (upper part of stem); Wickens, G.E., 1987. Crassulaceae. In: Polhill, R.M. (Editor): Flora of Tropical East Africa. A.A. Balkema, Rotterdam, Boston. p. 29, fig. 5 (inflorescence, flower in longitudinal section). Redrawn and adapted by Achmad Satiri Nurhaman.

Cannabis sativa: Bruneton, J., 1995. Pharmacognosy, phytochemistry, medicinal plants. Technique & Documentation. Lavoisier, Paris, France. p. 372 (branch of female plant); Mansfeld, R., 1986. Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen) [Register of agricultural and horticultural plants (excluding ornamentals)]. Vol. 1. 2nd edition by Schultze-Motel. J. Springer Verlag, Berlin, Germany. p. 88, 89, fig. 12A, 12B (part of branch with female inflorescence, female flower, part of branch of male plant, male flower); Backer, C.A., 1951. Cannabinaceae. In: van Steenis, C.G.G.J. (General editor): Flora Malesiana. Ser. I. Vol. 4. Noordhoff-Kolff, Djakarta, Indonesia. p. 222, fig. 1 (fruit). Redrawn and adapted by Iskak Syamsudin.

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Carmona retusa: Matthew, K.M., 1988. Further illustrations on the Flora of Tamilnadu Carnatic. The Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, India. p. 383, pl. 383 (flower, 4-merous corolla, 5-merous corolla); Riedl, H., 1997. Boraginaceae. In: Kalkman, C. et al. (Editors): Flora Malesiana. Series I. Vol. 13. Rijksherbarium/Hortus Botanicus, Leiden, The Netherlands. p. 66, fig. 2 (fruiting twig, fruit). Redrawn and adapted by Iskak Syamsudin.

Cassia fistula: Brown, W.H., 1954. Useful plants of the Philippines. Reprint of the 1941–1943 edition. Vol. 2. Technical Bulletin No 10. Department of Agriculture and Natural Resources, Bureau of Printing, Manila, The Philippines. p. 103, fig. 42 (section of pod showing seeds); Larsen, K., Larsen, S.S. & Vidal, J.E., 1980. Flore du Cambodge, du Laos et du Viêtnam. Vol. 18. Légumineuses– Caesalpinioïdées [Flora of Cambodia, Laos and Vietnam. Vol. 18. Leguminosae–Caesalpinioideae]. Muséum National d'Histoire Naturelle, Paris, France. p. 81, fig. 14 (flower); Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 44, fig. 9 (branch with inflorescence, mature pod). Redrawn and adapted by Achmad Satiri Nurhaman.

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Centella asiatica: Backer, C.A. & van Slooten, D.F., 1924. Geïllustreerd handboek der Javaansche theeonkruiden en hunne beteekenis voor de cultuur [Illustrated handbook of the weeds of Javanese tea plantations and their significance for tea growing]. Ruygrok, Batavia, Indonesia. pl. 185 (plant habit); Townsend, C.C., 1989. Umbelliferae. In: Polhill, R.M. (Editor): Flora of Tropical East Africa. A.A. Balkema, Rotterdam, Brookfield, p. 16, fig. 3 (leaf, stem base with young leaf, flowers and fruits, fruit); Kao, M.-T., 1993. Umbelliferae. In: Huang, T.-C. (Editor in Chief): Flora of Taiwan. 2nd edition. Vol. 3. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan, Republic of China. p. 1018, pl. 507 (inflorescence, flower). Redrawn and adapted by Iskak Syamsudin.

Chenopodium ambrosioides: Hitchcock, C.L., Cronquist, A., Ownbey, M. & Thompson, J.W., 1964. Vascular plants of the Pacific Northwest. Part 2. University of Washington Press, Seattle, United States. p. 197 (flowering plant, fruit enclosed by perianth); Ulbrich, E., 1934. Chenopidiaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien [The natural plant families]. Second edition, Band 16C. Verlag von Wilhelm Engelmann, Leizig, Germany. p. 481, fig. 183 (bisexual flower, female flower, ovary with glands, fruit after removal of perianth). Redrawn and adapted by Achmad Satiri Nurhaman.

Cinchona officinalis: Moens, J.C.B., 1882. De kinacultuur in Azië [The kina culture in Asia]. Ernst & Co., Batavia, Indonesia. tab. 1 (tree habit); Van den Abeele, M. & Vandenput, R., 1951. De voornaamste cultures van Belgisch-Congo [The most important cultures of Belgian Congo]. 2nd edition. Ministerie van Koloniën, Directie voor Landbouw, Veeteelt en Kolonisatie, Brussel, Belgium. p. 445, fig. 235 (flowering twig); Purseglove, J.W., 1968. Tropical crops. Dicotyledons 2. Longmans, London & Harlow, United Kingdom. p. 455, fig. 72 (flowers in longitudinal section showing heterodistyly); Schumann, K., 1891. Rubiaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien. Band 4(4) [The natural plant families. Volume 4(4)]. Verlag von Wilhelm Engelmann, Leizig, Germany. p. 41, fig. 13C (fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Cissampelos pareira: Troupin, G., 1956. Menispermaceae. In: Turrill, W.B. & Milne-Redhead, E. (Editors): Flora of Tropical East Africa. Crown Agents for Oversea Governments and Administrations, London, United Kingdom. p. 24, fig. 6 (flowering stems of male plant, flowering stem of female plant, male flower, sectioned male flower, part of female inflorescence, endocarp). Redrawn and adapted by Iskak Syamsudin.

Curculigo orchioides: Nasir, E., 1980. Amaryllidaceae. In: Nasir, E. & Ali, S.I. (Editors): Flora of Pakistan. No 134. National Herbarium, Pakistan Agricultural Research Council, Islamabad, Pakistan. p. 4, fig. 1 (flowering plant, flower); Bhaskaran, K. & Padmanabhan, D., 1983. Leaf development in Curculigo orchioides. Phytomorphology 31. p. 3, fig. 1 (rhizome); Matthew, K.M., 1982. Illustrations on the Flora of Tamilnadu Carnatic. The Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, India. pl. 733 (fruit, seed). Redrawn and adapted by Achmad Satiri Nurhaman.

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Cyclea barbata: Sastrapradja, S. (Editor), 1978. Tumbuhan obat [Medicinal plants]. Lembaga Biologi Nasional–LIPI, Bogor, Indonesia. p. 16 (leafy stem); Forman, L.L., 1991. Menispermaceae. In: Smitinand, T. & Larsen, K. (Editors): Flora of Thailand. Vol. 5, Part 3. The Forest Herbarium, Royal Forest Department, Bangkok, Thailand. p. 329, fig. 73K–O (stem with leaf and male inflorescence, male flower, male flower with calyx removed, fruit, endocarp). Redrawn and adapted by Iskak Syamsudin.

Cyperus brevifolius: Backer, C.A. & van Slooten, D.F., 1924. Geïllustreerd handboek der Javaansche theeonkruiden en hunne beteekenis voor de cultuur [Illustrated handbook of the weeds of Javanese tea plantations and their significance for tea growing]. Ruygrok, Batavia, Indonesia.

pl. 83 (plant habit); Kern, J.H., 1952. Notes on Malaysian Cyperaceae. Reinwardtia 2(1). p. 127, fig. 14 (inflorescence enclosed by involucral bracts, spikelet, nuts). Redrawn and adapted by Achmad Satiri Nurhaman.

Cyperus rotundus: Mercado, B.L., 1979. A monograph on Cyperus rotundus L. Biotrop Bulletin No 15. Biotrop, SEAMEO Regional Center for Tropical Biology, Bogor, Indonesia. p. 15 & 16, fig. 5 & 6 (young plant with rhizomes and tubers, tubers); Kern, J.H., 1974. Cyperaceae. In: van Steenis, C.G.G.J. (General editor): Flora Malesiana. Ser. I. Vol. 7. Noordhoff International Publishing, Leiden, The Netherlands. p. 594, fig. 49 (flowering plant). Redrawn and adapted by Achmad Satiri Nurhaman.

Datura metel: Backer, C.A. & van Steenis, C.G.G.J., 1973. Atlas of 220 weeds of sugar-cane fields in Java. Greshoff's Rumphius Fund, Amsterdam, The Netherlands. pl. 567 (flowering stem and young fruit); Mansfeld, R., 1986. Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen) [Register of agricultural and horticultural plants (excluding ornamentals)]. Vol. 3. 2nd edition by Schultze-Motel. J. Springer Verlag, Berlin, Germany. p. 1217, fig. 177 (fruit, seeds). Redrawn and adapted by Iskak Syamsudin.

Derris elliptica: Spoon, W. & Toxopeus, H.J., 1950. Derriswortel [Derris root]. In: van Hall, C.J.J. & van de Koppel, C. (Editors): De landbouw in de Indische archipel [Agriculture in the East Indian archipelago]. Vol. 3. W. v. Hoeve, The Hague, The Netherlands. p. 596, fig. 10 (root system); Greshoff, M., 1894. Schetsen van nuttige Indische planten [Sketches of useful Indonesian plants]. Serie 1. Extra Bulletin van het Koloniaal Museum. J.H. de Bussy, Amsterdam, The Netherlands. p. 99, fig. 25 (leaf, inflorescences and young leaves); Geesink, R., 1984. Scala Millettiearum. A survey of the genera of the tribe Millettieae (Legum.–Pap.) with methodological considerations. Leiden Botanical Series 8. E.J. Brill / Leiden University Press, Leiden, The Netherlands. p. 67, pl. V, fig. 39 (pod). Redrawn and adapted by Iskak Syamsudin.

Desmodium gangeticum: Backer, C.A., 1938. Onkruidflora der Javasche suikerrietgronden. Handboek ten dienste van de suikerriet cultuur en de rietsuiker fabricage op Java. Deel 7(11–12) (atlas) [Weed flora of Javanese sugarcane fields. Handbook for the cultivation of sugar- cane and manufacturing of cane-sugar in Java. Vol. 7(11–12) (atlas)]. Vereniging het Proefstation voor de Java-Suikerindustrie, Pasuruan. pl. 328 (plant habit); Matthew, K.M., 1988. Further illustrations on the Flora of Tamilnadu Carnatic. The Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, India. p. 155, pl. 155 (branch with infructescence, flower); Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 395, fig. 93 (mature pod). Redrawn and adapted by Achmad Satiri Nurhaman.

Desmodium styracifolium: Dy Phon, P., Ohashi, H. & Vidal, J.E., 1994. Flore du Cambodge du Laos et du Viêtnam. Vol. 27. Légumineuses (Fabaceae) Papilionoidea – Desmodiées. [Flora of Cambodia, Laos and Vietnam. Vol. 27. Leguminosae (Fabaceae) Papilionoideae – Desmodieae]. Muséum National d'Histoire Naturelle, Paris, France. p. 91, pl. 19 (flowering stem, young inflorescence, flowerbud, young pod, mature pod). Redrawn and adapted by Achmad Satiri Nurhaman.

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Erythroxylum novogranatense: Schulz, O.E., 1907. Erythroxylaceae. In: Engler, A. (Editor): Das Pflanzenreich [The plant kingdom]. IV, 134. Wilhelm Engelmann, Leipzig, Germany. p. 86, fig. 18 (flowering twig, short-styled flower with petals removed, long-styled flower with petals removed, petal showing 3-lobed ligule-like appendage, fresh fruit, dried fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Euphorbia heterophylla: Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 289, fig. 4.129 (plant habit, seed); Backer, C.A., 1939. Onkruidflora

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Eurycoma longifolia: Greshoff, M., 1894. Schetsen nuttige Indische planten [Sketches of useful Indonesian plants]. Serie 1. Extra Bulletin van het Koloniaal Museum. J.H. De Bussy, Amsterdam, The Netherlands. pl. 23 (tree habit, detached leaf and inflorescence); Engler, A., 1931. Simaroubaceae. In: Engler, A. & Prantl, K. (Editors): Die natürliche Pflanzenfamilien [The natural plant families]. Second edition, Band 19a. Wilhelm Engelmann, Leipzig. p. 381, fig. 175 (male flower, female flower, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Fatoua villosa: Koorders, S.H., 1913. Exkursionsflora von Java [Excursion flora of Java]. Vol. 4. Gustav Fischer, Jena, Germany. p. 464, fig. 743 (female flower); Liao, J.-C., 1996. Moraceae. In: Huang, T.-C. (Editor in Chief): Flora of Taiwan. 2nd edition. Vol. 2. Editorial Committee of the Flora of Taiwan, Taipei, Taiwan, Republic of China. p. 144, pl. 70 (flowering stem, male flower, fruits with perianth removed). Redrawn and adapted by Achmad Satiri Nurhaman.

Ficus benghalensis: Ghafoor, A., 1985. Moraceae. In: Nasir, E. & Ali, S.I. (Editors): Flora of Pakistan. No 171. National Herbarium (Stewart Collection), Pakistan Agricultural Research Council, Islamabad, Pakistan. p. 25, fig. 4 (fruiting twig, halfed fig, female flower, male flower). Redrawn and adapted by Achmad Satiri Nurhaman.

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Gloriosa superba: Matthew, K.M., 1982. Illustrations on the Flora of Tamilnadu Carnatic. The Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, India. p. 743, pl. 743 (flowering stem); Saralamp, P. et al. (Editors), 1996. Medicinal plants in the Sri Ruckhachati Garden. 2nd edition. Siambooks and Publications Co., Bangkok, Thailand. p. 115 (tubers); Watt, J.M. & Breyer-Brandwijk, M.G., 1962. The medicinal and poisonous plants of southern and eastern Africa. Second edition. E. & S. Livingstone Ltd., Edinburgh & London, United Kingdom. p. 701, fig. 193 (fruit). Redrawn and adapted by Iskak Syamsudin.

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Hydnocarpus alcalae: Brown, W.H., 1954. Useful plants of the Philippines. Reprint of the 1941–1943 edition. Vol. 2. Technical Bulletin 10. Department of Agriculture and Natural Resources. Bureau of Printing, Manila, The Philippines. p. 505, fig. 237 (leafy twig, male flower, female flower, fruits, fruit in longitudinal section). Redrawn and adapted by Achmad Satiri Nurhaman.

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Republic of China. p. 706, pl. 332 (plant habit, detail of stem, leaf, dehisced capsule, ovary in cross-section); Matthew, K.M., 1982. Illustrations on the Flora of Tamilnadu Carnatic. The Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, India. p. 54, pl. 54 (flower). Redrawn and adapted by Achmad Satiri Nurhaman.

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Momordica charantia: Siemonsma, J.S. & Kasem

Piluek (Editors), 1993. Plant Resources of South-East Asia No 8. Vegetables. Pudoc Scientific Publishers, Wageningen, The Netherlands. p. 208 (leafy shoot, male flower in longitudinal section, female flower in longitudinal section, fruit); Wight, R., 1840–1843. Icones plantarum Indiae orientalis [Drawings of East Indian plants]. Vol. 2(2). J.B. Pharoah, Madras, India. t. 504 (male flower in cross section with petals removed). Redrawn and adapted by P. Verheij-Hayes.

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Index of compounds

Index of pharmaceutical terms

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Index of vernacular plant names

Page numbers printed in bold refer to main treatment. For transcriptions of Vietnamese names, see at the end of the index.

Transcriptions of Vietnamese characters

[aa] = â	[ar] = ả	[ax] = ã	[ej] = ẹ	[oo] = ô	[ow] = ơ	[uj] = ụ	[uwx] = ữ
[aaf] = ầ	[as] = á	[ee] = ê	[er] = ẻ	[oof] = ồ	[owf] = ờ	[ur] = ủ	[ux] = ũ
[aaj] = ậ	[aw] = ă	[eef] = ề	[es] = é	[ooj] = ộ	[owj] = ợ	[us] = ú	
[aar] = ẩ	[awf] = ằ	[eej] = ệ	[ex] = ẽ	[oor] = ổ	[owr] = ở	[uw] = ư	
[aas] = ấ	[awj] = ặ	[eer] = ể	[if] = ì	[oos] = ố	[ows] = ớ	[uwf] = ừ	
[aax] = ẫ	[awr] = ẳ	[ees] = ế	[is] = í	[oox] = ỗ	[owx] = ỡ	[uwj] = ự	
[af] = à	[aws] = ắ	[eex] = ễ	[of] = ò	[or] = ỏ	[ox] = õ	[uwr] = ử	
[aj] = ạ	[awx] = ẵ	[ef] = è	[oj] = ọ	[os] = ó	[uf] = ù	[uws] = ứ	

The Prosea Foundation
(Plant Resources of South-East Asia)

Name, location, legal status and structure

- Prosea is a Foundation under Indonesian law, with an international charter, domiciled in Bogor. It is an autonomous, non-profit, international agency, governed by a Board of Trustees. It seeks linkage with existing regional and international organizations;
- Prosea is an international programme focusing on the documentation of information on plant resources of South-East Asia;
- Prosea consists of a Network Office in Bogor (Indonesia) coordinating 6 Country Offices in South-East Asia, and a Publication Office in Wageningen (the Netherlands).

Participating institutions

- Forest Research Institute of Malaysia (FRIM), Karung Berkunci 201, Jalan FRIM, Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Sasana Widya Sarwono, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology and Biological Resources (IEBR), Nghia Do, Cau Giay, Hanoi, Vietnam;
- Papua New Guinea University of Technology (UNITECH), Private Mail Bag, Lae 411, Papua New Guinea;
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific and Technological Research (TISTR), 196 Phahonyothin Road, Chatuchak, Bangkok 10900, Thailand;
- Wageningen Agricultural University (WAU), Costerweg 50, 6701 BH Wageningen, the Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and dissemination of reports and the research results.

Implementation

The programme period has been tentatively divided into 3 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–2000): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.

Documentation

A documentation system has been developed for information storage and retrieval called Prosea Data Bank. It consists of 7 data bases:
- BASELIST: primarily a checklist of more than 6200 plant species;
- CATALOG: references to secondary literature;
- PREPHASE: references to literature from South-East Asia;
- ORGANYM: references to institutions and their research activities;
- PERSONYM: references to specialists;
- TEXTFILE: all Prosea publications and additional information;
- PHOTFILE: photographs of useful plants of South-East Asia.

Publication

The handbook in blue cover (hardbound) is distributed by Backhuys Publishers, Leiden, the Netherlands (formerly by Pudoc, Wageningen, the Netherlands). The handbook in green cover (paperback) is distributed in two price-classes: a low-price paperback, distributed by Prosea South-East Asia for all developing countries; a medium-price paperback, distributed by Backhuys

Publishers, Leiden, the Netherlands, and by Prosea South-East Asia for developed countries (becoming available two years after publication of the hardbound edition). The bibliographies are distributed by Prosea South-East Asia.

The handbook

- No 1. Pulses. L.J.G. van der Maesen and Sadikin Somaatmadja (Editors). Pudoc, Wageningen. 1989/ESCAP CGPRT Centre, Bogor. 1990 (out of print)/Prosea, Bogor. 1992.
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- committed to rural development through diversification of resources and application of farmers' knowledge.

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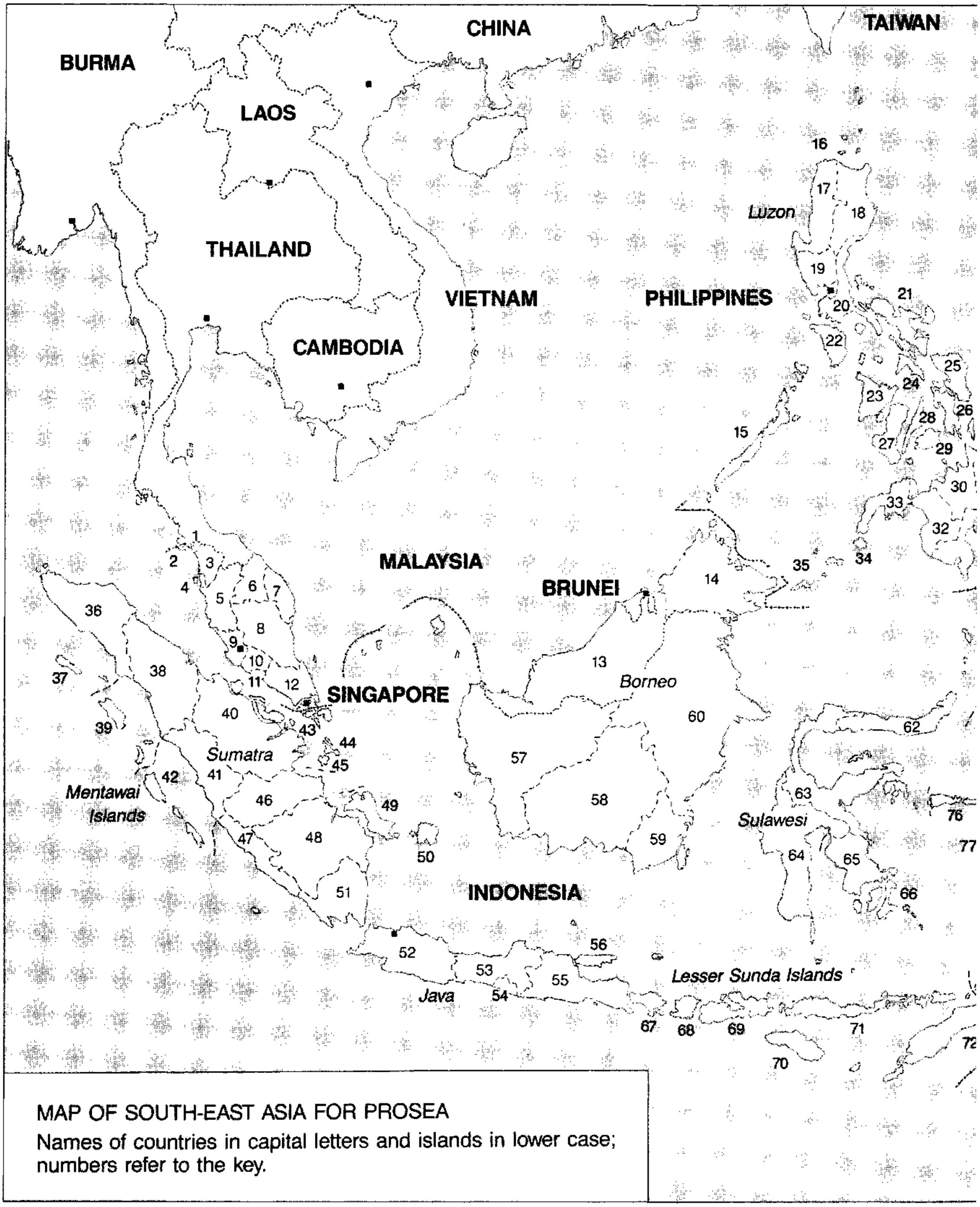
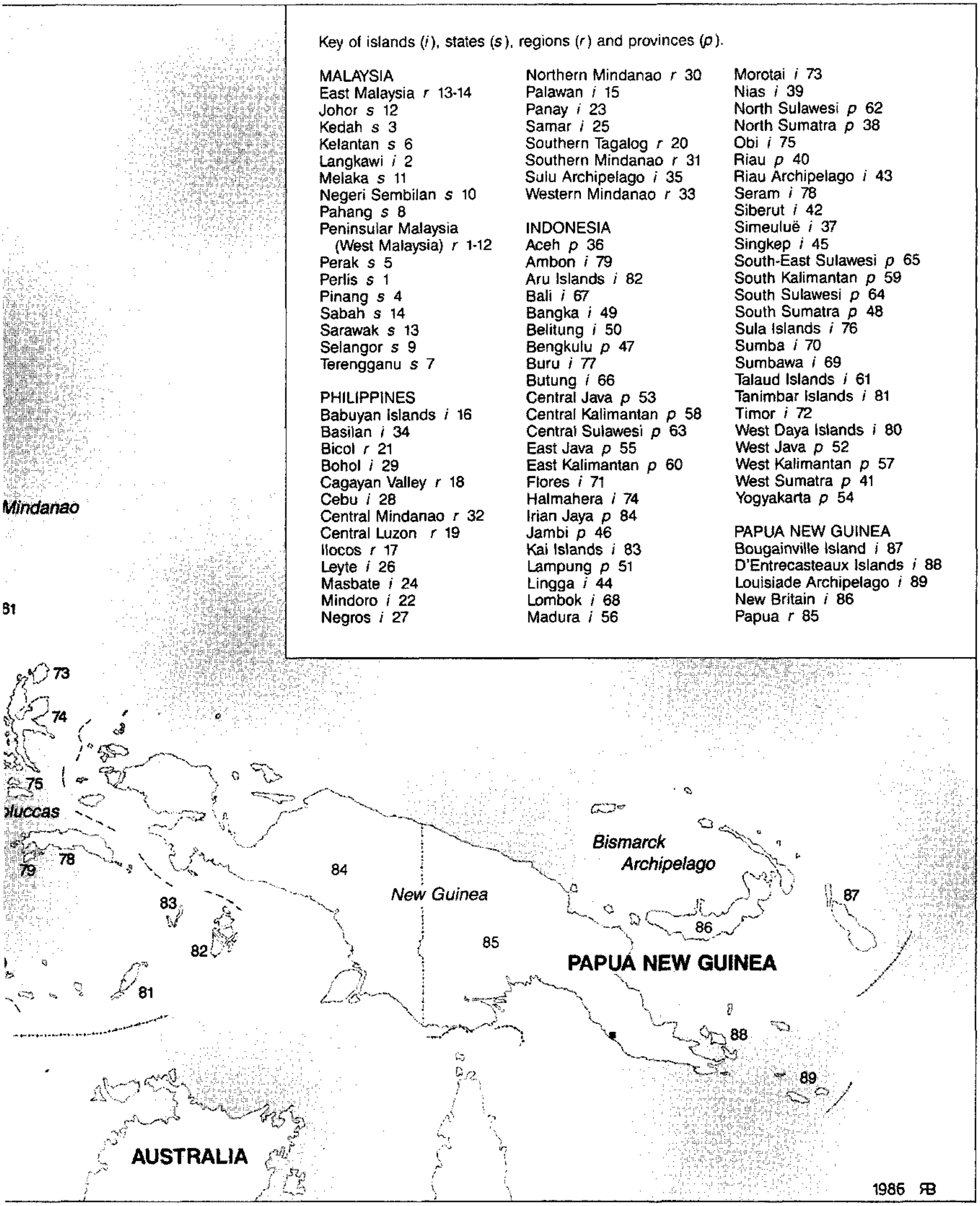


MAP OF SOUTH-EAST ASIA FOR PROSEA

Names of countries in capital letters and islands in lower case; numbers refer to the key.



Key of islands (*i*), states (*s*), regions (*r*) and provinces (*p*).

MALAYSIA
East Malaysia *r* 13-14
Johor *s* 12
Kedah *s* 3
Kelantan *s* 6
Langkawi *i* 2
Melaka *s* 11
Negeri Sembilan *s* 10
Pahang *s* 8
Peninsular Malaysia
(West Malaysia) *r* 1-12
Perak *s* 5
Perlis *s* 1
Pinang *s* 4
Sabah *s* 14
Sarawak *s* 13
Selangor *s* 9
Terengganu *s* 7

PHILIPPINES
Babuyan Islands *i* 16
Basilan *i* 34
Bicol *r* 21
Bohol *i* 29
Cagayan Valley *r* 18
Cebu *i* 28
Central Mindanao *r* 32
Central Luzon *r* 19
Ilocos *r* 17
Leyte *i* 26
Masbate *i* 24
Mindoro *i* 22
Negros *i* 27
Northern Mindanao *r* 30
Palawan *i* 15
Panay *i* 23
Samar *i* 25
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East Java *p* 55
East Kalimantan *p* 60
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Irian Jaya *p* 84
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