Plant Resources of South-East Asia

No 17

Fibre plants

M. Brink and R.P. Escobin (Editors)

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Foreword

Fibre plants form a fascinating, very diverse group, including plants used for textiles, cordage, paper making, packing, thatching and the manufacture of baskets, mats and wickerwork. The use of plant fibres has a long history. Fibre plants such as cotton (India, America), hemp (northern Europe), flax (the Mediterranean) and ramie (China, India and Indonesia) have all been used for many centuries for clothing, sails, cordage, fishing nets and many other purposes. Over the centuries, the extraction and processing of fibres developed into a highly skilled art producing economically important items of commerce. In the second half of the 20th Century synthetic fibres reduced the demand for natural fibres. In daily life, however, synthetics will never become as popular as natural fibres such as cotton. In view of growing concerns about environmental issues, fibres such as jute, kenaf, roselle and sisal might show a revival, for instance for insulation, packaging, geotextiles, composites, filters, sorbents and active surfaces. A very important application of fibre plants is in paper production. For almost two thousand years paper was made from hemp, ramie and cotton fibres. In the 19th Century straw and wood became more important and today wood is the main raw material for paper in Europe, North and South America and Africa, whereas in Asia bamboo and cereal straw predominate.
This volume of the Prosea Handbook comprises the well-known plant fibres of international trade such as cotton, jute and flax, as well as many lesser-known fibres important regionally or locally in South-East Asia. The information presented is the result of a truly collaborative, international effort with the input of specialists from South-East and South Asia, Europe, the United States, Australia and New Zealand. I am confident that this volume will stimulate research and be a reliable source of information for students, workers in extension, education and industry and others with an interest in fibre plants.
This book is the last volume of the Prosea Handbook published under responsibility of the Prosea Publication Office, which was based at Wageningen University. In the period 1989–2003, 19 Handbook volumes, in total 24 books, have been published by the Prosea Foundation. The Board and personnel of the Prosea Foundation are to be congratulated with this major achievement. I want to express my sincere thanks for our long, fruitful cooperation and I wish Prosea in South-East Asia a prosperous future.

Professor Dr A.A. Dijkhuizen
Chairman Executive Board
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1 Introduction

1.1 Definitions and choice of species

1.1.1 Definitions

Fibres in general are defined as 'slender strands of natural or man-made material usually having a length of at least 100 times their diameter and characterized by flexibility, cohesiveness and strength' (Lipton, 1995). The Textile Institute (Manchester, United Kingdom) has defined fibres as: 'units of matter characterized by flexibility, fineness, and a high ratio of length to thickness' (Morton & Hearle, 1993).

Definitions of plant fibres vary from very simple, such as 'a type of plant cell in which the wall has been thickened to perform a structural role' (Allaby, 1992), or 'the thick-walled cells giving strength to plant tissue' (Lipton, 1995), to more comprehensive, such as 'an elongate tapering cell that has at maturity a small lumen and no protoplasm content, that is found in many plant organs and is especially well developed in the xylem and phloem of the vascular system, and that imparts elasticity, flexibility, and tensile strength to the plant or organ' (after Webster's New International Dictionary).

Fibre plants are plants grown or collected for their fibres. They are often defined in a narrow sense, i.e. to include those plants from which fibres are extracted and used to make textiles, cordage, and sometimes also paper (Lipton, 1995; Wood, 1997). The present volume follows the commodity grouping adopted for the Prosea Handbook as presented in Jansen et al. (1991) and uses a wider definition of fibre plants, which are considered to comprise:

- Fibre plants in a narrow sense, used for textiles, cordage and paper (including those used for toothbrushes, sponges and cork).
- Plants used for making baskets, mats and wickerwork (including brooms).
- Plants used for packing and thatching (including leaves used as platters, for garments and as sandpaper).

1.1.2 Choice of species

In the present Prosea volume 72 species are described in detail in the 45 major treatments of Chapter 2. Brief descriptions of 129 minor species are given in Chapter 3. About 450 plant species whose use as fibre plants is secondary to other uses are listed in Chapter 4. An overview of the 72 major fibre plants is presented in Table 1. These include species producing the well-known plant fibres of international trade such as cotton (*Gossypium* spp.), jute (*Corchorus* spp.) and flax (*Linum usitatissimum* L.), and also lesser-known species used for weaving (e.g. *Donax canniformis* (G. Forster) K. Schumann, *Fimbristylis um-*

Table 1. Overview of the major fibre plants treated in this volume.

Scientific name	Common name	Main uses
Abroma augusta	devil's cotton	cordage
Actinoscirpus grossus	giant bulrush	weaving
Agave cantala	cantala	cordage
Agave sisalana	sisal	cordage
Anodendron candolleanum	akar katam	cordage
Anodendron oblongifolium	kapi	cordage, fishing gear
Anodendron paniculatum	Andamanese bowstring plant	cordage, fishing gear
Artocarpus elasticus	wild breadfruit	cordage, barkcloth
Arundo donax	giant reed	weaving
Boehmeria nivea	ramie	textile, cordage, fishing gear
Broussonetia papyrifera	paper mulberry	paper, barkcloth
Carludovica palmata	Panama hat palm	weaving
Ceiba pentandra	kapok	stuffing
Colona javanica	sampora	cordage, fishing nets
Colona serratifolia	jelunut	cordage
Corchorus capsularis	white jute	sacking, cordage
Corchorus olitorius	tossa jute	sacking, cordage
Corypha utan	gebang palm	thatching, weaving
Curculigo capitulata	palm grass	cordage, fishing nets, cloth, packing
Curculigo latifolia	lemba	cordage, fishing nets, cloth, packing
Cyperus elatus	wlingi	weaving
Cyperus malaccensis	Chinese mat grass	weaving, tying
Cyperus papyrus	papyrus	weaving
Cyperus procerus	rumput adem	tying
Donax canniformis	bamban	weaving
Enhalus acoroides	eel grass	fishing nets
Eugeissona triste	bertam	thatching
Fimbristylis umbellaris	globular fimbristylis	weaving
Furcraea foetida	Mauritius hemp	cordage
Gossypium arboreum	tree cotton	textile
Gossypium barbadense	sea island cotton	textile
Gossypium herbaceum	Arabian cotton	textile
Gossypium hirsutum	upland cotton	textile
Heliconia indica	lobster-claw	platters, packing
Helicteres isora	red isora	cordage, paper
Hibiscus cannabinus	kenaf	sacking, cordage, paper
Hibiscus sabdariffa	roselle	sacking, cordage, paper
Juncus effusus	soft rush	weaving
Lepironia articulata	purun	weaving
Linum usitatissimum	flax	textile, paper
Malachra capitata	wild okra	cordage
Malachra fasciata	wild okra	cordage
Miscanthus floridulus	floret silvergrass	thatching
Miscanthus sinensis	eulalia	thatching
Musa textilis	abaca	cordage, paper

Table 1. Continued.

Scientific name	Common name	Main uses
Nepenthes ampullaria	kantong teko	tying
Nepenthes rafflesiana	periuk kera	tying
Pandanus atrocarpus	mengkuang	weaving, thatching
Pandanus furcatus	bengkuang	weaving
Pandanus kaida	mengkuang	weaving
Pandanus odoratissimus	pandan laut	weaving, thatching
Pandanus tectorius	pandan pudak	weaving, thatching
Phormium tenax	New Zealand flax	weaving, cordage
Phragmites vallatoria	reed	thatching, weaving, brooms
Raphia farinifera	Madagascar raphia palm	thatching, tying, weaving
Raphia hookeri	wine palm	brushes, thatching, tying, weaving
Raphia vinifera	bamboo palm	brushes, thatching, tying, weaving
Sansevieria roxburghiana	Indian bowstring hemp	cordage
Sansevieria trifasciata	African bowstring hemp	cordage
Schoenoplectus lacustris	great bulrush	weaving
Schoenoplectus litoralis	endong	weaving
Schoenoplectus mucronatus	bog bulrush	weaving, tying
Scirpodendron ghaeri	rumbai	weaving
Tetrapanax papyriferus	ricepaper tree	ricepaper
Thespesia lampas	polompom	cordage
Typha domingensis	cattail	weaving, thatching
Typha orientalis	cattail	weaving, thatching
Urena lobata	Congo jute	cordage, textiles
Wikstroemia indica	small-leaf salago	paper, cordage
Wikstroemia lanceolata	lance-leaf salago	paper, cordage
Wikstroemia meyeniana	large-leaf salago	paper, cordage
Wikstroemia ovata	round-leaf salago	paper, cordage

bellaris (Lamk) Vahl), thatching (e.g. *Eugeissona triste* Griff.) and packing (e.g. *Heliconia indica* Lamk). Of the 72 fibre plants, 39 are mainly used for cordage or tying, 28 for plaiting and weaving, 13 for thatching, 11 for textiles (including sacks), 10 for paper making, 3 for brushes and mats, 3 for miscellaneous uses (packing), 2 for natural fabrics and 1 for filling (stuffing). Species also used as fibre plants in addition to their primary use are treated in other Prosea volumes, for instance pineapple (*Ananas comosus* (L.) Merrill) in Prosea 2 (Edible fruits and nuts), *Talipariti tiliaceum* (L.) Fryxell (syn. *Hibiscus tiliaceus* L.) in Prosea 5 (Timber trees), toddy palm (*Borassus flabellifer* L.), sago palm (*Metroxylon sagu* Rottboell) and nipa palm (*Nypa fruticans* Wurmb) in Prosea 9 (Plants yielding non-seed carbohydrates), hemp (*Cannabis sativa* L.) in Prosea 12 (Medicinal and poisonous plants), and coir (*Cocos nucifera* L.) in Prosea 14 (Vegetable oils and fats). Rattans and bamboos are dealt with in Prosea 6 (Rattans) and Prosea 7 (Bamboos). Many trees used to supply pulp for paper making, including *Acacia auriculiformis* A. Cunn. ex Benth., *A. mangium* Willd., *Eucalyptus camaldulensis* Dehnh., *E. deglupta* Blume and *Paraserianthes falcataria* (L.) Nielsen (syn. *Albizia falcataria* (L.) Fosb.) are treated in Prosea 5

Table 2. Important fibre plants treated in other PROSEA volumes.

Scientific name	Common name	Main fibre uses
Ananas comosus	pineapple	cloth
Borassus flabellifer	toddy palm	thatching, weaving
Cannabis sativa	hemp	cordage, nets, paper
Cocos nucifera	coir	cordage, mats, brushes, thatching, weaving
Crotalaria juncea	sunn hemp	cordage, nets, paper
Metroxylon sagu	sago palm	thatching, cordage, weaving
Nypa fruticans	nipa palm	thatching

(Timber trees). Wheat, rice and sorghum, from which residues are used for paper making, are treated in Prosea 10 (Cereals). An overview of important fibre plants with other primary use is presented in Table 2.

1.2 Role of fibre plants

1.2.1 Historical aspects

The use of plant and animal fibres for clothing dates back to the earliest civilizations. Wool became the main fibre for clothing in western and southern Europe, and hemp in northern Europe. Cotton was the ancient national textile of India and also a source of fibre for indigenous peoples in the Americas. Flax was probably first cultivated before 1000 BC, and linen from flax was used by the ancient Egyptians, Greeks and Romans. Ramie has been used since prehistoric times in China, India and Indonesia, and silk was important in China. Thus, the major textile fibres found today have all been in use for a very long time. Fibres have long been spun into yarns that were woven or knitted into fabrics for clothing. Over the centuries, the extraction of fibres and their processing into woven products developed into a highly skilled art, and fibres and fabrics became important items of commerce. Textile fibres were also used to produce articles such as sail cloth, furnishings, table linen and canvas. In addition, plant fibres were widely used for making rope, twine and fishing nets. The advent of steamships in the 19th Century, however, greatly reduced the demand for rope. The development of nylon and other synthetic fibres, with their excellent strength and durability, further reduced the demand for cordage produced from natural fibres. For example, leaf fibres from sisal (*Agave sisalana* Perrine) and henequen (*A. fourcroydes* Lem.) were long made into binder twine for the tying of hay bales, but they have now been largely replaced by synthetic fibres (Wood, 1997).

Old hemp clothing was one of the earliest materials to be used for paper making (Wood, 1997). The oldest surviving paper, made from hemp, was discovered in a tomb in China dating back to between 140 and 87 BC (Clarke, 1999). Paper making spread from China to India, Persia and Arabia, and from there through Spain into Europe in the 12th Century (Hill, 1952; Simpson & Conner Ogorzaly, 1995). Hemp, ramie, cotton, and rag fibres from plant or animal origin have been used for paper making for almost 2000 years (Croon, 1995; McDougall et al., 1993). In the 19th Century, straw and hardwood fibres began to be used as supplements, as technical and chemical knowledge increased (McDougall et al., 1993). Straw remained a major source of fibre in Europe and North America until the wood-based industry became fully established during the latter part of the 19th century (Moore, 1996). Softwood fibres became dominant with the advent of the sulphite pulping process, developed in 1857 (McDougall et al., 1993; Simpson & Conner Ogorzaly, 1995).

1.2.2 Uses

The end uses of fibre plants have been grouped in various ways, also depending on the definition of fibre plants applied (Hill, 1952; Kirby, 1963; Kochhar, 1986; Lewington, 1990; Schery, 1972; Simpson & Conner Ogorzaly, 1995). Fibre plants in a broad sense, as defined for the present volume, can be tentatively divided into 11 main groups: textiles, cordage and tying, brushes, filling, plaiting and weaving, thatching, natural fabrics, artificial fibres, paper, building and construction material, and miscellaneous uses.

Textiles

The most important use of non-wood plant fibres is for textiles. Fibres are first spun into thread or yarn and then woven or knitted into fabrics. Fabrics include cloth for clothing and domestic use, and also coarser materials such as burlap for sacking. By far the most important fabric fibre is cotton; other fabric fibres include flax, hemp and ramie. Jute is the most important fibre for coarse fabrics for sacking. Netting fibres are used for lace, hammocks and all forms of nets. They include most commercial textile fibres and many local fibres such as *Colona javanica* (Blume) Burret, *Curculigo* spp. and *Enhalus acoroides* (L.f.) Royle in South-East Asia.

Cordage and tying

In the process of cordage production, individual fibres are twisted together but not woven. Many kinds of cordage exist, including rope, twine, binder twine and fish lines. The most important cordage fibres are abaca (*Musa textilis* Née), sisal and hemp; lesser-known but nevertheless widely distributed cordage plants include *Abroma augusta* (L.) L.f., *Helicteres isora* L., *Malachra capitata* (L.) L., *Sansevieria* spp. and *Thespesia lampas* (Cav.) Dalzell & A. Gibson. Many other species are of local importance only, such as *Curculigo* spp. in South-East Asia. Rough cordage is obtained by simply twisting together bast ribbons, e.g. of *Anodendron* and *Colona* spp. Many plant species are traditionally used for tying without much processing, for instance the stems and branches of lianas such as *Bauhinia* and *Gnetum* spp.

Brushes

An important application of plant fibres is found in the manufacture of brushes, brooms and whisks. For these products fibres must be strong and stiff, but also flexible. Sometimes whole twigs, fine stems or roots are utilized; fibres are also obtained from leaf stalks of palms. The brush fibres include African piassava (from *Raphia hookeri* G. Mann & H. Wendl. and *R. palma-pinus* (Gaertn.) Hutch.), Bahia piassava (from *Attalea funifera* Mart.) and Para piassava (from *Leopoldinia piassaba* Wallace).

Filling

Filling fibres are used for stuffing (pillows, cushions, mattresses etc.), caulking (seams between planks, barrels etc.) and packing. The most valuable of all stuffing materials is kapok (*Ceiba pentandra* (L.) Gaertn.), but many other plant fibres are useful as filling material, such as *Bombax anceps* Pierre, *B. ceiba* L., the straw of cereals and other grasses, and the husks of maize.

Plaiting and weaving

Plaits are wide, flat, pliable, fibrous strands that are interlaced to make hats, sandals, baskets, chair seats, mats, etc. Non-textile weaving encompasses a number of different techniques such as plaiting, twining, coiling and wickerwork. Usually older or otherwise tougher, less supple strands are used for mats, whereas more supple strands are used for baskets, chairs and other forms of wickerwork. Hat fibres are obtained from the leaves of the Panama hat palm (*Carludovica palmata* Ruiz & Pav.) and many *Cyperaceae*, *Palmae* and *Pandanaceae*. Fibres for mats are obtained from many plants, including a range of *Cyperaceae*, *Palmae* and *Pandanaceae*. Numerous species of rattan and bamboo are used in basketry, as are many *Cyperaceae*, *Palmae* and *Pandanaceae*.

Thatching

Thatches are roof coverings made from non-wood plant material such as leaves, straw and reeds. They are widely used in South-East Asia, despite the growing popularity of zinc roofs. Zinc lasts longer, but requires cash outlay and gives a hotter indoor climate. For plant thatch, if locally available, usually no cash is required and it is cooler. It needs to be replaced more often than zinc, but this also depends on species used and construction technique. Thatched roofs are sometimes desirable in tourism, but also sometimes considered lower class and therefore avoided by people climbing the socio-economic ladder. The choice of material for thatching depends on local availability: cogon grass (*Imperata cylindrica* (L.) Raeuschel) is widespread and is often used. Rice straw is used in rice-growing areas such as Bali (Indonesia). Often palm leaves are applied, either harvested from wild trees, e.g. *Eugeissona triste*, or as by-products from homesteads or plantations, e.g. from *Borassus flabellifer*, *Cocos nucifera*, *Metroxylon sagu* and *Nypa fruticans*.

Natural fabrics

Natural fabrics are often made from tree basts that are extracted from the bark in layers or sheets and pounded into rough cloth ('barkcloth'). Probably the best known of these barkcloths is 'tapa cloth', obtained from the bark of paper mulberry (*Broussonetia papyrifera* (L.) L'Hér. ex Vent.). Other sources of barkcloth in South-East Asia include *Artocarpus elasticus* Reinw. ex Blume and *Antiaris toxicaria* Lesch.

Artificial fibres

Artificial fibres such as viscose, acetate and tri-acetate are obtained from cellulose contained in living plants. For a long time, cotton was the only source of the cellulose used in the production of artificial fibres and other cellulose products. Developments in wood technology have enabled the production of high-grade cellulose from wood. When certain woods are treated with concentrated acids or alkalis, the bond between the wood fibres and the lignin that cements them together is broken, and the fibres can be removed. These fibres may then be reorganized as paper or they may be further treated with chemicals. If this chemical treatment merely causes the fibre to dissolve into its component molecules, these molecules may be resynthesized into artificial fibres or converted into cellulose plastics.

Paper

Paper can be made from any natural fibrous material, including wood fibres, cereal straw, bamboo and textile fibres used in either the raw or manufactured state. Where wood-based fibres dominate, non-wood fibres usually only occupy small niche markets providing specialist properties to a range of high added-value products. However, where wood-based fibres are not sufficiently available, non-wood fibres are used across the spectrum of paper and paperboard products (Moore, 1996). Mills in Africa and Latin America mainly use wood, whereas in Asia non-wood raw materials predominate, due to (Moore, 1996):
- Lack of timber resources in some countries with a large population and consequently a high demand for paper, such as China, India, Bangladesh, Pakistan and Iran.
- Lower capital investment requirements for non-wood pulp and paper mills, due to smaller size and fewer technical problems.
- Less stringent pollution requirements from governments, in an attempt to promote investment in domestic paper manufacture.

Non-wood materials used for the production of pulp can be divided into 2 categories (Wood, 1997):
- Crop residues left after the primary product has been harvested or extracted. Examples are cereal straw residues (wheat, rice, sorghum) and bagasse left after the extraction of sugar from sugar cane (*Saccharum officinarum* L.). This group also includes waste fibres recovered from crops grown primarily for the manufacture of textile, sacking and cordage fibres. These waste fibres, referred to as tow, are recovered from the scutching and combing operations that form the initial operations prior to spinning.
- Crops specifically grown for paper production. Examples are bamboo, and textile and cordage fibres, e.g. abaca, hemp, jute, kenaf, New Zealand flax (*Phormium tenax* J.R. Forster & G. Forster), ramie and sisal. Hemp, jute, and ramie have specific applications in the manufacture of cigarette paper, tea bags, sack paper and saturating papers (Biermann, 1993). Traditional bast fibres such as kenaf (*Hibiscus cannabinus* L.) are removed from the

stem and can be used to produce high-quality writing and specialty papers. Alternatively, the whole stems or the separated bark and core fractions can be used to produce pulps with properties comparable to those of wood. The bast fibres provide strength to the pulp, whereas the shorter core fibres provide good surface characteristics. Pulping of the whole stem rather than the separated bast and core fibres has the advantage of saving considerably on the costs of labour involved in retting and decorticating.

In temperate climates the most important source of non-wood fibre for pulping is wheat straw; in Asia, rice and wheat straws and bamboo are important sources; and in Latin America sugar-cane bagasse is by far the main non-wood fibre (Moore, 1996). Sugar-cane bagasse has been considered as a source of raw material in various Asian countries, including Thailand and India. However, bagasse is also an important source of fuel for boilers of sugar mills, and for that reason in short supply for alternative applications (Moore, 1996).

Building and construction material

Current applications of non-wood plant fibres in building material include particle board, fibreboard, especially medium density fibreboard (MDF), and inorganic matrix composites (IMCs). Boards are mainly used indoors as insulation material. IMCs find application in plaster boards, tiles, concrete, mortars and plasters. Softwoods are the preferred raw material for particle boards and MDF; jute and kenaf sticks are used as well. Smaller quantities of hardwood are also used, especially for particle board, but generally not preferred, because the higher dust levels associated with their processing can increase resin consumption and processing costs, and can increase the risk of fire and explosion in the factory (Hague, 1997). Straw and bagasse are quite widely used for the production of low- and medium-density particle board. The use of timber for construction purposes has been dealt with in the Prosea volumes on timber trees.

Miscellaneous uses

Jute and similar fibres are traditionally used for carpet backing, carpet underlays and for the manufacture of felt. Other potential uses include geotextiles for erosion control on slopes and for agricultural mulching. Fibres from coir, sisal, jute and flax are made into biodegradable plant pots, e.g. in Germany (Groot, 1996). A relatively new and increasingly popular use of plant fibres is found in the automotive industry, where they are used to make press-moulded composites for door panels, hat racks and trunk liners. In Germany, for instance, the use of plant fibres in the automotive industry grew from 4000 t in 1996 to about 14 000 t in 1999. The main fibre used in 1999 was flax (11 000 t), but kenaf (1100 t), hemp (1100 t), jute (700 t) and sisal (500 t) were also used (Karus & Kaup, 1999).

1.2.3 Economic aspects

Various developments during the 20th Century have led to a decline in the importance of non-wood fibres other than cotton: the mechanization of production and thus increased market share of cotton, the development of synthetic fibres from petroleum (nylon, acrylic, terylene, polyester) or from cellulose contained in living plants (viscose, acetate, tri-acetate), and a decline in the use of sacking for the transport of agricultural products due to the advent of transport in containers (Lewington, 1990; Wood, 1997). Although many species are or have been used as fibre plants, only a few are grown at present on a large enough scale to be of importance in international trade. Most fibre plants are indigenous species collected or cultivated for local use only. Table 3 presents statistics on the production and trade of the most important fibre crops (excluding woods for paper making) from 1996 to 2000. Separate statistics for kenaf and roselle are not available. They are usually included in the 'jute-like fibres', a group also including China jute (*Abutilon theophrasti* Medik., synonym: *A. avicennae* Gaertn.), Congo jute (*Urena lobata* L.), other *Malvaceae*, and sunn hemp (*Crotalaria juncea* L.). Kenaf is estimated to make up about 90% of the total, and roselle about 10%.

Table 3 shows that cotton is by far the most important fibre crop in terms of area under cultivation, production, and export value, followed by jute and flax. Across all countries, the export fraction does not exceed 35% of total production; this means that the largest proportion of the fibres produced worldwide is consumed domestically. When fibre plants are defined in a broad sense, by far the most important fibre plants on a world scale are woody species used for paper making, with an estimated annual production in the early 1990s of about 1750 million t (Bolton, 1995).

The estimated production of the major fibre crops in South-East Asia (except woods for paper making) is presented in Table 4, which shows that for most of these crops South-East Asia plays only a minor role in world production, the exceptions being kapok and abaca. Statistics on the production of flax and hemp in South-East Asia are not available, but fibre production of these crops is limited in the region.

In 1994 the annual world production of paper pulp was 170 million t, of which only 12.5 million t (8%) were produced from non-wood materials, including bamboo and bagasse (Croon, 1995; Wood, 1997). The explanation for the popularity of wood is its low cost and high fibre quality. To be successful, alternative sources must have both these characteristics (Clarke, 1999). China produces about half of the world's non-wood pulp (Croon, 1995; Wood, 1997). The pulp and paper industries in industrialized countries have generally shown little interest in non-wood fibre crops, partly because it is felt that enough forest resources are available and that non-wood fibre crops are not cost-competitive.

1.3 Properties

1.3.1 Morphological properties

The main morphological properties determining the suitability of fibres for different uses, such as textile or paper, are the length and width of the individual fibre cells ('ultimate fibres') which form the skeleton of the fibres (Maiti, 1997; McDougall et al., 1993). Cell wall thickness and lumen diameter are generally less important (McDougall et al., 1993). In Table 5 the dimensions of selected plant fibres are presented.

Table 3. Annual production and trade of the most important fibre crops (except woods for paper making) in the period 1996–2000 in the world.

Crop	**Area (×1000 ha)**	**Production (×1000 t)**	**Export (% of production)**	**Export value (×million US$)**
Abaca	132	98	34	32
Coir	n.a.	663	20	36
Cotton (lint)	33 232	18 684	29	7873
Flax (fibre + tow)	489	502	25	228
Hemp (fibre + tow)	60	65	5	5
Jute	1494	2813	14	90
Jute-like fibres[1]	371	498	<1	<1
Kapok	n.a.	124	0	0
Ramie	89	141	2	10
Sisal	300	283	25	40

[1] Including kenaf, roselle, Congo jute, China jute, other *Malvaceae*, and sunn hemp.
Sources: FAO databases.

Table 3. Continued.

Crop	Main producing countries (in order of importance)	Main exporting countries (in order of importance)	Main importing countries (in order of importance)
Abaca	Philippines Ecuador	Philippines Ecuador	United Kingdom United States Japan Spain
Coir	India Sri Lanka Malaysia Bangladesh Thailand	Sri Lanka India Philippines	China Germany Netherlands United States United Kingdom
Cotton (lint)	China United States India Pakistan Uzbekistan	United States Uzbekistan Australia Argentina Turkmenistan	China Indonesia Brazil Turkey Italy
Flax (fibre + tow)	China France Spain Russian Federation Belarus	France Belgium	Belgium China Italy
Hemp (fibre + tow)	China Spain North Korea Romania Russian Federation	Netherlands Romania	Spain
Jute	India Bangladesh China	Bangladesh	India Pakistan China
Jute-like fibres[1]	India China Thailand Russian Federation		
Kapok	Indonesia Thailand		
Ramie	China Brazil Philippines Laos	China	Japan
Sisal	Brazil China Kenya Tanzania Madagascar	Brazil Kenya Tanzania Madagascar	Portugal Spain

Table 4. Estimated annual production (× 1000 t) of major fibre crops in South-East Asia in the period 1996–2000 (no information available for Papua New Guinea).

Crop	BUR[1]	CAM	IND	LAO	MAL	PHI	THA	VIE	SE Asia	% of world
Abaca			0.6			71.9			72.5	74.2
Coir					32.3		8.4		40.7	6.1
Cotton (lint)	55.2	0.1	8.9	6.0		1.2	15.2	23.9	110.4	0.6
Jute	36.5	1.0					5.3	14.5	57.3	2.0
Jute-like fibres[2]	<0.1		5.9				60.0		65.9	13.2
Kapok			79.9				44.5		124.5	100.0
Ramie				1.4		1.6			3.0	2.1
Sisal			0.5				<0.1		0.5	0.2

[1] BUR = Burma (Myanmar); CAM = Cambodia; IND = Indonesia; LAO = Laos; MAL = Malaysia; PHI = Philippines; THA = Thailand; VIE = Vietnam

[2] Including kenaf, roselle, Congo jute, China jute, other *Malvaceae*, and sunn hemp.

Sources: FAO databases; estimations by various authors.

The fibre cells of ramie are the longest of all the vegetable fibres, followed by cotton, flax and hemp. For the industrial production of fine textiles, e.g. for clothing, a length:width ratio of over 1000 is generally required (McDougall et al., 1993). Cotton, flax and ramie generally have a length:width ratio of 1000 or higher. The length:width ratio of abaca, jute, kenaf, roselle and sisal is well below 1000, and these fibres can only be used for coarser textiles. Kapok has a length:width ratio of about 1000, but the fibre cells are normally too smooth to be spun into yarns, and thus not suitable for the production of textiles. For the production of burlap bags jute is superior in quality to kenaf, because it possesses fibre cells with more uniform morphology. Some other fibre crops have desirable qualities for burlap bags. Among these, *Sida rhombifolia* L. and *Urena lobata* are of good quality, associated with a high length:width ratio of the fibre cell.

For cordage, rough fibres are used in general, such as abaca and sisal. The fibres of these plants are uniform on the surface and the cell tips, and the fibre cells have an intermediate length:width ratio. Rough fibres such as those of *Furcraea* spp., *Abelmoschus esculentus* (L.) Moench and *Hibiscus radiatus* Cav., as well as several other *Agave* spp., also have the desirable qualities (Maiti, 1997).

Fibres used for brushes normally have thick filaments, with orderly cells very compactly arranged in the fibre bundle, a low length:width ratio of fibre cells, and thick fibre walls. Coir and the leaf stalks of *Cocos nucifera* and *Borassus flabellifer*, for instance, possess fibres characterized by low length:width ratio of fibre cells and thick cell walls (Maiti, 1997).

The properties of paper-based products are to a large extent determined by the types of pulp from which they are manufactured, whereas the properties of the pulp are determined by the properties of the raw material (fibre dimensions, chemical composition) and the pulping process used (Hague, 1997). The length:width ratio is important, because it affects the paper's flexibility and resistance to rupture. Softwood ultimate fibres are 2.7–4.6 mm long and hardwood ultimate fibres have a length of 0.7–1.6 mm (Karakus et al., 2001). Soft-

Table 5. Dimensions of the ultimate fibres of selected fibre plants.

Fibre	**Length (mm)**	**Width (μm)**	**Length: width ratio**
Non-wood fibres			
Abaca	(2–)4–8(–12)	(6–)13–29(–53)	250–350
Cotton	10–40(–64)	(12–)18–28(–38)	1000–4000
Flax	(1–)10–40(–85)	(5–)10–30(–38)	1000–2000
Hemp	(5–)20–25(–55)	(10–)20–25(–60)	250–1000
Jute	(0.5–)2–2.5(–6.5)	(9–)15–20(–33)	40–400
Kapok	(8–)19–22(–35)	(10–)19–20(–30)	1000
Kenaf	(1.5–)2–3(–12)	(7–)15–25(–41)	40–130
Ramie	(10–)40–250(–600)	(10–)25–60(–100)	1000–3000
Roselle	(1.2–)1.9–3.1(–6.3)	(10–)12–25(–44)	40–130
Sisal	(0.3–)1.5–4(–15)	(8–)15–30(–50)	100–150
Sugar-cane bagasse	(0.8–)1.2(–2.8)	(10–)12(–34)	50–100
Sunn hemp	(3.7–)7–8(–12)	(19–)25–30(–50)	130–300
Wheat straw	1–3	8–40	30–100
Wood fibres			
Eucalyptus	1–2	18–30	30–80
Spruce	3–4	20–50	70–160

Various sources.

wood fibres are ideal for paper making, because their long, thin, flexible structure allows them to pack closely together into non-porous, tightly bonded sheets. Hardwood fibres do not pack as tightly together, because they are shorter and less flexible (McDougall et al., 1993).

1.3.2 Chemical properties

Plant fibres consist of primary and secondary cell walls (Figure 1). The main components of plant fibres are cellulose, non-cellulosic polysaccharides (NCP), often subdivided into hemicelluloses (mainly composed of neutral sugar residues) and pectin (characterized by a high content of D-galacturonic acid residues), and lignin (Biermann, 1993; McDougall et al., 1993). The term holocellulose refers to the entire carbohydrate fraction of the material, i.e. cellulose plus hemicelluloses, whereas α-cellulose is the fraction isolated by a caustic extraction procedure. It is generally considered to be pure cellulose, but it actually is 96–98% cellulose (Biermann, 1993). The ratio of the different constituents and the chemical nature of the lignin and hemicelluloses varies widely between plant types and species (McDougall et al., 1993; Moore, 1996). Table 6 presents the chemical properties of selected plant fibres.

In contrast to plant fibres, animal fibres such as wool mainly consist of protein. This difference in chemical composition affects properties such as the resistance to washing in hot water and the acceptance of dyes. In general, plant fibres are less elastic than animal fibres, but they have a higher affinity for water and are thus more absorbent than animal fibres. Animal fibres are susceptible to animal pests such as moths and silverfish, to which plant fibres are

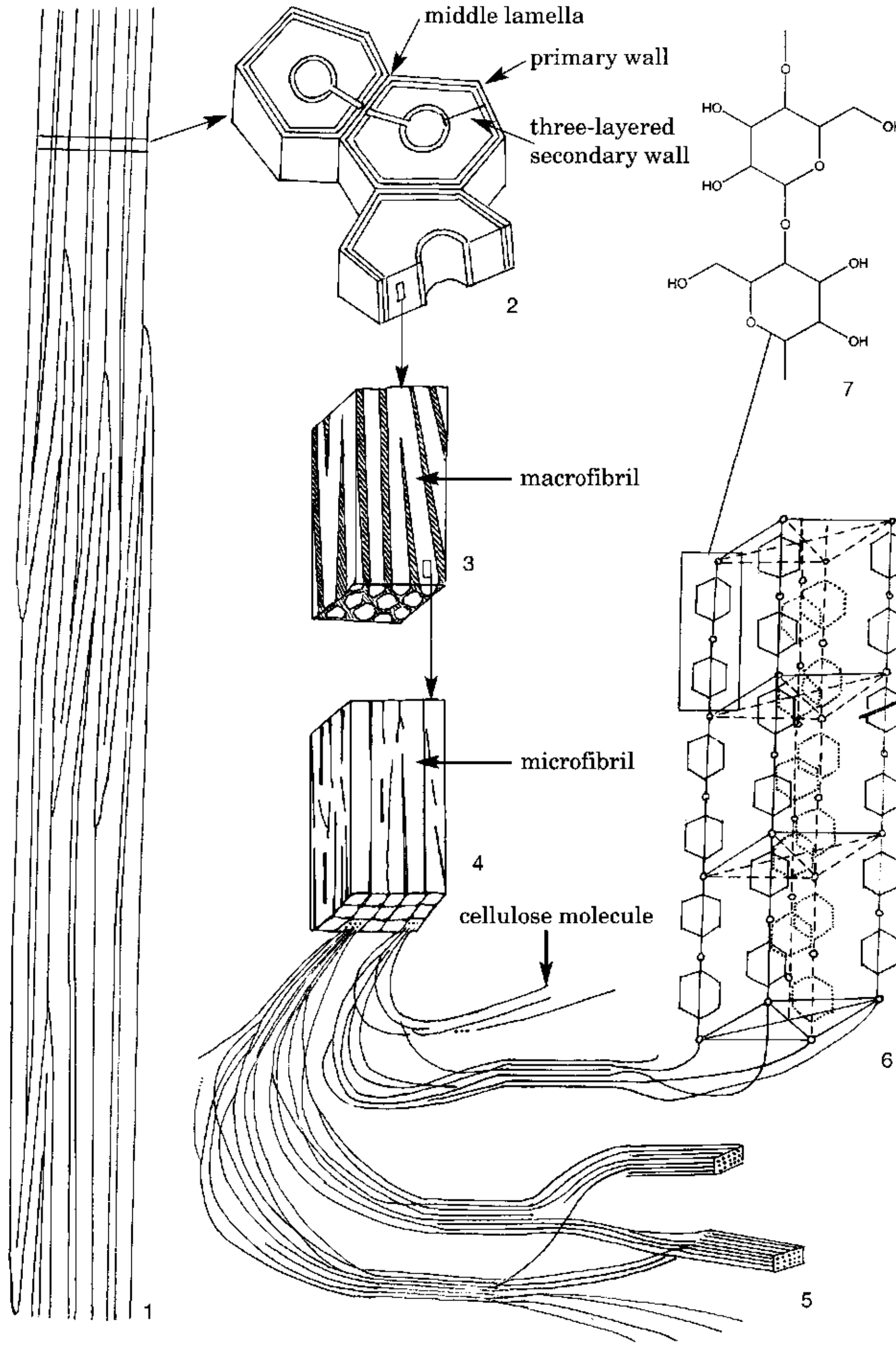

Figure 1. Cell wall structure of plant fibres – 1, strand of fibre cells; 2, cross-section of fibre cells, showing interconnecting pits, the primary cell wall, and the 3-layered secondary cell wall; 3, fragment of middle layer of secondary cell wall, showing macrofibrils of cellulose (white) and interfibrillar spaces of non-cellulosic material (black); 4, fragment of macrofibril, showing microfibrils; 5, structure of microfibrils; 6, individual chains of cellulose molecules; 7, repeating cellobiose unit of cellulose (after Esau, 1977).

usually immune, whereas plant fibres are readily attacked by fungi and termites (Simpson & Conner Ogorzaly, 1995).

Cellulose

The primary structure of all celluloses is a β-1,4-linked polymer of D-glucopyranose residues (Figure 1). All evidence indicates that cellulose is a homopolymer, not covalently bonded to other constituents of the cell wall. Every D-glucose residue is inverted at an angle of 180° to the next residue, which means that the repeating unit is cellobiose. The cellobiose chains are mutually connected by hydrogen bonds (McDougall et al., 1993). The cellulose molecule of purified cotton consists of at least 2000–3000 simple glucose sugar molecule residues, joined end to end in the form of a long chain (Kirby, 1963).
The higher the cellulose content of a fibre, the greater its value (Kirby, 1963). Cotton contains 88–96% α-cellulose, ramie 69–91%, hemp 62–67%, sisal 54–66% and jute 45–64% (Table 6).

Hemicelluloses

Hemicelluloses consist of short, highly branched chains of sugars. In contrast to cellulose, which is a polymer of only glucose, hemicelluloses are polymers of different sugars. They are built up from pentoses (usually D-xylose and L-arabinose), hexoses (D-galactose, D-glucose, and D-mannose) and uronic acid residues (Biermann, 1993). The polymerized pentoses are called pentosans.

Table 6. Chemical properties of selected plant fibres.

Fibre	α-Cellulose (%)	Hemicelluloses (%)	Lignin (%)	Pectin (%)
Non-wood fibres				
Abaca	55–64	18–23	5–18	1
Bamboo	36–43	15–16	21–31	
Cotton	88–96	3–6	1–2	
Flax (unretted)	57	15	2	4
Flax (retted)	64	17		2
Hemp	62–67	8–16	3–4	0.8
Jute	45–64	12–26	11–26	0.2
Kapok	43	32	13–15	
Kenaf	44–62	14–20	6–19	4–5
Ramie	69–91	5–13	1	2
Sisal	54–66	12–17	7–14	1
Sugar-cane bagasse	32–48	22–32	19–24	
Wheat straw	29–54	26–30	16–21	
Wood fibres				
Eucalyptus	49	15	28	
Pine	42	24	27	
Poplar	48	23	19	

Various sources.

Hemicelluloses form, together with lignin, the cementing material of the middle lamella between the ultimate fibre cells. The branched nature of hemicelluloses makes them amorphous and easier to hydrolyse into their constituent sugars than in the case of cellulose. Hemicelluloses are soluble in 18.5% NaOH and this is the basis for their measurement in TAPPI test methods (Biermann, 1993). When hydrolysed, the hemicelluloses from hardwoods release products high in xylose, whereas the hemicelluloses contained in softwoods yield more hexoses.

The presence of hemicelluloses in material for paper making increases the pulp yield and the strength of the resulting paper. Hemicelluloses are not wanted in dissolving pulps for cellulose-based plastics (Biermann, 1993).

Lignin

Lignin is a complex aromatic polymer, often present in the middle lamella and the mature secondary wall (Biermann, 1993; McDougall et al., 1993). Lignification increases the rigidity of the cell wall, makes it less susceptible to predation and less permeable to water (McDougall et al., 1993). The structure of naturally occurring lignins is not yet well known, but they are formed by the radical-induced polymerization of phenylpropenoid monomers. These monomers are based on coumaryl alcohol and may have 1 or 2 methoxyl groups at C-3 and/or C-5 on the benzenoid ring (McDougall et al., 1993; Palit et al., 2001). Many types of linkages between the monomers have been found, but the β-*O*-4 aryl ether is the most common. Sometimes ferulic and *p*-coumaric esters are found (McDougall et al., 1993).

High-quality fibres like cotton, ramie, flax and hemp contain very little (less than 5%) lignin, whereas jute, kenaf and roselle generally contain 10–20% lignin, making them inferior for fine fabrics (Palit et al., 2001). In paper making, removal or modification of lignin is essential for the production of pulp for quality papers (McDougall et al., 1993).

Pectin

Pectin is a material that binds fibre cells together (Kirby, 1963). Pectic acid is defined as a polysaccharide containing more than 90% D-galacturonic acid. However, some 'pectins' have only 20% galacturonic acid and 80% neutral sugar residues, which is one of the reasons for combining them with hemicelluloses in the non-cellulosic polysaccharides. The D-galacturonic acid residues are connected by α-1,4-linkages, but α-1.2-linked L-rhamnose residues also occur in the main chain. Methyl and acetyl esters are additional constituents of the polymer, whereas complex arabinans and 2 types of arabinogalactan are linked to the rhamnogalacturan backbone. Very little pectin is typically present in cell walls, but in some fibre plants, for instance flax, considerable amounts of pectin are present in the middle lamellae between fibre cells and other cells (McDougall et al., 1993). The pectin content of important fibres is for unretted flax 4%, retted flax 2%, ramie 2%, sisal 1%, hemp 0.8% and jute 0.2% (Table 6).

1.3.3. Physical properties

The physical properties of plant fibres are a function of the properties of the individual fibre cells and those of the matrix of intercellular cementing materials in which the fibre cells are embedded (Mukherjee & Radhakrishnan, 1972). Important physical properties of plant fibres include strength, durability, cohesiveness (the ability of individual fibres to stick together when spun into yarn), pliability (the quality enabling the filaments to be wrapped around each other during spinning), and colour (Weindling, 1947). These characteristics usually vary widely within species, even between fibre strands within the same plant. They also depend on a range of other factors, including temperature, moisture content and test methods. Weindling (1947) has made an attempt to rank some bast and leaf fibres with respect to these properties (Table 7).

The strength of plant fibres can be expressed in various ways. *Strength* or *tenacity* is a measure of resistance to steady forces, and is the appropriate quantity to consider when material is subject to a steady pull, for instance in the case of a rope used for hoisting heavy weights (Morton & Hearle, 1993). The strength may be given by the *breaking load*, which can be measured by hanging weights on to a fibre strand to determine at what weight the fibre breaks. As the breaking load depends on the cross-sectional area of the fibre, a more useful characteristic is the *tensile strength*: the breaking load or force per unit area of cross-section, usually expressed in N/mm^2 (10^6 Pa) or in kg/mm^2. An older method of expression is the *breaking length*: the length at which the material, when hung up, will break under its own weight. It is usually expressed in km. Another useful characteristic is the *elongation at break*, which is a measure of the resistance of material to elongation. It is defined as the amount of extension when the fibre breaks, expressed as a percentage of the original length of the fibre. The *elasticity* is the degree to which the fibre recovers its original length after extension. The *Young's modulus* or *modulus of elasticity* is the ratio of the stress (force per unit area) or applied load to the strain or defor-

Table 7. Ranking of selected bast and leaf fibres according to various physical properties.

Characteristic	**Rank**			
	1	**2**	**3**	**4**
Bast fibres				
Tensile strength	ramie	hemp	flax	jute
Durability	ramie	flax	hemp	jute
Cohesiveness	flax	hemp	jute	ramie
Pliability	flax	ramie	jute	hemp
Colour	ramie	flax	hemp	jute
Leaf fibres				
Tensile strength of fibre strands	abaca	sisal	New Zealand flax	Mauritius hemp
Durability	abaca	sisal	New Zealand flax	Mauritius hemp
Pliability	Mauritius hemp	New Zealand flax	abaca	sisal

Source: Weindling, 1947.

mation produced in a material that is elastically deformed; the higher the value, the stiffer the material. Its reciprocal is the *coefficient of elasticity*. Table 8 presents typical values of the tensile strength, elongation at break and Young's modulus of selected plant fibres.

1.4 Botany

1.4.1 Taxonomy and morphology

In general the most important textile and cordage fibre-yielding families are the *Malvaceae* (cotton, kenaf, roselle) and *Tiliaceae* (jute). Plants used for basketry are primarily found in the *Cyperaceae*, *Gramineae*, *Palmae* and *Pandanaceae*. Material for thatching is often obtained from *Gramineae* (*Imperata* spp., *Miscanthus* spp.), *Palmae* (*Borassus flabellifer*, *Cocos nucifera*, *Corypha utan* Lamk, *Eugeissona triste*, *Nypa fruticans*) and *Pandanaceae* (*Pandanus* spp.). Paper is mainly obtained from trees in the *Pinaceae* (*Pinus* spp.) and *Myrtaceae* (*Eucalyptus* spp.). The main non-wood sources of paper are *Gramineae* (bamboos, cereal straw).

The major South-East Asian fibre plants treated in Chapter 2 comprise 72 species belonging to 25 plant families. Families with the greatest number of species are the *Cyperaceae* (11 species), *Malvaceae* (10 species), *Palmae* and *Pandanaceae* (5 species each), *Tiliaceae*, *Gramineae*, and *Thymelaeaceae* (4 species each) and *Agavaceae* (3 species) (Table 9). All the 11 *Cyperaceae* are perennial herbs, whereas the 10 *Malvaceae* are herbs, shrubs or trees (Table 9).

The 129 minor fibre plants treated in Chapter 3 belong to 37 plant families, with the greatest number of species in the *Pandanaceae* (23 species), *Cyperaceae* (14 species), *Moraceae* (12 species), *Malvaceae* (10 species), *Tiliaceae* (8 species), *Urticaceae* and *Palmae* (7 species each) and *Leguminosae* (6 species).

Fibres and fibrous material are obtained from various plant parts, mainly from the stems, leaves and fruits or seeds.

Fibrous material from the stem can be classified into:

- Bast fibres ('soft fibres'): the soft and flexible fibres extending through the inner bark ('bast') of stems of dicotyledonous plants. The fibre strands of commerce usually consist of bundles of individual sclerenchyma fibre cells, the exception being ramie, where commercial fibres are single fibre cells. This

Table 8. Physical properties of selected plant fibres.

Fibre	Tensile strength (N/mm^2)	Elongation at break (%)	Young's modulus (10^9 Pa)
Coir	175	30.0	4.0–6.0
Cotton	285–595	7.0–8.0	5.5–12.6
Flax	345–1035	2.7–3.2	27.6
Hemp	690	1.6	n.a.
Jute	395–775	1.5–1.8	26.5
Ramie	400–940	3.6–3.8	61.4–128.0
Sisal	510–635	2.0–2.5	9.4–22.0

Source: Eichhorn et al., 2001.

group includes the fibres from jute, flax, hemp, sunn hemp, ramie, kenaf, roselle and Congo jute (*Urena lobata*).
- Bast: sometimes the bast fibres are not separated, but the bast is used entirely or in ribbons, often for rough cordage (e.g. *Colona* spp.). Formerly, bast sheets of *Artocarpus elasticus* and *Broussonetia papyrifera* were widely used in South-East Asia for the production of barkcloth.
- Wood fibres: the fibres occurring inside the vascular cambium of softwood or hardwood stems. Softwoods yield tracheids and xylem fibres, and hardwoods produce a mixture of tracheids, vessel elements and xylem fibres. Both softwoods and hardwoods are used in a wide range of papers. Examples of softwoods are *Pinus* spp., examples of hardwoods are *Eucalyptus* spp.
- Fibres from monocotyledonous stems: consisting mainly of vascular tissues and their sclerenchymatous bundle sheaths, and used for paper making and the production of building boards. Examples are cereal straw, bamboo, bagasse from sugar cane, and the stems of reeds such as *Phragmites* spp. Pulps from these materials typically have low strengths but can be blended with high-strength bark pulps to produce pulps with good paper-making characteristics.
- Entire or split stems: used for plaiting and weaving (many *Cyperaceae*), for thatching (many *Gramineae*), or for tying (e.g. *Bauhinia* spp. and *Nepenthes* spp.)
- Pith: sometimes used for paper making, e.g. in the production of ricepaper from *Tetrapanax papyriferus* (Hook.) K. Koch. The pith of the stem of *Cyperus papyrus* L. was used by early civilizations to make a primitive form of paper.

Fibrous material from the leaves can be distinguished into:
- Leaf fibres: fibres separated from the non-fibrous leaf tissue. The main leaf fibres are the 'hard fibres' of commerce: the fibres extending lengthwise through the pulpy tissues of long leaves of monocotyledonous plants, with the fibres being characteristically hard and stiff in texture. The 'hard fibres' include fibres from the vascular bundles in the leaves of *Agavaceae* such as sisal, henequen, cantala (*Agave cantala* Roxb.), the leaf-sheaths in the pseudostems of abaca, and the petioles of *Raphia* spp.
- Entire leaves or leaf strips: used for plaiting and weaving (*Palmae* and *Pandanaceae*), thatching (many *Palmae* and *Pandanaceae*), as platters (e.g. *Heliconia indica*), and for packing (e.g. the leaf blades of *Musa* spp.).

Seed and fruit fibres include cotton, formed by elongation of individual epidermal hair cells of the seed, kapok, a fruit hair fibre, and coir, the fibre comprising the mesocarp of the coconut.

Of the 72 major fibre plants treated in this volume, 44 mainly yield stem material, 25 are mainly exploited for their leaves (including leaf-sheaths), and 5 provide seed or fruit fibres (Table 9). The plants yielding stem fibres include 23 species yielding bast material, 20 species of which entire or split stems are used, and 1 species of which the pith of the stems is used. The plants yielding leaf fibres include 18 species of which the entire leaf or leaf strips are used, and 13 of which leaf fibres are separated. The plants yielding seed or fruit fibres are 4 species yielding seed fibres and 1 species yielding fruit fibres.

Table 9. Taxonomic and morphological data on the major fibre plants treated in this volume.

Family	Scientific name	Type of plant	Main plant parts used
Agavaceae	*Agave cantala*	perennial herb	leaf fibre
	Agave sisalana	perennial herb	leaf fibre
	Furcraea foetida	perennial herb	leaf fibre
Apocynaceae	*Anodendron candolleanum*	liana	bast fibre
	Anodendron oblongifolium	liana	bast fibre
	Anodendron paniculatum	liana	bast fibre
Araliaceae	*Tetrapanax papyriferus*	shrub–tree	pith
Bombacaceae	*Ceiba pentandra*	tree	fruit fibre
Cyclanthaceae	*Carludovica palmata*	perennial herb	leaf
Cyperaceae	*Actinoscirpus grossus*	perennial herb	stem
	Cyperus elatus	perennial herb	stem
	Cyperus malaccensis	perennial herb	stem
	Cyperus papyrus	perennial herb	stem
	Cyperus procerus	perennial herb	stem
	Fimbristylis umbellaris	perennial herb	stem
	Lepironia articulata	perennial herb	stem
	Schoenoplectus lacustris	perennial herb	stem
	Schoenoplectus litoralis	perennial herb	stem
	Schoenoplectus mucronatus	perennial herb	stem
	Scirpodendron ghaeri	perennial herb	leaf
Dracaenaceae	*Sansevieria roxburghiana*	perennial herb	leaf fibre
	Sansevieria trifasciata	perennial herb	leaf fibre
Gramineae	*Arundo donax*	perennial grass	stem
	Miscanthus floridulus	perennial grass	stem
	Miscanthus sinensis	perennial grass	stem
	Phragmites vallatoria	perennial grass	stem
Hemerocallidaceae	*Phormium tenax*	perennial herb	leaf, leaf fibre
Hydrocharitaceae	*Enhalus acoroides*	perennial herb	leaf fibre
Hypoxidaceae	*Curculigo capitulata*	perennial herb	leaf fibre, leaf
	Curculigo latifolia	perennial herb	leaf fibre, leaf
Juncaceae	*Juncus effusus*	perennial herb	stem
Linaceae	*Linum usitatissimum*	annual herb	bast fibre
Malvaceae	*Gossypium arboreum*	annual or perennial shrub	seed fibre
	Gossypium barbadense	annual or perennial (under)shrub or tree	seed fibre
	Gossypium herbaceum	annual or perennial (sub)shrub	seed fibre
	Gossypium hirsutum	annual herb or perennial shrub	seed fibre
	Hibiscus cannabinus	annual herb	bast fibre
	Hibiscus sabdariffa	annual herb	bast fibre
	Malachra capitata	annual or perennial herb	bast fibre
	Malachra fasciata	annual herb	bast fibre
	Thespesia lampas	shrub–tree	bast fibre
	Urena lobata	annual or perennial shrub	bast fibre
Marantaceae	*Donax canniformis*	perennial herb	(peel from) stem
Moraceae	*Artocarpus elasticus*	tree	bast
	Broussonetia papyrifera	tree	bast

Table 9. Continued.

Family	Scientific name	Type of plant	Main plant parts used
Musaceae	*Heliconia indica*	perennial herb	leaf
	Musa textilis	perennial herb	fibre from leaf-sheath
Nepenthaceae	*Nepenthes ampullaria*	climber	stem
	Nepenthes rafflesiana	climber	stem
Palmae	*Corypha utan*	palm	leaf
	Eugeissona triste	palm	leaf
	Raphia farinifera	palm	leaf, leaf fibre
	Raphia hookeri	palm	leaf, leaf fibre
	Raphia vinifera	palm	leaf, leaf fibre
Pandanaceae	*Pandanus atrocarpus*	tree	leaf
	Pandanus furcatus	tree	leaf
	Pandanus kaida	tree	leaf
	Pandanus odoratissimus	tree	leaf
	Pandanus tectorius	tree	leaf
Sterculiaceae	*Abroma augusta*	shrub–tree	bast fibre
	Helicteres isora	shrub–tree	bast fibre
Thymelaeaceae	*Wikstroemia indica*	shrub	bast fibre
	Wikstroemia lanceolata	shrub	bast fibre
	Wikstroemia meyeniana	shrub	bast fibre
	Wikstroemia ovata	shrub	bast fibre
Tiliaceae	*Colona javanica*	tree	bast
	Colona serratifolia	tree	bast
	Corchorus capsularis	annual herb	bast fibre
	Corchorus olitorius	annual herb	bast fibre
Typhaceae	*Typha domingensis*	perennial herb	stem, leaf
	Typha orientalis	perennial herb	stem, leaf
Urticaceae	*Boehmeria nivea*	perennial herb or shrub	bast fibre

1.4.2 Growth and development

Most fibre plants treated in this volume are perennials (Table 9). Many of those that are harvested for leaf fibres are monocarpic: they flower only once after a certain number of leaves have formed, and die after flowering. Examples are the perennial herbs *Agave cantala, A. sisalana, Furcraea foetida* (L.) Haw., *Musa textilis, Phormium tenax, Sansevieria roxburghiana* J.A. Schultes & J.H. Schultes and *S. trifasciata* Prain, and the palms *Corypha utan* Lamk, *Eugeissona triste, Raphia farinifera* (Gaertn.) Hylander, *R. hookeri* and *R. vinifera* P. Beauv. In sisal, for instance, 200–250 leaves are formed before the plant flowers. As the leaf emergence rate depends on ecological conditions (mainly temperature and rainfall) the lifespan of a sisal plant may vary from 3 to 20 years. Annual bast fibre plants such as jute, kenaf, roselle and flax are usually not allowed to complete their life cycle, because the fibres are located in the vegetative parts, and optimum fibre quality is obtained by harvesting immature plants. Seed and fruit fibre plants such as cotton and kapok, on the other hand, are harvested after completion of a generative phase. Cotton is basically a perennial plant with an indeterminate growth habit, but it is usually grown as an annual, with the formation of nodes on the main stem arrested by fruit load, temperature, soil moisture, photoperiod, or a combination of these factors.

1.5 Ecology

1.5.1 Climatic factors

Day length influences growth and development of several fibre plants, indirectly affecting growth and yield. Hemp, jute, kenaf, roselle and ramie, for instance, are short-day plants, requiring photoperiods of less than about 12.5 hours for flower induction. When days are longer than the critical photoperiod (in practice often around 12.5 h, but this depends on species, cultivar and temperature), flowering is delayed, which is desirable for bast-fibre producing crops. Flax, on the other hand, is a long-day plant. Modern cotton cultivars are generally photoperiod-insensitive. The variation in photoperiod-sensitivity among cultivars can be exploited by choosing sowing dates and cultivars in such a way that the duration of the vegetative period and yield are optimal.
The majority of the fibre plants treated in this volume, including abaca, cantala, coir, Congo jute, cotton, jute, kapok, roselle and sisal, grow best at average temperatures of about 25°C. Several species, such as kenaf, ramie and paper mulberry, also grow well at somewhat lower temperatures. Fibre hemp, flax, *Juncus effusus*, *Miscanthus* spp., *Phormium tenax* and *Tetrapanax papyriferus* (Hook.) K. Koch require a temperate climate; in South-East Asia they can usually only be grown successfully at higher altitudes. Most fibre plants treated in this volume are not frost-hardy, but mature *P. tenax* is tolerant to frost and *T. papyriferus* may also survive light frost.
Rainfall requirements vary widely. Among the perennial fibre plants, the minimum annual requirements of *Sansevieria* spp. (250 mm), *P. tenax* (500 mm) and sisal (< 1000 mm) are low, but these crops are also found in areas with much higher rainfall, for instance 3500 mm for *P. tenax*. Cantala also prefers semi-arid conditions, though it can be grown in higher rainfall areas as well. Abaca, on the other hand, needs 2000–3000 mm of rainfall per year. Perennials with intermediate annual requirements include kapok and *Thespesia lampas* (1500–1700 mm). Monocarpic perennials such as sisal and cantala form fewer leaves per year and have a longer life cycle under dry conditions or at low average temperatures. For annual fibre crops, the rainfall during the growing season is more important than the total annual rainfall, with cotton, for instance, needing at least 500 mm during the growing season. In general, jute and kenaf require about 100–125 mm per month, flax 150–200 mm, Congo jute 160–210 and roselle 150–270 mm.
Some fibre plants tolerate a wide range of ecological conditions. As such, they are easy to grow and in fact behave as weeds in many instances. *Arundo donax* L., for example, grows at average annual temperatures between 9 and 29°C and an annual rainfall of 300–4000 mm.

1.5.2 Soil factors

The soil requirements of fibre plants vary, but rich alluvial, sandy loams,

loams and clayey soils are generally preferred. The pH affects the efficient utilization of soil nutrients; generally, soils which are slightly acidic are suitable for most of the species treated, though cantala prefers limestone soils. Most textile and cordage fibre plants, including abaca, cantala, kenaf, ramie, roselle and sisal, need well-drained soils, as they do not tolerate waterlogging, but white jute (*Corchorus capsularis* L.) is relatively tolerant to inundation in later development stages. Many plants used for weaving, on the other hand, grow in swampy or inundated locations: *Donax canniformis*, *Juncus effusus*, *Phragmites vallatoria* (Pluk. ex L.) J.F. Veldkamp, *Typha* spp. and *Cyperaceae* such as *Actinoscirpus grossus* (L.f.) Goetgh. & D.A. Simpson, *Cyperus* spp., *Fimbristylis umbellaris*, *Lepironia articulata* (Retz.) Domin, *Scirpodendron ghaeri* (Gaertn.) Merr. and *Schoenoplectus* spp. A special case is *Enhalus acoroides*, which is subaquatic.

1.6 Agronomy

1.6.1 Production systems

Although naturally occurring plants have been important sources of fibre since the beginning of history, it is desirable for a viable industry to be able to obtain raw material from sustainable and well-managed farmers' plots or industrial plantations. Supply from the wild may be sufficient for the local needs of communities in the immediate vicinity. Species collected from the wild are sometimes over-exploited and may be threatened with extinction, especially those with restricted and endemic distribution such as some *Pandanus* spp. In the Philippines, for example, gatherers of fibre plants collect and sell fibre plants from the wild for their livelihood and a shortage of some wild species has already arisen, for example, various rattan species. Nevertheless, many species treated in this volume are collected from the wild and some have become important raw materials for local use and small-scale cottage and handicraft industries. Sometimes propagules are collected from the wild and planted in home gardens or fields, either as sole crops or as components of intercropping systems. Many of the perennial species intended for domestic and local uses are intercropped, whereas annual herbs are mostly grown as sole crops. Industrial plantations of major crops in South-East Asia include those of cotton, abaca, ramie, kenaf, roselle, jute, cantala and sisal, the extent of which differs from country to country and depends on the requirements of domestic and export needs. The stiff competition offered by fibre crop producing countries outside South-East Asia limits the scope for industrial plantations in the region.

1.6.2 Propagation and planting

Many fibre plants are propagated by seed but a range of vegetative methods are employed as well (Table 10). The disadvantage of seed propagation for cross-pollinating species is the genetic variation of the resulting progeny that may express undesirable fibre characteristics, and extensive use may sometimes rapidly decrease seed viability. Most fibre plants in Table 10 show no seed dormancy but *Pandanus* spp. possess a hard exocarp which should be soaked in water first for faster germination. Methods of vegetative propagation

Table 10. Propagation methods of the major fibre plants treated in this volume.

Species	Propagation methods
Abroma augusta	seed, stem cuttings, suckers
Actinoscirpus grossus	seed, stolons
Agave cantala	suckers, bulbils, in vitro culture
Agave sisalana	suckers, bulbils, in vitro culture
Anodendron spp.	unknown
Artocarpus elasticus	seed
Arundo donax	division, suckers
Boehmeria nivea	rhizome cuttings, seed, division, air layering, stem cuttings, in vitro culture
Broussonetia papyrifera	seed, wood or root cuttings, suckers, layering, grafting, in vitro culture
Carludovica palmata	seed, suckers, rhizomes
Ceiba pentandra	seed, wood cuttings
Colona spp.	unknown
Corchorus spp.	seed, stem cuttings, in vitro culture
Corypha utan	seed, in vitro culture
Curculigo spp.	division, suckers, seed, in vitro culture
Cyperus spp.	seed, division, cuttings
Donax canniformis	unknown
Enhalus acoroides	seed
Eugeissona triste	seed
Fimbristylis umbellaris	division, seed
Furcraea foetida	bulbils
Gossypium spp.	seed, in vitro culture
Heliconia indica	division, seed
Helicteres isora	seed, stem cuttings
Hibiscus cannabinus	seed, stem cuttings
Hibiscus sabdariffa	seed, stem cuttings
Juncus effusus	division, rhizomes, seed, in vitro culture
Lepironia articulata	division
Linum usitatissimum	seed
Malachra spp.	seed, cuttings
Miscanthus spp.	division, rhizome cuttings, seed, in vitro culture
Musa textilis	suckers, corms, seed, in vitro culture
Nepenthes spp.	layering, cuttings, seed
Pandanus spp.	sucker shoots, stem cuttings, seed
Phormium tenax	division, seed
Phragmites vallatoria	division, seed, in vitro culture
Raphia spp.	seed, in vitro culture
Sansevieria spp.	division, suckers, leaf cuttings, seed, in vitro culture
Schoenoplectus spp.	seed, division
Scirpodendron ghaeri	offsets
Tetrapanax papyriferus	seed, suckers
Thespesia lampas	seed, cuttings
Typha spp.	division, seed
Urena lobata	seed
Wikstroemia spp.	seed, stem cuttings, in vitro culture

Various sources.

include the use of stolons, rhizomes, bulbils and suckers, whereas stem and branch cuttings are also common. The desired fibre characteristics can be maintained by vegetative propagation. Rooting is easily stimulated by application of growth regulators.

Though most species can be propagated in several ways, often one specific method is practised. Most annual fibre plants, including cotton, flax, hemp, jute, kenaf, roselle and sunn hemp, are propagated by seed. The preferred propagation methods for perennial fibre plants are mostly vegetative, for example using rhizome cuttings (ramie), suckers (cantala), bulbils (sisal, *Furcraea foetida*) and corms (abaca). Kapok is propagated by either seed or cuttings, and in Indonesia seedlings are grafted with high-yielding clones.

Although commonly used in other major crops, in vitro propagation techniques are rarely used in fibre crops, though they have been developed for abaca, cantala, sisal, paper mulberry, *Juncus effusus*, *Raphia* spp. and *Wikstroemia* spp. The application of in vitro propagation techniques may prove beneficial in the near future, as this may be a way to provide disease-free and homogeneous plant material in sufficient quantities. At present, the only mass-propagation of fibre plants through in vitro culture in South-East Asia is with abaca in the Philippines, where tissue-cultured plants are used in replanting programmes.

Many fibre plants, especially those with small seeds, are broadcast directly in the previously prepared field, but other crops are raised first in nursery seedbeds before being planted out. Adequate spacing between plants is required to allow for weeding and harvesting. Close planting is observed, for instance in jute, kenaf, roselle and *Helicteres isora*, to avoid branching which would lower the quantity and quality of the fibre obtained. Sisal is sometimes planted in a double-row system ('twin-row planting'), in which pairs of rows are alternated by wider spaces ('lanes'); the plants in the rows nearest to each other are staggered, so that they are as far apart as possible (Lock, 1969). Table 11 presents an overview of commonly applied plant spacings and densities for the most important fibre crops.

1.6.3 Husbandry

Cropping techniques for fibre plants differ little from those of other annual and perennial crops. Weed control is a primary concern as weeds may reduce the quantity and quality of the fibre. It is especially important in plants with little competitive ability (e.g. flax), and during the early stages of development for most crops. Furthermore, weeds sometimes harbour diseases and pests that may be detrimental to the crop.

Irrigation of fibre crops in industrial plantations occurs in Indonesia for roselle, but most fibre plants are planted at the onset of the rainy season and grown under rainfed conditions. Cotton, however, may be grown under irrigated or rainfed conditions.

Fertilizer recommendations depend on soil characteristics and nutrient uptake of the fibre crop. The nutrient uptake of flax, for instance, is relatively low: for a crop yielding 5–6 t straw and 0.6–0.8 t seed per ha it is 50–75 kg N, 10–16 kg P and 40–60 kg K. Cotton and jute have moderate nutrient uptake. For a yield of about 1.7 t/ha seed cotton, the uptake is about 105 kg N, 18 kg P and 66 kg K per ha (Halevy & Bazelet, 1989). The uptake by 1 ha of *Corchorus capsularis*

Table 11. Common plant spacings and densities for selected fibre crops.

Crop	Spacing (cm)	Density (pockets/ha)
Annual		
Cotton	50–120 × 20–60	14 000–100 000
Flax	6–15 (between rows)	18 000 000–33 000 000
Jute	broadcast	330 000–440 000
	30 × 7–8	420 000–440 000
Kenaf	broadcast	400 000
	20–30 × 5–10	330 000–1 000 000
Roselle	20–40 × 15–30	80 000–330 000
Perennial		
Abaca	200–300 × 200–300	1100–2500
Ramie	25–140 × 5–60	12 000–800 000
Sisal	200–250 × 80–100 (single rows)	2500–5000
	270–400 × 75–100 (double rows; 90–100 cm between rows of each pair)	4000–7200

Various sources.

producing 2 t dry retted fibre is about 63 kg N, 14 kg P and 132 kg K (Dempsey, 1975). An example of a fibre plant with a high nutrient uptake is Congo jute: for a typical production of about 2.2 t dry retted fibre per ha, the nutrient uptake is 190 kg N, 24 kg P and 175 kg K per ha (Dempsey, 1975). The nutrient removal may be less than the nutrient uptake, because plant parts containing absorbed nutrients, such as leaves, are sometimes returned to the field. In flax, kenaf and roselle, for instance, stems are left to defoliate in the field after harvesting. In cotton, however, the destruction of harvested plants is prescribed to control pests and soil-borne diseases. Crop rotation and the use of organic fertilizers may also be applied to maintain soil fertility.

1.6.4 Crop protection

Diseases and pests of fibre crops in South-East Asia include fungi, bacteria, viruses, nematodes, insects and parasitic plants. Important fungal diseases of fibre plants include seedling and stem rot (*Macrophomina phaseolina*) on jute and kenaf, white fungus disease (*Rosellinia necatrix*) on ramie, collar rot (*Phytophthora nicotianae* var. *parasitica*) on kenaf and roselle, Fusarium wilt on cotton, abaca, kenaf and roselle, and Verticillium wilt on cotton. An important bacterial disease is bacterial blight (*Xanthomonas campestris* pv. *malvacearum*) on cotton. Important virus diseases are bunchy top and abaca mosaic on abaca. Nematode problems are often caused by root-knot nematodes (*Meloidogyne* spp.), for example on cotton and kenaf. Important pests include various bollworms on cotton, the jassid leaf hopper (*Amrasca biguttula*) on roselle, and the Mexican sisal weevil (*Scyphophorus interstitialis*) on sisal. Parasitic plants include *Loranthaceae*, which damage kapok, and *Orobanche ramosa* L. on hemp (Wulijarni-Soetjipto et al., 1999). For many lesser-known species there is little or no information available on diseases and pests.

Control of diseases and pests includes cultural, chemical and biological methods. Cultural methods include field sanitation by destroying crop residues, eradication of affected plants or plant parts, destruction of weeds that serve as alternate or collateral hosts, the use of resistant genotypes and clean planting material, crop rotation, harvesting in the dry season, application of appropriate tillage practices and manual removal of pests. Cultural methods may be sufficient in small-scale agriculture, but they are often uneconomic in large-scale industrial plantations. Here, diseases and pests are usually controlled by chemicals, but care should be taken to reduce toxic side-effects. Chemical control is effective only if the timing is correct and often supplementary cultural methods are necessary. Cotton is notoriously sensitive to pests, which has led to excessive spraying of insecticides. Resistance breeding and approaches such as Integrated Pest Management (IPM), comprising a range of techniques including the use of specific cultivars, a short planting period, adequate fertilization, planting of trap crops, weekly pest monitoring, spraying with *Bacillus thuringiensis* at an early growth stage, the release of natural enemies (e.g. *Trichogramma chilonis*) and the use of synthetic insecticides when the pest population reaches a critical level, are applied to reduce pesticide use in cotton (Pascua et al., 1997).

1.7 Harvesting and processing

1.7.1 Harvesting

The time from planting to first harvest ranges from a few months in annual herbs such as jute and kenaf to several years in perennials such as abaca and sisal.

The time of harvest for annual bast fibre plants such as jute, flax, kenaf and roselle involves a trade-off between fibre yield and quality, and these plants are usually harvested at a specific developmental stage. Jute, for instance, is harvested at mid-flowering; earlier harvesting results in lower yields of fine fibre, whereas later harvesting results in higher yields, but a coarser and lower-quality fibre. Annual bast fibre plants are usually harvested manually, by cutting or pulling. Often bundles of harvested material are left for some days in the field to accelerate defoliation and desiccation.

In perennial fibre crops such as sisal the leaves are also cut manually. Care must be taken to leave sufficient leaf area at each cutting to enable the plant to continue optimal growth. In sisal, for instance, about 20–25 leaves are left on the plant at the first cutting, which is usually decreased to 15–20 leaves at subsequent cuttings.

1.7.2 Post-harvest handling and processing

Various basic procedures are used to separate fibres from the surrounding plant tissues. The main processes are retting, scutching, chemical treatment, decorticating and ginning (Simpson & Conner Ogorzaly, 1995; Wood, 1997). Excessive processing, whether microbial, chemical or mechanical, results in degradation of the cellulose fibrils and a decrease in fibre quality (McDougall et al., 1993).

Retting

Retting is the usual extraction procedure for bast fibres. It is a microbiological process in which the combined action of water and microbial (mainly bacterial) enzymes decomposes the pectic material around the fibre bundles so freeing the fibre bundles, which can then be extracted manually (McDougall et al., 1993; Wood, 1997). It normally involves the immersion of bundles of stems in ponds or streams. The time required depends on temperature and varies widely. Where temperature and humidity are high and there is little wind, stems can be dew-retted in the field. In this case, the active organisms are fungi that break down the pectic substances in the bark (Wood, 1997).

Scutching

The retted stems of flax and hemp are dried, after which they are passed through fluted rollers to break the core into pieces of woody matter called 'shiv' that remain attached to the fibre. The material is then passed through a 'scutching' machine, which removes the shiv from the fibre by beating and scraping. The fibre is subjected to a special combing operation ('hackling') prior to spinning (Simpson & Conner Ogorzaly, 1995; Wood, 1997).

Chemical treatment

Fibres extracted by retting are still encrusted with lignins and hemicelluloses, affecting the fibre quality. Fibres to be used for textile production are often subjected to additional chemical treatment to remove these compounds. Ramie, for instance, contains a gummy pectinous material that is not broken down by retting, and separation of the fibre requires a chemical treatment. This is usually done in the spinning mill prior to the spinning operation. The treatment involves soaking the separated bark in weak alkali baths for a given period at a given temperature. The chemical most often used is caustic soda, but other sodium-based alkalis are also used. The specific combination of treatment time, temperature, the alkali type and its concentration, are usually proprietary information (McDougall et al., 1993; Wood, 1997).

Decortication

Decortication is used primarily for hard leaf fibres such as sisal, cantala and henequen. It involves crushing the plant material and scraping the non-fibrous material from the fibres. In this process, the leaves are trimmed to remove the spines and subsequently passed through decorticating machines that crush them between rollers and scrape them against a bladed drum. During scraping, water is sprayed onto the leaves to help separate the fleshy waste material from the fibre. Wet decorticated fibre is usually washed before being dried. After drying, the fibres are brushed mechanically to remove dust and other matter and to increase the lustre.

Ginning

Ginning is applied to seed fibres such as those from cotton. It is a process during which seeds are pulled free from the fibres covering them, in the case of cotton followed by extensive further cleaning and combing of the fibres (Simpson & Conner Ogorzaly, 1995). The invention and development of the saw gin in the 1790s largely contributed to a rapid expansion of cotton production (Smith, 1995).

Other mechanical procedures

Bast fibres can also be extracted from green or dried stem material by mechanical means without being retted first. A simple method is to pass dried stems through a sloping rotating cylinder with bars that abrade the material as it passes through the cylinder. The core material is broken down and screened out, whereas the fibre bundles remain intact and pass through the length of the cylinder. Machines of this type have been developed for kenaf in the United States.

Ribboning machines are used for green stem material, in which the bark separates easily from the stem. The stems are fed through the machine, with the bark being recovered. The bark ribbons may subsequently be retted in the usual way (Wood, 1997).

Further processing

Spinning is the process in which a partly tangled mass of fibres is combed or carded, and separated into a parallelized rope form known as a 'sliver'. This sliver is drawn out to a certain thickness so that it can be twisted into a yarn. In the course of these operations the fibres are combed with steel pins and made to bend around various fluted rollers moving at fast speeds. If the fibres are not sufficiently strong they will not be able to withstand such treatment and the strength of the final yarn will be unsatisfactory. To soften and lubricate the fibres, they may be sprayed with a lubricant or batching oil before processing (Kirby, 1963). Fibre filaments of good spinning quality have a small diameter, high intrinsic resistance and uniform surface structure (Maiti, 1997). In the ancient form of spinning, employed by cultures in both hemispheres and still in use in some cultures, a spinning stick (also called 'spindle') is rotated by one hand to take up the yarn produced by twisting the fibres between the thumb and forefinger of the other hand. The spinning wheel was probably invented in India between 500 and 1000 AD. In early versions the wheel, rotating the spindle by means of a band or belt, was turned by hand. Later additions were foot pedals for turning the wheel and a distaff to hold the unwoven fibre mass, thus freeing both hands for twisting. In response to the rising demand for cotton yarn, the first spinning machines were developed in England in the middle of the 18th Century (Smith, 1995).

Weaving is the process of producing fabric by interlacing one set of yarn with another set at right angles, usually by means of a loom. The yarns running the length of the fabric are termed warp (or warp yarns), whereas the crosswise yarns are called filling or weft (or weft yarns) (Smith, 1995).

In the manufacture of rope, lengths of fibre are spun into yarns, which are twisted together into strands. The strands are twisted in the opposite direction to the yarns to form a rope. Most rope consists of 3 strands twisted in a right-hand direction.

1.7.3 Pulping

The primary aim of pulping is to separate fibres and to produce a fibre surface suitable for bonding in the process of paper making (Moore, 1996). Many pulping processes have been developed to convert raw materials into separated fibres suitable for use in paper making. The pulping methods can be divided into three main processes: chemical, mechanical and semi-chemical. The processes differ in their nature and the pulp yield obtained. The chemical processes separate the cellulose from the lignin, whereas the mechanical processes convert all the constituents present. As a consequence, chemical processes give pulp yields of only 30–50%, whereas mechanical processes give yields of over 80%. The choice of the appropriate pulping process depends on the raw material to be pulped and the grade of paper or board product to be made from it (Moore, 1996).

Chemical pulping processes

Chemical processes involve the use of chemicals to separate the lignin fraction of raw materials. The processes rely on the action of one or more radicals acting on the lignin compounds. Chemical separation causes little or no damage to the fibre length. Recovery of the active chemicals is an important environmental and economic consideration.
Chemical pulping processes are applied to both hardwoods and softwoods. The yield of fibre for paper making from wood is typically 40–50%. Chemical pulps from softwoods have high tear, tensile and burst strengths and are particularly suitable for sacking and wrapping papers. Pulps from hardwood generally have lower strength, but have properties making them more suitable for printing and writing papers. Often hardwood and softwood pulps are blended to make a particular product (Hague, 1997). So-called 'woodfree paper' contains at least 90% chemical pulp.
Chemical pulping processes include:

- *Sulphite process*: one of the earliest chemical processes (Moore, 1996), normally involving the heating of raw material with a solution of $NaHSO_3$ and/or Na_2SO_3 (McDougall et al., 1993). This process is less applied nowadays, because of the imperfect recovery of the chemicals (Moore, 1996). It is, however, still used for the production of papers with specific properties, such as sanitary and tissue papers which must be soft, absorbent and of moderate strength (McDougall et al., 1993).
- *Kraft or sulphate process*: the most widely used chemical pulping process, in which the raw material is treated with a solution of NaOH and Na_2S, forming the reactive anions S^{2-} and HS^- (McDougall et al., 1993). A disadvantage is the occurrence of sulphur-based air emissions. The kraft process is well established for wood-based materials, but too severe for most non-wood materials, where lignin is less strongly bonded to the cellulose.

- *Soda process*: based on sodium hydroxide and widely used in the processing of non-wood fibres. Chemical recovery is straightforward and the virtual absence of reduced sulphur compounds in the process means that there are few emission problems. Yield improvements have been obtained by using additives such as anthraquinone.
- *Organosolv process*: an organic solvent or mixture of organic chemicals is used. This makes the recovery possible of all the components of the raw material (cellulose, hemicelluloses, lignin) and the solvent itself. The advantages over other chemical processes are higher pulp yields, easy bleaching, lower costs and less environmental stress. However, only an alcohol-based system has been developed into a commercial operation (Hague, 1997; Moore, 1996).

Mechanical pulping processes

In mechanical pulping processes the whole material or large part of it is converted into pulp by mechanical action. These processes are characterized by high yields. The resulting pulp contains cellulose, hemicelluloses and lignin. Mechanical processes are cheaper than chemical processes, with higher yields and less pollution (Sabharwal et al., 1995). Disadvantages of mechanical processes are the high energy demand and the damage caused to the fibres; they generally cause severe shortening of fibre length (Moore, 1996; Sabharwal et al., 1995). Mechanical pulping is mainly applied for softwoods such as spruce. The pulps are usually used for short-life, low-cost products such as newsprint (Hague, 1997; Hill, 1952).
Mechanical pulping processes include:
- *Stone groundwood (SGW) process*: the earliest mechanical process, in which raw material is ground by means of a rotating stone. Resulting pulps have a short fibre length. The addition of long-fibre chemical pulp is often necessary to give the required strength to the final paper sheet.
- *Pressurized groundwood (PGW) process*: developed from the SGW process to produce pulps with better strength properties and using less energy. The process is basically the same except that the pulp is prepared at a steam pressure of 1–2 bar.
- *Refiner mechanical pulping (RMP) process*: chips of raw material are fed into a rotating disc refiner, which breaks them into single whole fibres. Subsequently some of the whole fibres are fibrillized (converted into fibrils and cell wall fragments), which enhances the bonding characteristics of the pulp. RMP production is usually a multi-stage process involving a primary and a secondary refiner. The energy consumption of RMP can be reduced by pretreatment of the raw material by chemicals before or during refining (chemirefiner mechanical pulping, CRMP) or fungal treatment before mechanical refining (bio-refiner mechanical pulping, BRMP) (Sabharwal et al., 1995).
- *Thermo-mechanical pulping (TMP) process*: heat in the form of steam is applied to the raw material prior to fibre separation by means of disc refiners. Heating has a softening effect on the chips and reduces fibre damage during the mechanical action. TMP production is more energy intensive than SGW or RMP, but the pulp has better strength properties. Newsprint, for instance, can be manufactured from 100% TMP (Moore, 1996; Hague, 1997).

A range of mechanical processes have been developed involving chemical pretreatment (mostly with sodium sulphite), either alone or in combination with a temperature pretreatment. Examples are the *chemi-mechanical pulping (CMP) process*, the *chemi-thermo-mechanical pulping (CTMP) process* and the *thermo-chemi-mechanical pulping (TCMP) process*. Of these, CTMP, using a pretreatment with 1–4% sodium sulphite, has become the most widely used. Most chemical pretreatments do not affect pulp yields, but only soften the chips prior to fibre separation. These essentially mechanically based processes are often difficult to distinguish from semi-chemical processes (Moore, 1996). Promising results have been obtained with CTMP and TMP for kenaf bark and comparable results may be obtained with other bast fibre crops (Wood, 1997).
Processes with biological pretreatments (biomechanical pulping) are mainly based on the use of fast-growing lignin-degrading white rot fungi (*Phanerochaete chrysosporium* and *Phlebia tremellosa*). The pretreatment involves inoculation of the material followed by an incubation period of up to 4 weeks at 39°C prior to fibre separation. Reductions in energy use and enhancement of strength properties of the pulp have been achieved (Moore, 1996).

Semi-chemical pulping processes

Semi-chemical pulping processes consist of a chemical and a mechanical pulping stage. Wood chips are initially cooked in a digester, and then defibrated with disc refiners. Pulp yields are typically in the range of 65–85% (Hague, 1997). The principal semi-chemical pulping process is the *neutral sulphite semi-chemical process (NSSC)*, which involves chemical pretreatment followed by refining (Hague, 1997; Moore, 1996). The major differences between this and chemically pretreated mechanical processes are the concentration of the chemicals used and the conditions under which the pretreatment takes place. The chemical treatment typically involves the use of up to 15% sodium sulphite by mass of material, and approximately 4–5% sodium carbonate by mass. The process has been used extensively for the production of pulps for corrugating media, as NSSC pulps have the necessary stiffness characteristics required. Other semi-chemical processes include the *sodium bisulphite*, *cold soda*, and *neutral sulphite-anthraquinone (NS-AQ) processes* (Moore, 1996).
Hardwoods are commonly pulped using the NSSC process, with the pulps particularly suitable for use in packaging grades of paper, e.g. corrugating medium (Hague, 1997).

Further processing

Bleaching is used to remove or inactivate chromophores, and techniques used in paper making are similar to those used in textile industries. Most methods remove lignin not removed through pulping, though some techniques remove chromophores without degrading the residual lignin. Most bleaching techniques use Cl_2, NaOCl or ClO_2 as active agent. Chlorinated bleaching methods are efficient, but produce toxic and mutagenic effluents (McDougall et al., 1993; Nezamoleslami et al., 1998). Therefore, non-chlorinated bleaching agents, producing less toxic waste, are very much in demand nowadays. Examples are oxygenated agents such as O_2/OH^-, H_2O_2 and O_3. However, the alkaline condi-

tions used in oxygen bleaching cause swelling of the fibres, reducing their strength and hemicelluloses content, thereby reducing the ability of the fibres to bond together (McDougall et al., 1993). Another possibility is to replace chlorine-based bleaching of wood and non-wood pulps with biological bleaching using ligninolytic white-rot fungi, such as *Phanerochaete chrysosporium* and *Trametes versicolor* (Nezamoleslami et al., 1998).
For electrical insulating papers the fibre must be free from ions, and therefore unbleached pulps, washed with purified water, are used (McDougall et al., 1993).
Once bleached, paper pulp, while still hydrated, may be beaten to give a fluffy, highly absorbent fibre suitable for sanitary products (McDougall et al., 1993).

1.7.4 Boards

Particle board is manufactured by hot-pressing pre-formed mattresses consisting of fibrous particles blended with resin and wax. Medium density fibreboard (MDF) is manufactured by defiberizing softened wood chips at elevated temperatures (170°C) using disc refiners, blending the resulting fibres with resin and wax, followed by drying, mattress forming and hot-pressing. The resin most commonly used to bind particles together in particle board and MDF is urea formaldehyde (UF). Melamine reinforced UFs (MUF) are used where some moisture resistance is needed. For exterior use phenol formaldehyde (PF) or isocyanates (MDI) may be used. They are more expensive than UFs, but lower quantities are needed and formaldehyde release from finished boards is significantly reduced. Small amounts of wax are added to boards to improve their short-term resistance to thickness swelling in damp or wet environments (Hague, 1997).

1.7.5 Artificial fibres

The production of the artificial fibre rayon requires highly purified cellulose as raw material. Originally cotton was used, because of its high cellulose content, but it has almost entirely been replaced by wood fibres (McDougall et al., 1993). The cellulose is dissolved by soaking pulp in strong alkali (18% NaOH), after which hemicelluloses and degraded cellulose are removed with the excess alkali. The damp cellulose is shredded, aged in air, and made to react with CS_2 to form cellulose xanthate. After dissolution in aqueous NaOH a solution is formed known as 'viscose', which is filtered and extruded while spinning into an acid bath. The xanthate groups are hydrolysed and the cellulose structure is re-established. The physical properties of the resulting product are mainly determined by the spinning conditions (McDougall et al., 1993).

1.8 Genetic resources and breeding

1.8.1 Genetic resources

Progress in crop improvement requires access to adequate resources of genetic variability. The collection, conservation and characterization of germplasm has developed into a highly specialized activity carried out in genebanks established by national and international agricultural research organizations (FAO, 1996). The International Plant Genetic Resources Institute (IPGRI) in Rome (Italy) has a mandate to advance the conservation and use of genetic diversity. It coordinates global genebank activities with emphasis on plant genetic resources in developing countries (IPGRI, 1999). In the case of fibre plants, active collection and conservation of genetic resources is limited to the economically most important crops. Table 12 presents an overview of genebanks with germplasm collections of 9 major fibre crops.

The cotton collection (COT) of the United States Department of Agriculture, Agricultural Research Service (USDA/ARS) at College Station in Texas, United States, is the world largest repository for cotton germplasm. This genebank holds seed samples of some 9000 accessions, including about 4600 of *Gossypium hirsutum* L., 2500 of *G. arboreum* L., 1200 of *G. barbadense* L., 200 of *G. herbaceum* L. and various numbers of accessions of a further 37 *Gossypium* spp. Another very important cotton genebank is that of CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) in Montpellier, France, with seed of 3600 accessions of the 4 main species and 31 other *Gossypium* spp. This latter collection is regularly evaluated and rejuvenated in grow-outs at a seed multiplication centre in Costa Rica (Hau, 1999). Smaller working collections of cotton germplasm are maintained by national agricultural research systems in China, India and several other cotton-producing countries. Molecular fingerprinting has contributed considerably to a better understanding of the genetic and genomic relationships between cotton varieties and species (Abdalla et al., 2001). Such information will facilitate more efficient utilization of cotton genetic resources in the future.

The Bangladesh Jute Research Institute (BJRI) in Dhaka is the mandated world repository for germplasm of jute and its allied fibre crops kenaf and roselle. This genebank stores and maintains about 6000 accessions, including some 4000 for jute alone (*Corchorus capsularis*, *C. olitorius* L. and other *Cor-*

Table 12. Germplasm collections of selected fibre crops.

Crop	**Principal germplasm repository and/or coordinator**[1]	**Other important collections**
Abaca	NARC, Philippines	Philippines (IPB)
Cotton	USDA/ARS, United States CIRAD, France	United States, China, India, Greece
Flax	INRA, France CGN, Netherlands FAL, Germany VIR, Russia	United States, Canada, India, China, Australia, Argentina
Jute and allied fibres	BJRI, Bangladesh CSIRO, Australia	India, Thailand, Indonesia
Kapok	ITOFCRI, Indonesia	
Ramie	IBF-CAAS, China	Brazil, Philippines
Sisal	IAC, Brazil	Tanzania

[1] IPGRI is the overall coordinator for most crops.
Various sources.

chorus spp.). A duplicate set of seed samples for these accessions is stored in the genebank of the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Canberra, Australia.

Genetic resources for *Linum usitatissimum* (flax and linseed) totalling more than 3000 accessions, representing mostly landraces and cultivars, are conserved in genebanks of many countries including France (Institut National de la Recherche Agronomique (INRA), Versailles), the Netherlands (Centre for Genetic Resources (CGN), Wageningen), Germany (Bundesforschungsanstalt für Landwirtschaft (FAL), Braunschweig; Genebank, Institute for Plant Genetics and Crop Plant Research (IPK), Gatersleben), the Russian Federation (N.I. Vavilov Research Institute of Plant Industry, St Petersburg), United States (United States Department of Agriculture (USDA), Beltsville), Canada (Plant Gene Resources of Canada (PGRC), Saskatoon), India (National Bureau of Plant Genetic Resources (NBPGR), Akola Regional Station), China (Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences (CAAS), Beijing), Australia, eastern European countries and Argentina (Fu et al., 2002; IPGRI, no date; Marshall, 1989). Molecular fingerprinting is also applied here to establish genetic diversity in flax and linseed germplasm (Fu et al., 2002).

Germplasm collections are maintained by national agricultural research systems in the main producing countries for each of the remaining 4 fibre crops. Brazil (Instituto Agronômico de Campinas (IAC), Campinas, São Paulo) has collections of ramie and sisal, the Philippines (Institute of Plant Breeding (IBP), College, Laguna; National Abaca Research Centre (NARC), Baybay, Leyte) of ramie and abaca, China (Institute of Bast Fiber Crops of the Chinese Academy of Agricultural Sciences (IBF-CAAS), Yuanjiang) of ramie, Tanzania (Mlingano Agricultural Research Station) of sisal and Indonesia (Indonesian Tobacco and Fibre Crops Research Institute (ITOFCRI), Malang) of kapok.

1.8.2 Breeding

The general objective of plant breeding is the development of cultivars with the potential to provide maximum economic benefits to the growers. This usually requires the simultaneous selection for plant type and vigour, ecological adaptation, yield, quality and other characters. Host resistance to diseases and pests may assume the highest priority in breeding, when these have become a threat to the profitability or even survival of the crop (Simmonds, 1979). The breeding plans applied to a particular crop species are very much determined by its life cycle (annual or perennial), mating system (self- or cross-pollinating) and methods of multiplication. These determinants are presented in Table 13 for major fibre crops with active breeding programmes and cultivar development.

The three most important fibre crops (cotton, jute and its allied fibres kenaf and roselle, flax) are predominantly self-pollinating annual species which are multiplied by seed. The breeding methods commonly applied include line and pedigree selection – starting from landraces, older cultivars, or segregating progenies after crossing and backcrossing – all leading to uniform, homozygous cultivars. These are true to type and can be multiplied in seed blocks with simple precautions such as guard-rows and minimum distances (specific for each crop) to avoid illegitimate outcrossing. F_1 hybrid cultivars with considerable hybrid vigour for yield have been successfully developed during the past two

Table 13. Life cycle, mating system and multiplication of selected fibre crops.

Crop	Predominant mating system	Multiplication
Annual		
Cotton	self-pollinating (70–95%)	seed (lines, F_1 hybrids)
Flax	self-pollinating (97–100%)	seed (lines)
Jute		
C. capsularis	self-pollinating (95–100%)	seed (lines)
C. olitorius	self-pollinating (88–100%)	seed (lines)
Kenaf	self-pollinating (88–99%)	seed (lines)
Roselle	self-pollinating (99–100%)	seed (lines)
Perennial		
Abaca	cross-pollinating	clones (suckers, corms), seed
Ramie	cross-pollinating	clones (rhizome cuttings)
Sisal	cross-pollinating	clones (suckers, bulbils)

Various sources.

decades for cotton. However, the available systems of cytoplasmic male sterility have been inadequate for large-scale production of hybrid seed, mainly due to incomplete expression of fertility restorer genes in the male parents. Current use of cotton hybrids is limited to South Asia and China, where seed production by manual emasculation and pollination is economically feasible due to low labour costs (Hau et al., 1997).

The perennial fibre crops sisal, ramie and abaca are cross-pollinating species. The cultivars are clones developed from single plants selected within open-pollinated seedling progenies of existing varieties, or populations following intra- and interspecific hybridization.

Breeding objectives for the most important fibre crops include, in addition to the general aim of higher yields:

- Cotton: photoperiod-insensitivity, early crop maturity, adaptation to mechanical harvesting (in industrialized countries), high quality lint fibre (length, fineness and strength), seed quality (oil content and low gossypol content by glandless plants), resistance to diseases (e.g. bacterial blight and *Fusarium* wilt) and pests (e.g. bollworms, jassids), and drought tolerance (Hau et al., 1997; Poehlman, 1987).
- Jute: early crop maturity and low photoperiod-sensitivity, finer and whiter fibre quality, resistance to diseases (*Macrophomina phaseolina*) and improved seed production (Dempsey, 1975).
- Flax: resistance to lodging, fibre quality (fineness, strength and homogeneity), disease resistance (anthracnose, *Fusarium* wilt, rust), oil content and fatty acid composition of the seed (Dempsey, 1975).

Molecular breeding

Plant biotechnology is providing powerful new tools for plant breeding with the potential to increase selection efficiency and creating new approaches to hitherto unattainable objectives. Molecular marker technology is applied in many crops for germplasm characterization and management, accelerating gene introgression from related species and for marker-assisted selection (MAS). MAS enables early selection of important major genes (e.g. disease resistance) with molecular markers closely linked to the genes controlling the trait. In the case of polygenic traits (e.g. components of yield and quality) a more complex quantitative trait loci (QTL) analysis is required for the identification of significantly linked markers. A prerequisite to such a QTL analysis is the availability of a saturated genetic linkage map (Mohan et al., 1997). Genetic modification (GM) is still limited to characters controlled by major genes for which gene isolation and transfer is relatively easy. It also requires the possibility of routine application of transformation technologies and regeneration of plants from in vitro explants or embryogenesis. Tolerance to herbicides (e.g. glyphosate or glufosinate) and insect resistance based on Bt genes (derived from *Bacillus thuringiensis*) are the main characters that have been successfully expressed and commercialized so far. Genetically modified soya bean, maize, cotton and rapeseed/canola crops were grown in 2001 on 52.6 million ha worldwide, with 96% of the area in North America and Argentina (James, 2001).

All the above-mentioned options of molecular breeding are being applied to cotton with considerable success (Hau, 1999; Kohel et al., 2001). Bt-cotton (GM cotton cultivars with resistance to bollworms based on Bt genes, partly in combination with herbicide tolerance) is already grown on 4.3 million ha, including 1.5 million ha in China alone. Bt-cotton was first released in Indonesia in 2001 and India is likely to follow soon (James, 2001). Cotton alone accounts for 25% of the world use of insecticides and Bt-cotton has proven to be a most effective way of reducing pesticide use, particularly because host resistance to bollworms and other important insect pests have not been detected so far in cotton germplasm. Risks of early breakdown of host resistance due to the occurrence of new biotypes of the pest appear lower than assumed initially (Tabashnik et al., 2000). Work is in progress to develop wide-spectrum insect resistance based on a combination of several Bt and proteinase-inhibitor genes (Hau, 1999). Flax is another fibre crop with numerous biotechnology applications in breeding (Friedt et al., 1989). These have already led to the release of GM cultivars with resistance to herbicides in Canada (Trouvé, 1996).

1.9 Research and development

The principal organizations and institutes conducting research and development on fibre plants in South-East Asia are the following:

Indonesia

- Indonesian Tobacco and Fibre Crops Research Institute, Malang
  * various aspects (agronomy, breeding, ecophysiology, plant protection), mainly of cotton, but also of jute, kapok, kenaf, ramie and roselle.
- Institute for Research and Development of Cellulose Industries, Bandung

Malaysia

- Forest Research Institute Malaysia (FRIM), Kepong

  * utilization of kenaf for pulp and paper and composite products.
- Malaysian Agricultural Research & Development Institute (MARDI), Serdang
  * utilization of kenaf for animal feed.
- Malaysian Institute for Nuclear Technology (MINT), Kajang
  * utilization of kenaf for pulp and paper and composite products.
- University Putra Malaysia (UPM), Serdang
  * utilization of kenaf for composite products.

The Philippines

- Cotton Development Authority (CODA), Pasig City
  * cotton (all aspects).
- Fibre Industry Development Authority (FIDA), Department of Agriculture (DA), Quezon City
  * all aspects: propagation, production, utilization, etc.
- Forest Products Research and Development Institute (FPRDI), Department of Science and Technology (DOST), College, Laguna
  * research and development on fibre crops for pulp and paper, composite boards, furniture and handicrafts.
- Institute of Plant Breeding (IPB), University of the Philippines Los Baños (UPLB), College of Agriculture (CA), College, Laguna
  * propagation and breeding.
- National Abaca Research Centre (NARC), Leyte State University, Baybay
  * all aspects of abaca, e.g. collection and characterization of abaca germplasm, production and processing.
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Department of Science and Technology (DOST), Los Baños, Laguna
  * evaluation, monitoring and funding of research and development projects on fibre crops.
- Philippine Industrial Crops Research Institute (PICRI), University of Southern Mindanao (USM), Kabacan, North Cotabato
  * propagation and breeding.
- Philippine Textile Research Institute (PTRI), Department of Science and Technology (DOST) Complex, Bicutan, Taguig, Metro Manila
  * production and processing of fibre crops for textiles.

Thailand

- Department of Agriculture
  * research and development on cotton, jute and jute-like fibre, kenaf.
  * technology transfer to extensionists, farmers and companies.
- Department of Agricultural Extension
  * development and transfer of the fibre plant production practices to farmers.
- Department of Industrial Promotion
  * technology transfer with respect to the production of handicrafts and cloth from fibre plants such as jute, cotton and paper mulberry.
  * promotion of the production of handicrafts from fibre plants.

1.10 Prospects

1.10.1 Supply and demand

In South-East Asia, as in the rest of the world, many plants are available that produce fibres suitable for various end uses. However, apart from woody species for paper making, only a few of them, such as cotton, abaca, jute, kenaf, roselle, sisal and *Wikstroemia* spp. have reached the international market and persisted there. After the Second World War, demand for plant fibres was high, but since then the demand for natural fibres (except cotton) has gradually decreased due to the development of synthetic fibres which are often cheaper to produce, more durable and easily converted into attractive designs and colours. More recently, however, growing concerns about environmental issues and hazards to the environment brought about by synthetics has led to renewed interest in plant fibres. Markets where plant fibres such as jute, kenaf, roselle and sisal may gain terrain over synthetic fibres include those for insulation, packaging, geotextiles, composites, filters, sorbents and active surfaces (Bolton, 1995). Because of its excellent fibre characteristics, cotton will undoubtedly remain an important commodity in the world market, and an increased share of South-East Asia in world cotton production seems attainable.

The largest potential market for non-wood plant fibres is that of paper and paperboard; even a small percentage deficit in supply of wood fibre would create huge opportunities for non-wood plant fibres (Bolton, 1995). World paper consumption rose steadily from 40 million t in 1950 to 226 million t in 1988, an average increase of 4.7% per year. The 1994 world consumption of paper and paperboard was 268 million t. The increase in paper production has led to a decline in forest resources in some countries, and there is now a greater emphasis on the recycling of paper and the planting of plantations for future pulp production. Both recycling and plantation forestry can be expected to lead to increases in the cost of pulp, which in turn is expected to increase the competitiveness of non-wood fibre plants as a source of pulp and paper (Wood, 1997).

Some advantages of non-wood fibres over wood fibres are (Moore, 1996):

- They can be derived from annual crops, which can be grown as part of existing farming systems; the total area planted is easily adapted to changes in world demand.
- Low lignin content.
- Reduced chemical usage and effluent.
- Decreased use of forest resources and, where fibres are extracted from agricultural wastes, less emissions of carbon monoxide and carbon dioxide arising from the burning of these waste products).

Disadvantages of non-wood fibres compared to wood fibres include (Moore, 1996):

- Supply problems. Large stocks and adequate storage at constant quality by drying or ensilage may be necessary to service large-scale operations. Alternatively, where non-wood pulp mills are based on agricultural residues or annual crops that are grown in scattered locations, they must be kept small to minimize transport costs, which means they cannot benefit fully from the economies of scale enjoyed by wood-based mills.
- Difficult chemical recovery. Non-wood fibrous materials usually have higher

ash and silica contents. Most of the silica dissolves during cooking and remains as an undesirable component in the spent pulping liquor. There are no commercial installations with operating recovery systems for use with non-wood fibrous materials. The size of operation also has an impact on the chemical recovery problem. If the technical problems of chemical recovery in non-wood pulping are solved along the lines of today's pulping process technology, the size and cost of chemical recovery, effluent treatment and other control measures will increase, which will reduce much of the financial advantage non-wood fibre pulping has had in some regions.
- Some annual plants have a low fibre content. *Miscanthus* spp. have only a 30% fibre fraction and flax a 20% usable bast fibre. In grasses, nodes are often unwanted and need to be separated out.

Potential paper-making species for South-East Asia include jute, kenaf, roselle, paper mulberry, *Arundo donax*, *Helicteres isora*, and *Miscanthus* spp. Abaca and *Wikstroemia* spp. have potential in the market for specialty papers.

Many of the species treated in this volume are important only at a very restricted or local level. Some remain as secondary species for substitution and are only utilized when the major ones are in short supply. Reasons for the comparatively low demand for these secondary species compared with that of the major ones include the following:
- Lower yields, partly because of the lack of research and development work on lesser-known species.
- Lower product quality and more difficult processing techniques needed for them, thereby increasing production costs.
- Environmental and ecological factors restricting massive production: some species are suited only for a specific region with specific environmental conditions.
- The weedy behaviour of many species such as *Cyperus*, *Malachra* and *Miscanthus* spp. discouraging cultivation.
- Unwanted morphological characters of species, such as the irritating hairs of *Abroma augusta* and the spines of *Corypha utan*, rendering them less attractive for mass production.

A decisive factor in the potential success of a fibre is the cost of production, because the cost is as important a factor as quality for many uses; any fibre of reasonable quality that can be produced more cheaply than others will find a market (Schery, 1972).

1.10.2 Research priorities

Priorities in research and development efforts to expand the fibre industry in South-East Asia may include the following:
- Development of germplasm collections for lesser-known species (cultivated or wild-harvested) with high potential. Germplasm collections will help conserve and preserve species that may be found suitable for production in the future, especially those with a limited distribution.
- Breeding programmes for lesser-known fibre plants, focusing on fibre yield and quality (homogeneity, degree of lignification, strength, fineness and water uptake characteristics), improved ecological adaptation and resistance to diseases and pests. For industrial fibres, e.g. for paper making, productivity

is an important factor. In cases where conventional breeding methods are difficult to use, breeding programmes should be complemented with research and development on a range of biotechnological techniques.
- Establishment of industrial plantations for economic exploitation of potential species, e.g. *Wikstroemia* spp., to ensure a continuous supply of raw materials for various end-uses.
- Development of improved cropping practices and processing methods.
- Development of mechanical harvesting methods, preferably combined with fibre extraction.
- Product improvement, product diversification and waste utilization. In many cases, not only fibres but also other products can be obtained from the same crop, thus enhancing crop value, as multiple-use crops will give a higher return. Waste-material and by-products may also be useful, for instance sisal short fibres, poles and boles for pulping, and leaf waste for animal feed.
- Substitution of established products by those from lesser-known species; e.g. *Donax canniformis* is sometimes substituted for rattans, which are increasingly being over-harvested from the wild.

M. Brink, R.P. Escobin & H.A.M. van der Vossen (genetic resources and breeding)

2 Alphabetical treatment of genera and species

Abroma augusta (L.) L.f.

Suppl. pl.: 341 (1782) ('*Ambroma*, 1781').
STERCULIACEAE
$2n = 16, 20, 22$.

Synonyms *Abroma fastuosum* Jacq. (1776, nom. illeg.), *Theobroma augusta* L. (1776), *Abroma mollis* DC. (1824).

Vernacular names Devil's cotton, perennial Indian hemp, abroma (En). Abrome, abrome royal (Fr). Indonesia: kapasan (Javanese), kaworo (Sundanese), rebong pengayoh (Lampung). Malaysia: rami sengat. Philippines: anabo (Ibanag, Ilokano, Tinggian, Tagalog, Bisaya), ambong (Tagalog), pakalkal (Pampango). Thailand: thian dam (central), thian dam luang (Chiang Mai). Vietnam: chi tai m[ef]o, b[oo]ng v[af]ng.

Origin and geographic distribution *A. augusta* is distributed from India throughout South-East Asia to southern China, the Solomon Islands and northern Australia. It is sometimes cultivated in India and New Guinea and experimental plantings have been set up in the Philippines and Africa (Uganda, Democratic Republic of Congo).

Uses In the Philippines the strong bast fibre from *A. augusta* serves for making rope, twine, fishing lines, pouches and the like. Rope made of it is valued for its strength and is used for clothes-lines, since it does not stain. In the Philippines *A. augusta* is also considered a substitute for rattan, and bark splits are made into products such as potholders, hampers, baskets and trays. In New Guinea the fibre is utilized for clothing, bags, hunting-nets and for lashing. Dyed, very fine fibres are used as false hair in Sumatra (Lampung). In Bali the inner bark is split into threads, yielding a fine, white yarn, which is made into lines and rope. In the Minahassa Peninsula (Sulawesi) the fibre is utilized for making nets.

The leaves are eaten as a supplementary source of food in New Guinea and India. In the Philippines and India the fresh or dried root bark is considered an emmenagogue and in Indonesia the root is used against scabies. *A. augusta* has been recommended for soil reclamation.

Production and international trade In the Philippines considerable quantities of *A. augusta* fibre have been traded on the local market, but no export market has developed. Statistics on production and trade are not available.

Properties The fibre obtained from *A. augusta* is located in the secondary phloem. The fibre content of fresh, defoliated stems is (4–)5–6.5(–8)%. The ultimate fibre cells are (1.4–)2–3(–6.4) mm long and (6–)12–20(–39) μm wide, with the lumen diameter being about one third of the total diameter. The ends of the ultimate fibre cells are tapered and sometimes forked. The cellulose content of the fibre is 75–78%. The extracted fibres, consisting of connected ultimate fibre cells, are 0.5–2.5 m long. Properly prepared fibre is fine, creamy white to golden brown, lustrous, rather silky in appearance, strong and supple. However, the fibre bundles are irregular and coarse and it is difficult to separate the bundles into individual strands. *A. augusta* fibre is difficult to spin, but can be used mixed with jute in the manufacture of hessian. On its own it is considered suitable for making twines and yarn for sack-cloth and it can serve as a substitute for jute (*Corchorus* spp.) and hemp (*Cannabis sativa* L.) fibre. The tensile strength of rope made of crude bast strips of *A. augusta* in the Philippines was 545 kg/cm^2, whereas that of rope made of fibres that had been retted in water for about 10 days was 645 kg/cm^2. The breaking length of these ropes was 5.8 and 7.7 km, respectively. When the rope made of crude strips was wetted, the tensile strength decreased by almost 50%. An important obstacle to the use of *A. augusta* as a source of fibre is that the plants are covered with irritating hairs, making handling very unpleasant and causing dermatitis in sensitive persons.

The seed of *A. augusta* yields 20% oil containing linoleic acid (72%), palmitic acid (14%), oleic acid (9.4%) and stearic acid (4%). The oil does not contain cyclopropenoid acids. Methanol extracts of leaves, stem bark and root bark of *A. augusta* have shown antibacterial activity.

Description An erect shrub or small tree, 2–4 m tall, normally branching at 1–2 m height but due to coppicing often multistemmed from the base, stem and branches with tenacious bark, smooth or armed with prickles, all parts often with prickly-pointed, irritating, stellate hairs and sometimes also with glandular hairs; orthotropic branches usually remain vegetative, flowering branches are usually plagiotropic. Leaves alternate, simple, highly variable but two main forms exist (heterophylly), lobed (often on plagiotropic branches) or unlobed (often on orthotropic branches); unlobed form with petiole up to 1.5 cm long, blade lanceolate, 16–23 cm × 9–12 cm, cordate at base, margin denticulate, palmate-pinnately veined; lobed form with petiole 10–40 cm long, blade 3–5-lobed, cordate-ovate in outline, up to 30–40 cm × 30–40 cm, base palmately 3–5–7-veined, margin irregularly dentate. Inflorescence a leaf-opposed or terminal

Abroma augusta (L.) L.f. – 1, habit fruiting branch; 2, flower seen from above; 3, fruit; 4, seed.

1–4-flowered cyme (usually only 1 flower develops); flowers pendent, 3–5 cm in diameter, bisexual, 5-merous; peduncle and pedicel 1–3 cm long each, slightly enlarging in fruit; calyx deeply divided, 5 lobes entire, triangular, about 15–20 mm × 6 mm, greenish; petals 5, spoon-shaped, 2–3.5 cm × 1 cm, base concave and white, blade dark purple, red or yellow, and ciliate; staminal tube short, apically with 5 fascicles of anthers alternating with 5 petal-like staminodes, each fascicle with 3(–4) anthers; pistil with 5-lobed, 5-celled ovary 2–3 mm long, containing numerous ovules, and 5 stigmatic style-branches 1–2.5 mm long. Fruit an obconical capsule, about 4–5 cm × 3–4 cm, base rounded, top truncate, 5-winged and angled, sometimes beaked, enveloped by the slightly enlarged calyx, densely prickly hairy, apical portion loculicidal, lateral parts septicidally dehiscent, with numerous seeds. Seed cylindrical to obovoid, 3–4 mm × 2 mm, without wings or aril, black.

Growth and development In Java *A. augusta* flowers year-round. It is protogynous and allogamous, with pollination by wind and insects. The flowers fall off at the latest a day after opening. *A. augusta* normally spreads by seed, but when the stems are cut, new shoots may emerge from the buds in the axils of the leaf scars at the base of the plant. Suckers may also develop from lateral roots running parallel to the soil surface.

Other botanical information The correct name for *A. augusta* has always been disputed. Linnaeus described this species as *Theobroma augusta* L. in 1776. Jacquin, also in 1776, did not agree with Linnaeus and described the plant as *Abroma fastuosum* Jacq., quoting Linnaeus' name as a synonym. In 1782 Linnaeus' son (L.f.) published this plant as *Ambroma augusta* L.f., quoting Linnaeus's and Jacquin's names as synonyms. Later many more names became involved, but most probably only these 3 names play a role in the correct naming. Most authors agree that this species is not a *Theobroma* L., so *Abroma* Jacq. or *Ambroma* L.f. remain. According to botanical nomenclatural rules Jacquin should have used Linnaeus' specific name '*augusta*' and L.f. should have used Jacquin's genus name '*Abroma*'. The view followed here is that the correct name is *Abroma augusta* (L.) L.f., assuming that L.f. made an orthographic error writing '*Abroma*' as '*Ambroma*'.

Another continuing dispute is the number of species in *Abroma*. Based on the presence or absence of prickles on the stems and branches, the colour of the flowers and the number of seeds in the capsules up to 3 species have been distinguished: *A. augusta*, unarmed, flowers red, capsule with more than 200 seeds; *A. mollis* DC., unarmed, flowers yellow, capsule with more than 200 seeds; *A. fastuosa* R.Br., armed, capsules with 50–60 seeds, only occurring on Madagascar. Here we accept the view that there is only one widespread, highly variable species, but a critical revision is needed.

The English vernacular name devil's cotton stems from the fact that *Abroma* fruits have the shape of cotton fruits but, due to the belief of the influence of the devil, they do not contain fibres like a cotton fruit.

Ecology The distribution area of *A. augusta* is characterized by mean daily temperatures of 27–30°C in the hottest months, an average annual rainfall of at least 1500 mm, and a high relative humidity. It is not suitable for areas with a marked dry season. *A. augusta* is not frost-hardy and it is not found at altitudes above 1100 m. It is a short-day plant. The best soils for *A. augusta* are fertile alluvials with a good structure and good drainage, as it does not tolerate waterlogging for a long period. However, it will also survive and grow when soil conditions are less favourable. When occurring naturally, *A. augusta* is found in thickets or tufts, secondary forest, waste places and village borders and along railways and roads, seemingly preferring forest edges and the banks of clearings or watercourses. As a light-loving plant, it does not occur in primary forest. In the Moluccas it occurs in dry valleys on poor, sandy locations or in fallow fields.

Propagation and planting *A. augusta* can be propagated by seed, stem cuttings or suckers emerging from lateral roots. For seed propagation fresh material should be used, as seeds show low germination rates and lose viability rather quickly. Soaking may be necessary, e.g. in water for 15 minutes at 28°C. At a temperature of 33°C germination is more rapid and the final germination percentage higher than at 20–25°C. Seeds can be sown directly in the field or in nurseries for transplanting. Soil preparation before sowing is desirable, and farm manure or green manure may be incorporated. Spacings of 0.4 m × 0.4 m or 1 m × 0.2 m gave the highest yields in spacing trials in Africa, but wider spacings have been advocated in South-East Asia.

Husbandry In cultivated *A. augusta* normally only 2 weedings are necessary, the first at about 20–30 days after sowing, the second about 1 month later.

Diseases and pests No information exists on diseases and pests affecting *A. augusta* in Asia. In Uganda, however, it is very susceptible to *Verticillium* wilt.

Harvesting *A. augusta* stems are harvested at flowering, 3–4 months after sowing, when fibre quality is optimal. However, if only coarse fibre suitable for cordage is to be obtained, harvesting may be done later, resulting in higher yields but a more lignified product. In the Philippines 7–8 months is considered the proper harvesting age for cordage. In the Moluccas 6–8 month-old stems are cut. The stems are coppiced at about 25 cm above the ground, as cutting at a lower height may endanger regrowth. Vigorous regrowth normally occurs, with 2–3(–5) new shoots per plant. Up to 4 harvests per year may be possible, but 1–2 harvests is most common. On good soils the plants may be harvested for 3 years, but on poor soils yields decrease sooner.

Yield Fibre yields of *A. augusta* depend on a number of factors including climate, soil and whether wild or cultivated plants are involved. The average dry fibre yield for the whole economic life of a planted crop has been estimated at 700–1000 kg/ha. *A. augusta* can yield 250 kg/ha seed per year.

Handling after harvest The fibre bundles of *A. augusta* can be extracted by retting the whole stems (fresh or dried) or only the bark (fresh or dried). Where only the bark is retted, it is manually removed from the stems immediately after the harvest, when the bark is easiest to remove. Drying of stems or bark may be done in the open field or under shelters. Properly dried bark can be stored for several months. The required retting period depends on prevailing conditions, especially temperature, with older stems needing a longer retting period than young ones. After retting, the fibre is usually washed, dried and rubbed or beaten to make it supple and to separate the strands. Over-drying makes the fibre brittle. In South-East Asia processing practices vary. In southern Mindanao (the Philippines), for instance, harvested plants are left on the ground for about 2 days for the leaves and bristles to fall off. Then the bark is stripped from the stem and placed in water for 4–6 days, after which the fibre is washed and freed from adhering materials, dried and bundled. In the Philippines material to be used for weaving is prepared by splitting the bark in the same way as rattan and drying the strips in the sun. In Lampung (Sumatra) stems are retted for 10–15 days, after which the outer bark is washed off and the fibres are pulled off the wood. After drying, the fibre ribbons are divided into strips of the desired width. In Bali stems and thick branches are buried in mud for 2–3 days after which the outer bark is scraped off. In Buru (Moluccas) the stems are soaked and the bast is pulled off, retted in water until the outer bark starts to rot, cleaned, washed and dried. In North Sulawesi the stems are laid in the mud until the bast comes loose, usually after about 3 days, after which it is retted in running water and cleaned. In Central Sulawesi the green bark is scraped off the stems with a knife and the white fibre layer is pulled off the wood, dried in the sun, and twisted into rope.

Genetic resources and breeding No germplasm collections or breeding programmes of *A. augusta* are known to exist. Priorities in any future breeding programme should be higher yields and the development of cultivars without irritating hairs.

Prospects *A. augusta* yields a strong fibre suitable for cordage and will remain useful for this purpose locally. It has been proposed from time to time as a promising perennial source of bast fibre, avoiding the labour and costs involved in growing annual bast fibre crops. However, the presence of irritating hairs all over the plant and the relatively low yields make an increase in the importance of its fibre very unlikely.

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N.O. Aguilar, P.C.M. Jansen & M. Brink

Actinoscirpus grossus (L.f.) Goetgh. & D.A. Simpson

Kew Bull. 46: 171 (1991).

CYPERACEAE

$2n$ = unknown

Synonyms *Scirpus grossus* L.f. (1781), *Hymenochaete grossa* (L.f.) Nees (1834), *Schoenoplectus grossus* (L.f.) Palla (1911).

Vernacular names Giant bulrush (En). Indonesia: mensiang (western Sumatra), lingi (Javanese), walingi (Sundanese). Malaysia: rumput menderong, rumput menerong, rumput morong. Philippines: tikiu, titiu (Tagalog), agas (Bikol). Thailand: kok, kok prue, kok saamliam (central, Bangkok). Vietnam: chi c[os]i d[uf]i.

Origin and geographic distribution *A. grossus* probably originated in South-East Asia and is widely distributed in the Old World tropics from India, Sri Lanka and southern China throughout South-East Asia to the Bonin Islands (south of Japan), Micronesia and tropical Australia.

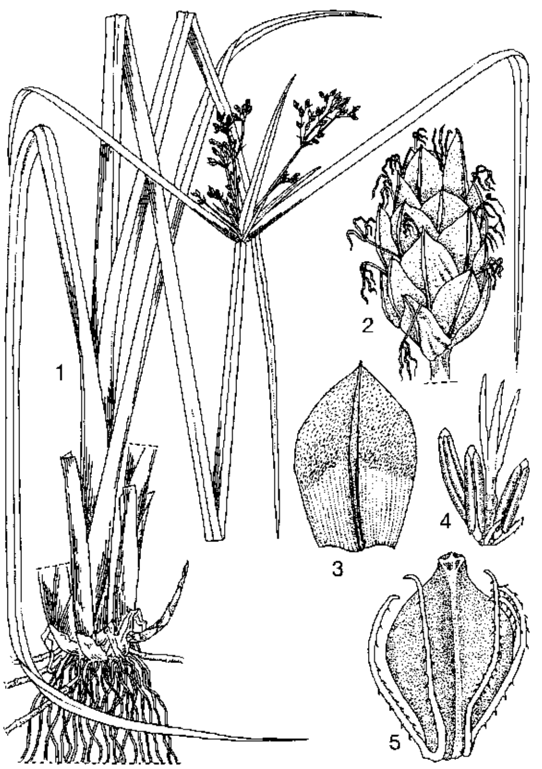
Uses In Indonesia the stems of *A. grossus* are commonly utilized for the production of cheap but strong and durable products such as coarse mats and bags, and for lining pandan mats. *A. grossus* is usually preferred to other *Cyperaceae*, except *Fimbristylis umbellaris* (Lamk) Vahl. In Malaysia it is the most commonly used sedge, chiefly in Perak and to the north of Perak. Stems have been used locally as string or rope. In the Philippines the whole stems serve for making thick sleeping mats, whereas the split stems are employed for fine mats. The stems are also used for making bags and baskets in the Philippines. In Thailand it is used for making mats. In India it is used for plaiting mats, bags and baskets and for roofing. In Peninsular Malaysia *A. grossus* sometimes forms up to 90% of the herbage in rice fallows and is ploughed in as green manure. In India the tubers are eaten raw or ground into flour to make bread. The tubers are also used medicinally in India for stopping vomiting and diarrhoea and are credited with, among others, astringent, laxative, tonic, cooling and diuretic properties. *A. grossus* can also be used as a fodder.

Production and international trade No production or trade statistics of *A. grossus* are available. Within Thailand stems are brought from the Bangkok area to Khon Kaen when local supplies are short.

Properties Pulping experiments with *A. grossus* in Indonesia showed it can yield pulp of moderate quality. On average the ultimate fibre length was 1.6 mm, the diameter 5.3 μm and the lumen width 2.1 μm. The plants contained 61.8% cellulose, 26.1% lignin, 21.2% pentosans, 11.5% ash and 8.3% silica. The solubility was 6.9% in alcohol-benzene, 10.1% in cold water, 14.4% in hot water and 49.7% in a 1% NaOH solution. With a beating time increasing from 0 to 30 minutes, the freeness of unbleached and bleached (value between parentheses) pulp sheets increased from 18(17)°SR to 66(56)°SR, the burst factor from 32(17) to 54(26), and the folding endurance from 2300(3200) m to 4400(7600) m, whereas the tear factor decreased from 133(64) to 47(17).

A. grossus tubers are sweet and starchy and considered to be highly nutritious. They contain 60–80% digestible carbohydrates and 7–12% protein.

Description An erect, stout, rhizomatous perennial herb, up to 2 m tall, with rather long runners 5 mm thick ending in small tubers. Stem sharply 3-angled with concave sides, 80–200 cm × 0.5–2.5 cm, smooth, spongy, strongly septate-nodulose, with a corm-like hard enlargement at base, growing singular, in small groups or in dense tufts. Leaves basal, few, sheathed, pale yellow; sheath spongy, prominently septate-nodose, tightly surrounding the stem base; blade sublinear, 50–180 cm × 1–3 cm, in the lower half keeled and 3-sided, somewhat thickish, soft, strongly septate-nodulose, in the upper half almost flat and gradually acuminate, margin subscabrous. Inflorescence terminal, corymbiform with primary, secondary and tertiary rays, 6–15 cm long; involucral bracts 3–4, leaf-like, flat, linear, 15–70 cm long, at least 2 overtopping the inflorescence; primary rays several, spreading, unequal, scaberulous, secondary rays 1–4 cm long; spikelets numerous, solitary, peduncled except terminal one, ellipsoidal, 4–10 mm × 3.5–4 mm, with many bisexual flowers; glumes spirally arranged, appressed, concave-ovate, about 3 mm × 2 mm, membranous, glabrescent, midrib prominent and green, sides red-brown with finely ciliolate margins, apex obtuse to short mucronulate; hypogynous bristles (perianth) 4–6, retrorsely scabrous, slightly longer than the fruit; stamens 3, very short, with linear anthers about 1 mm long; style 3 mm long, in upper half branching into 3 stigmas. Fruit a nut-like, trigonous, obovate achene about 1–2 mm × 1 mm, apiculate, brown.



Actinoscirpus grossus (L.f.) Goetgh. & D.A. Simpson – 1, habit flowering plant; 2, spikelet; 3, dorsal view glume; 4, flower; 5, fruit with bristles.

Growth and development In the Philippines *A. grossus* flowers from May to November. It spreads by runners and by fruits, the latter being dispersed by water and animals.

Other botanical information The taxonomy of the *Cyperaceae*, particularly of the genus *Scirpus* L. s.l., is far from stabilized. For a long time, *A. grossus* (as *Scirpus grossus* L.f.) formed the section *Actinoscirpus* in the genus *Scirpus* but in addition to the name used now, it has also been classified in *Hymenochaeta* Beauv. ex Lestib. and *Schoenoplectus* (Rchb.) Palla. *Hymenochaete*, however, is a name used earlier for fungi (*Hymenochaete* Lév.) and thus not available for *Cyperaceae*. *A. grossus* would fit in *Schoenoplectus* for several characteristics, but its leafy, spreading inflorescence bracts do not fit. Therefore it is preferable to keep it in a separate genus rather than widening the circumscription of *Schoenoplectus*. *A. grossus* is the only species in the genus *Actinoscirpus* (Ohwi) R.W. Haines & Lye. Due to its wide distribution it is quite variable and several infraspecific taxa have been distinguished. Var. *kysoor* (Roxb.) Noltie (synonyms: *Scirpus grossus* L.f. var. *kysoor* (Roxb.) Clarke, *S. kysoor* Roxb.) is restricted to India, Pakistan, Nepal, Bangladesh and Burma (Myanmar), and has hispid stem angles, glumes narrowed towards apex and strongly mucronate, and bristles plumose with twisted, spreading, glandular, multicellular hairs. Var. *grossus* (distribution as the species) has smooth stem angles, glumes with wide rounded apex and minutely apiculate, and bristles not plumose but with sharp, backward pointing, unicellular hairs.

Ecology *A. grossus* occurs, often abundantly, in swampy or inundated locations, pools, ditches and rice fields, from sea level up to 900 m altitude. It is an important aquatic weed in South-East Asia. In Indonesia it is considered a weed of minor importance in lowland-irrigated and tidal rice fields, where it can be controlled manually, by deep-ploughing before seed formation, or with herbicides. In Peninsular Malaysia it is one of the major weeds of transplanted rice.

Propagation and planting *A. grossus* can be propagated by seed and by stolon parts.

Husbandry In north-eastern Thailand stands of *A. grossus* (and *Cyperus corymbosus* Rottb.) are often protected by fences to prevent grazing by buffalo or cattle, implying some degree of controlled cultivation.

Diseases and pests The dark-headed rice-borer *Chilotraea polychrysa* (synonyms: *Chilo polychrysa*, *Proceras polychrysa*) feeds on *A. grossus* in Indonesia.

Handling after harvest In Indonesia the stems of *A. grossus* are prepared by removing one of the ribs, after which they are dried, flattened (e.g. with a stump knife or piece of bamboo) and bleached in the sun and dew. In Thailand the stems are cut to the required length, split 2 or 3 times, hung to dry on special racks and often dyed a bright colour before being woven into mats on simple, hand-operated looms.

Genetic resources and breeding No germplasm collections or breeding programmes of *A. grossus* are known to exist.

Prospects *A. grossus* will remain important as a local source of cheap but strong weaving material, providing an additional source of income for rural people, e.g. in the Philippines. It may have potential as a raw material for paper making, though this needs more research.

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P.C.M. Jansen & M. Brink

Agave cantala Roxb.

Hort. bengal.: 25 (1814).

AGAVACEAE

$2n = 90$ (triploid)

Synonyms *Agave cantula* Roxb. (1832), *A. rumphii* Jacobi (1865), *A. candalabrum* Tod. (1877 or 1878).

Vernacular names Cantala, maguey, Bombay hemp (En). Indonesia: nanas sabrang (general, Javanese), nanas kosta (general), danas sabrang (Sundanese). Philippines: maguey, magai, pita (Cebu Bisaya). Vietnam: d[uwr]a s[owj]i n[aj]c, d[uwr]a s[owj]i gai.

Origin and geographic distribution Cantala almost certainly originated in Mexico, where it is now rare. It was brought by the Spanish from Mexico to the Philippines, Indonesia and Malaysia, where it later evolved into a fibre crop. Cantala fibre industries developed in the 19th Century in Indonesia and the Philippines. Cantala was introduced by European traders into southern Asia, specifically India, where it was planted initially as a hedge and fence plant and to control erosion in some areas. Only later did it become a source of fibre. It naturalized in tropical Asia centuries ago and is now common in South and South-East Asia from India to the Philippines. Cantala is also cultivated as a fibre plant in the Bahamas and grows in Pakistan, Iran (uncommonly), Tanzania and Fernando Po.

Uses Cantala leaves are a source of fibre, which is known as 'cantala', 'kantala' or 'cantula' fibre and locally as 'Manila maguey', 'Manila aloe', 'Philippine maguey' (Philippines), 'Java sisal' (Indonesia), 'Indian sisal' and 'Bombay aloe' (India). It belongs to the 'hard fibres' of commerce, together with e.g. abaca (*Musa textilis* Née) and sisal (*A. sisalana* Perrine). Cantala fibre is made into baskets, hammocks, bags, sandals, carpets, rugs, doormats, sacks and cordage, of which binder twine is the most important. The fibre has also been used in fishing gear. In the Philippines cantala fibre is usually blended with abaca fibre in the manufacture of ropes, carpets, binder twine and fishing nets, and also of slippers, flowers and other decorative items. It has been used for pulp manufacturing, but because of supply problems production was short-lived.

For centuries cantala has served in Java (Indonesia) as hedges to protect homesteads or fields from grazing animals. The shoot buds, cut into pieces, are eaten as a cooked vegetable in Java. In Mexico cantala is cultivated for the production of the alcoholic drink 'pulque' and fleshy leaves are also used as fodder.

Production and international trade Cantala production is mainly concentrated in the Philippines, Indonesia and India. In the early part of the 20th Century, cantala was grown throughout northern Luzon and western Visayas in the Philippines, where yearly production of cantala fibre reached 19 000 t, of which 14 000 t was exported. Demand for cantala fibre was considerable during the Second World War. In the second half of the 20th Century, low cantala prices and other factors such as low yields and difficulties in handling the crop due to the prickly leaves, led to a decline in the production of cantala fibre as farmers shifted to more profitable crops. The development and use of other natural fibres and synthetics for the manufacture of cordage products were important factors in this decline. The area under cantala in the Philippines decreased from 1200 ha in 1991 to about 500 ha in 2000 (300 ha in Bohol, 100 ha in Cebu and 100 ha in Ilocos). The fibre production decreased from 159 t in 1991 to 25 t in 2000, mainly from Pangasinan (Ilocos). The decline since 1991 has been attributed to the prohibition of seawater-retting to reduce pollution, the low price offered by buyers and the low productivity of old plantations needing rehabilitation. The average annual production in 1996–2000 was about 32 t, most of which was used for processing into cordage and fibre craft within the country. In 1998 and 1999 some cantala fibre was exported from the Philippines: 3 and 4 t, respectively, mainly to the United Kingdom and the United States. In 1987–1990 cantala pulp was exported from the Philippines to Japan, Taiwan, Germany and Belgium.

In Indonesia cantala has been grown in Java by smallholders since the end of the 17th Century and on estates since the beginning of the 19th Century, but it was soon outstripped by sisal. In the first half of the 20th Century cantala was grown both on estates in Java, for export, and by smallholders in Java and Madura, mainly for local use. In the 1930s the average estate production in Java was 3000–6000 t cantala fibre per year, from 4500–5000 ha. No recent production and trade statistics for Indonesia or India are available.

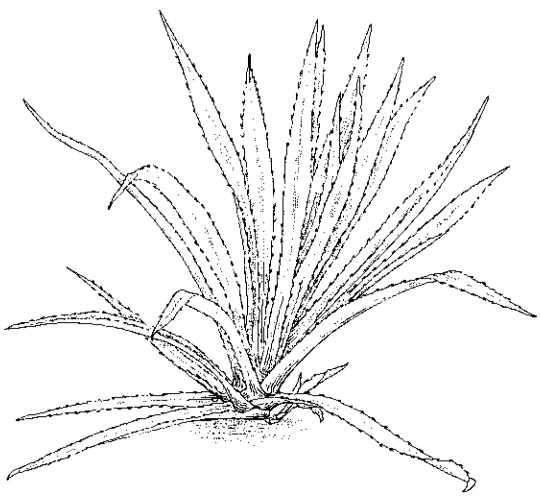
Properties Cantala leaves, like those of other *Agave* species, contain 2 types of fibres: mechanical fibres, mainly concentrated in the peripheral zone beneath the epidermis, and ribbon fibres, associated with the vascular bundles and more strongly developed in the median line. The fibre bundles in the peripheral zone of the leaf are horseshoe-shaped in other *Agave* species, but more irregularly oval in *A. cantala*. Cantala leaves yield 3–6% of a white fibre. The fibre strands may be over 1 m long. The ultimate fibre cells are (1.0–)2.4(–5.0) mm long, with a diameter of (16–)20–30(–37) μm, a lumen width of (4–)11 (–17) μm and a cell wall thickness of (6–)8(–10) μm. The Runkel ratio is (1.15–)1.35(–2.87). The fibre contains approximately 64–71% α-cellulose, 7–17% lignin and 1–2% ash. Cottonized cantala fibre can be blended with acrylic or polyester fibre and spun into industrial yarns used in the production of, for example, wall-coverings, upholstery and bags. Cantala fibre can be pulped for the production of, for instance, wrapping paper, heavy-duty bags and wallboards.

Cantala leaves contain steroidal saponins (glycosides of sapogenins) based on sapogenins such as hecogenin, tigogenin, neotigogenin, β-sitosterol, gitogenin, chlorogenin and manogenin. Hecogenin can be used as a precursor in the partial synthesis of corticosteroids, but tigogenin is considered a contaminant of hecogenin. The hecogenin content of waste material after fibre extraction of cantala leaves is 0.3–0.5%. The fruits contain hecogenin, gitogenin and tigogenin. The hecogenin-based saponin cantalasaponin-2 from the stolons, the tigogenin-based saponin cantalasaponin-7 from the leaves, and a chlorogenin-based glycoside from the inflorescence have shown molluscicidal activity against the schistosomiasis vector *Biomphalaria glabrata*. Cantalasaponin-1 (a hongguanggenin-based glycoside) from the stolons significantly inhibited the growth of human cervical carcinoma cells. An acetone extract of the leaves has shown weak insecticidal effects against the diamondback moth (*Plutella xylostella*). Cantala reportedly has piscicidal properties.

Adulterations and substitutes The main competitor for cantala is sisal. Cantala fibre is finer, whiter, more supple and more suitable for spinning than sisal, but less strong. Furthermore, the fibre yield of cantala is lower than that of sisal, the prickly leaves of cantala make handling more difficult, and cantala leaves are harder to decorticate. In the Philippines sisal is imported as a substitute for locally produced cantala.

Description A robust, monocarpic, xerophytic perennial herb, 4–8.5 m tall when flowering, producing subterraneous stolons (rhizomes) and suckers, and numerous, crowded leaves in a rosette; stem 30–60 cm long. Leaves sessile, often subrecurved, linear-lanceolate, 1–2 m × 6–10 cm, thin, widest above the middle, channelled towards the base, margins straight with erect black spines 3–6 mm long of which the tips are upcurved, spines 2–3 cm apart but reduced or lacking toward apex, apex ending in a sharp black spine up to 2.5 cm long, flat to concave-convex, dark blue-green, rough to the touch below, young leaves firmly appressed against each other (initially cylindrically inrolled) leaving impressions. Inflorescence a panicle on long peduncle, 3.5–8 m long, many-flowered; branches spreading, more or less flattened; flowers 6–8 cm long on short pedicel, protandrous, rich in nectar; perianth funnel-shaped, separated from the inferior ovary by a constriction, widened at the apex, with 6 equal lobes; tube 12–17 mm × 15 mm, grooved; lobes oblong to linear–spatulate, 2.5–3 cm long, yellow-green, tinged purplish or reddish, on the inside of the apex with a tuft of hairs; stamens 6, inserted above the middle of the tube, filaments 5 cm long, anthers slender, purplish; ovary conical but 6-ribbed, 3–4 cm long. Fruit not well known, apparently very rarely produced. After anthesis numerous bulbils are produced on the inflorescence.

Growth and development Cantala has a life cycle of 6–15(–25) years and it produces about 250 leaves during its lifetime. It develops a long flowering shoot ('pole') towards the end of its life cycle. In Java flowering ('poling') may occur any time of the year. Bulbils are copiously produced in the inflorescence after anthesis. After the production of flowers and bulbils the entire plant dies. Cantala develops many more suckers than sisal.



Agave cantala Roxb. – habit.

Other botanical information Cantala can easily be distinguished from sisal and henequen (*Agave fourcroydes* Lem.) by the upwards curving spines on the leaf margins and the long black terminal spine, which make the plant difficult to handle. It can further be recognized by its thin, long, narrow, weak leaves, which are frequently reflexed above the middle, and large, green-purplish flowers in broad, widely spreading and slenderly peduncled panicles. Plants used for hedge in Honduras, with shorter and sturdier leaves with more robust terminal spines and shorter flowers, have been classified as *A. cantala* Roxb. var. *acuispina* (Trel.) Gentry (synonym: *A. acuispina* Trel.). Some authors consider the name *A. cantala* Roxb. from 1814 as a 'nomen nudum' and prefer *A. cantula* Roxb. from 1832 as the correct name.

Ecology Cantala can be grown in a range of tropical climates, with an annual rainfall up to 2500 mm, but it grows best in a semi-arid tropical climate. In Java it can be grown up to 1500 m altitude. It grows on any well-drained soil, but does best on limestone soils. Although it is claimed to tolerate wet climates and soils better than sisal and henequen, it is sensitive to water logging, which results in stunted growth and destruction of the plant.

Propagation and planting Cantala can be propagated vegetatively by means of suckers or bulbils. In the Philippines and Indonesia suckers are the preferred planting material, because mature leaves of plants raised from suckers yield more fibre than those of plants raised from bulbils and leaf production in the first 3 years after planting is higher. Suckers are usually planted directly in the field, but bulbils are first grown in a nursery and planted out when the plants are at least 20–30 cm tall. Adequate spacing is important because it allows for easier cultivation, weeding and harvesting and prevents leaves from touching each other when fully grown. In the Philippines planting distances are generally (1–)1.5(–3) m between plants and (1.5–)2.5(–3) m between single rows or 2 m × 2.5 m between double rows. The plants are placed in holes on sloping and rocky soils and in furrows on clay and sandy soils. In Indonesia 2 methods of spacing have been followed: the first with 0.9 m between plants within rows, 0.3 m between the 2 rows forming a double row and 2.5–3 m between sets of double rows; the second with 1.2 m between plants within rows, 0.3 m between the 2 staggered rows in the double row and 2.5–3 m between sets of double rows. If the area for planting is covered with underbrush, weeds or secondary forest, clearing is necessary, but intensive land preparation is not required. In the Philippines sometimes only furrows are made and the land is normally not ploughed before planting. In commercial plantations, however, the field is ploughed and harrowed and planting materials are set in furrows. Cantala may be planted in arid and rocky soils without initial soil tillage but plant growth will not be as fast or vigorous.

A procedure for rapid in vitro propagation of cantala has been developed using explants from stolon plantlets. The explants were cultured on Murashige and Skoog (MS) basal medium containing 2% sucrose, 10% coconut water and 0.8% agar. The addition of 0.075 mg/l naphtalene acetic acid (NAA), 0.1 mg/l indolylbutyric acid (IBA) and 0.5 mg/l kinetin resulted in an extensive proliferation of multiple shoot primordia, which were subcultured on the same medium. The shoots were rooted on hormone-free MS medium.

Husbandry In the Philippines ploughing the soil once or twice during the first year of plant establishment of cantala is recommended to prevent weeds from crowding and shading the plants. Weeding can also be done with a hoe or a 'bolo'. It is better to remove most suckers (retaining only 1 or 2) because they make harvesting more difficult. Though cantala will grow in almost any soil, fertilizer application usually improves growth. A general recommendation in the Philippines is to apply annually 12–18 kg N, 8–12 kg P and 20–30 kg K per hectare. Cantala needs less K than sisal: in Indonesia cantala remained healthy on soils where sisal showed K-deficiency symptoms. Adding compost or waste material from the decorticating process to improve the organic content of the soil is recommended.

Diseases and pest Cantala is not seriously affected by diseases or pests. Scale insects (*Aspidiotus* spp.) and mealy bugs infest cantala but do not cause serious damage and can be easily controlled by chemical insecticides. In Central Java cantala has been affected, especially in the dry period, by the coccus *Pinnaspis aspidistrae*, causing leaf death.

Harvesting The first harvest of cantala raised from suckers takes place (1–)2–3(–4) years after planting. When bulbils are used as planting material, the first harvest is 9–12 months later. In Indonesia it is common to harvest twice a year, but in the Philippines harvesting is usually only once a year or even only once in 2, 3 or more years. Harvesting generally continues until 7–10 years after planting and stops when the plants become generative and the newly unfolded leaves become shorter. In the Philippines harvesting usually begins in November and ends in June of the following year but it may also be done throughout the year. A sharp knife is used to cut the lowest and most mature leaves at not less than 2–3 cm from the stem. In general 6–8 leaves are retained on the plant. After harvesting, the terminal and marginal spines of the leaves are trimmed and 20–50 leaves are tied together in bundles before transport for further processing.

Yield Cantala yields depend on many factors but (10–)25–30(–35) leaves per plant per year can be harvested in the Philippines, or 30–80 leaves when the plants are cut every other year. It is estimated that 1000 mature, average-sized leaves produce 18–22 kg of dry fibre. If the retting method is used, up to about 3 t of fibre per hectare per year can be obtained, and with decortication up to about 2 t. Annual fibre yield estimates for Indonesia range from 1.5–5 t/ha.

Handling after harvest Cantala fibre is extracted from the leaves either by retting or by decortication. In the Philippines retting is traditionally done in fresh- or salt water, in tanks or alongside rivers or creeks. Leaves to be retted in salt water are split lengthwise into 2 or 4 pieces, whereas those to be retted in fresh water are split into sections 1–2 cm wide, because retting in fresh water is much slower. The leaf pieces are retted in bundles for 15 days in salt water or 20–30 days in fresh water, but the optimum retting period varies according to the time of the year and the size of the bundles. When the leaves have decomposed sufficiently, they are usually pounded with a piece of wood and the fibres are washed, dried and baled. In the Philippines retting in sea water is now prohibited to reduce pollution of beaches. In India the leaves are split into thin strips, which are partly dried and subsequently retted, after which they are beaten, and the extracted fibre washed and dried.

Extraction with decorticators is faster and gives fibre of superior quality and lighter colour, which can be made into higher grade cordage. The extracted fibres are washed and dried. In Indonesia cantala leaves are decorticated mechanically with 'raspadors' or by decorticators also used for sisal fibre extraction. These machines are not as efficient as when used for sisal; 25% of the raw fibre is lost and the fibre strands are inadequately cleaned.

A grading system in the Philippines classifies fibres as: MR-1 ('Maguey 1'), very clean, with a high strength and dull white colour; MR-2 ('Maguey 2'), fairly clean, but with many scales and some leaf parts, and with an average strength and off-white colour; MR-3 ('Maguey 3'), uncleaned, weak and light brown coloured, usually all as a result of excessive retting and insufficient washing and drying; MR-Y ('Maguey Damaged'), very low quality fibre with excessive discolouration and very low strength, due to overretting, insufficient retting or improper decortication; MR-O ('Maguey String'), twisted or knotted strands; and MR-T ('Maguey Tow'), very short or tangled fibres. Length designations are: Long (1 m and longer); Normal (0.6–1.0 m); Short (0.4–0.6 m) and Very Short or Tow (under 0.4 m).

Genetic resources and breeding *A. cantala* has a narrow (clonal) genetic base and offers little opportunity for breeding and selection. Seed is not often formed, but by pruning the roots and cutting back the inflorescence, viable seeds have been obtained in Indonesia, both after selfing and after crossing with sisal. No germplasm collections of *A. cantala* are known to exist.

Prospects The production of cantala in South-East Asian countries such as the Philippines and Indonesia is steadily declining due to factors such as the low price of cantala fibre and the increasing use of synthetics which has led to a reduction in demand for natural fibres. In the Philippines locally produced cantala fibre is being replaced by imported sisal. Unless new markets and demand for the fibre and its products develop, the prospects for the revival of the cantala industries in this region are bleak.

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Agave sisalana Perrine

U.S. 25th Congress, 2nd Session – House of Reps Rep. 564 (Tropical Plants): 8, 9, 16, 47, 60, 86; Senate Rep. *300*: 36, *105*, *140*, pl. *1*, *2*, *4* (1838).

AGAVACEAE

$2n = 150$ (pentaploid)

Synonyms *Agave rigida* Mill. var. *sisalana* Engelmann (1875).

Vernacular names Sisal, sisal hemp, sisal agave (En). Sisal, langue de boeuf, pite sisal (Fr). Indonesia: sisal. Thailand: sapparot thet (central), pan-sonnarai. Vietnam: d[uwr]a s[owj]i tr[ow]n, d[uwr]a s[owj]i kh[oo]ng gai.

Origin and geographic distribution Sisal is probably of southern Mexican origin, but this is not entirely certain, as wild forms are not known. Sisal has been widely introduced and cultivated in the tropics and subtropics. It was introduced into Florida in 1836–1843, Tanzania in 1893, Brazil at the end of 19th Century and Kenya in 1903–1908. In Asia it was introduced into India between 1885 and 1892, Malaysia a few years later, the Philippines around 1905 and Indonesia in 1913. At present it is cultivated in a range of countries, including Indonesia, Thailand, Burma (Myanmar) and India.

Uses The main sisal product is the long fibre ('line fibre') from its leaves, which form the major part of the 'hard fibres' of commerce. Sisal fibre is mainly used to make twines, ropes, strings, fishing nets and hammocks. In Madura (Indonesia), for instance, sisal cordage is used for making ship cords, fishing gear and for packing tobacco. Sisal has been widely used for the manufacture of binder and baler twines, but this use has declined steadily in the past decades due to the increasing application of synthetic twines. Sisal fibre is also woven into material for carpet-backing, sacks, industrial fabrics and matting and is used as padding in cars and upholstery. Shorter fibres ('tow') are used for the production of upholstery material, mats, carpets, building panels and cellulose. Sisal fibres serve for making specialty papers, such as cigarette paper, newsprint, bag paper, carbon paper, safety and banknote paper, filter paper and tea bags. However, sisal pulp is more often used in the production of common grade paper, in blends with wood pulp to add porosity or to reinforce weaker pulps, such as those from recycled paper. Sisal waste material after fibre extraction and discarded sisal products may also be utilized for papermaking.

Hecogenin from sisal leaves has been used as a precursor in the partial synthesis of corticosteroids such as cortisone, hydrocortisone and prednisone, whereas waxes and pectin can also be obtained from sisal leaves. The inflorescence stalks are used for house construction, fencing and thatching. Waste material after fibre extraction and boles may serve as animal feed, either directly or after ensilage.

Production and international trade World sisal production reached its peak of over 600 000 t per year in the 1960's, but has declined gradually since then with the introduction of synthetic fibres such as polypropylene. The annual sisal production in Tanzania peaked in 1964 at about 230 000 t from about 230 000 ha, whereas in Brazil the peak of about 300 000 t was reached in the 1970s. The average annual world sisal fibre (line fibre and tow) production in 1996–2000 was about 300 000 t, the major producers being Brazil (153 000 t), China (35 000 t), Kenya (24 000 t), Tanzania (22 000 t) and Madagascar (17 000 t). Indonesia produced only about 450 t annually in this period, which is very little compared to the estimated estate sisal production of about 80 000 t in 1939. In Thailand 35–40 t was produced annually in 1996–2000.

The international trade in sisal amounted to about 72 000 t per year in 1996–2000, the principal exporters being Brazil (31 000 t), Kenya (17 000 t), Tanzania (12 000 t) and Madagascar (5 000 t). Sisal from East Africa, where the crop is mainly grown on estates, is of better quality than that from Brazil, where it is mainly produced by smallholders, and fetches a higher price on the world market. The main importing countries were Portugal (23 000 t) and Spain (9 000 t). South-East Asian countries were net importers in this period, with the Philippines importing about 600 t annually, Thailand 200 t and Indonesia 100 t.

Properties Each sisal leaf contains (700–)1000–1200(–1400) fibre bundles which, as in other *Agave* species, can be distinguished into 2 main types:

- 'mechanical fibres', constituting 75% of the fibres in the leaf and mainly concentrated in 3–4 rows in the peripheral zone below the epidermis; these fibre bundles, nearly round or horseshoe-shaped in cross-section, keep the leaf rigid and rarely divide during processing, thus being the main determinant of the fineness of the resulting fibre.
- 'ribbon fibres', constituting 25% of the leaf fibres, are found in a line in the centre of the leaf; they coalesce and become lignified towards the end of the leaf to form the terminal spine. They are also present in other parts of the leaf and serve to protect the vascular bundles; those covering the phloem are large and crescent-shaped and tend to split longitudinally during processing, whereas those covering the xylem are weak, thin-walled and mostly lost during decortication.

The average fibre content of the leaves is about 3.5–4%, but it increases during the life cycle from about 2% to 4.5–5%. The fibre bundles are composed of fusiform cells, strongly bonded together. The ultimate fibre cells are (0.3–)1.5–4(–15) mm long and (8–)15–30(–50) μm in diameter, circular, polygonal or oval-polygonal in cross-section with greatly thickened walls (about 6(–9) μm) and a small roundish lumen. The fibre cells may taper to a blunt point or be rounded. The fibre number, length and strength do not change with the age of the leaf after it has unfurled. However, the average strength of the fibres increases and the fineness decreases slightly with the age of the plant at which the leaf was formed. Sisal fibre is hard, coarse, long (1–1.5 m), very strong and nearly white, cream or pale yellowish. Quantitative information on the physical properties show wide variation in, for example, tensile strength of the fibre (170–640 N/mm^2) and elongation at break (2–29%). Typical values of the tensile strength, elongation at break, and Young's modulus of sisal fibre are 510–635 N/mm^2, 2.0–2.5% and 9.4–22.0

GPa, respectively. Sisal can be used for making sacks, but cannot be spun as fine as jute. On a dry weight basis sisal fibre contains approximately 54–66% α-cellulose, 12–17% hemicelluloses, 7–14% lignin, 1% pectin and 1–7% ash.

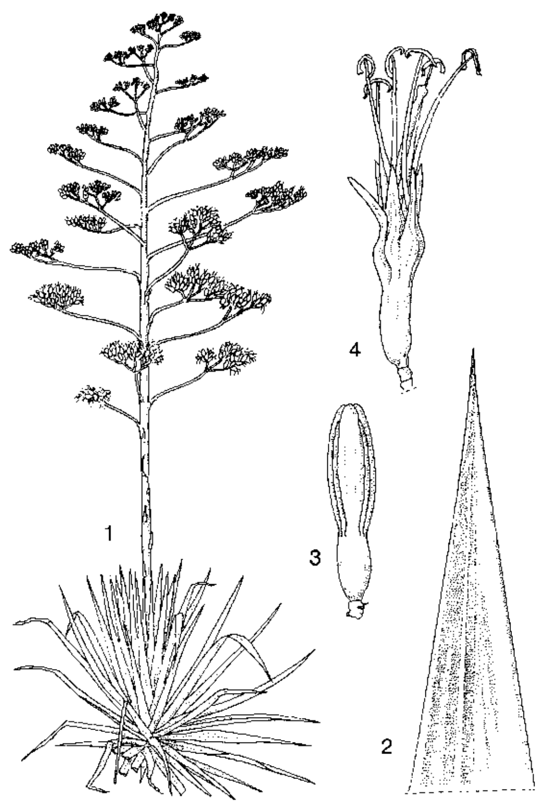
Sisal pulp has an exceptionally high tear strength, good porosity, high bulk, high absorbency and high folding endurance, making it suitable for specialty papers and for reinforcing other pulps. Sisal is best pulped using chemical methods. Normally the cold soda process is used, because it is relatively cheap and produces no harmful chemicals. The yield with this process is 50–55%.

Sisal contains hecogenin, with the content increasing with the age of the plant. Hecogenin from sisal can be used in the partial synthesis of corticosteroids, but only if it is not overly contaminated by tigogenin, another sapogenin, because this results in unacceptable losses in product quality and yield. East African sisal yields relatively clean hecogenin with only 5–10% tigogenin, but sisal from other parts of the world often contains more tigogenin, e.g. 20–30% in Brazil. Sisal has shown molluscicidal activity against the schistosomiasis vector *Biomphalaria glabrata*. The protein content of sisal waste is about 5–6% and that of the bole only about 2%.

Adulterations and substitutes Abaca (*Musa textilis* Née) and henequen (*Agave fourcroydes* Lem.) may be substituted for sisal or mixed with it. Compared to abaca, sisal ropes are less strong, harsher on the hands, swell more and quicker in water without regaining their shape on drying, and tend to break without warning, whereas abaca will show signs when it starts to break. For these reasons and because sisal ropes become stiff when wet and do not float, sisal is less suitable for marine purposes than abaca. Cantala (*Agave cantala* Roxb.) fibre is less strong than sisal fibre, but finer, more supple and whiter. Fibres from New Zealand hemp (*Phormium tenax* J.R. Forster & G. Forster), Mauritius hemp (*Furcraea foetida* (L.) Haw.) and *Sansevieria* spp. are softer than sisal fibre and may be used instead of sisal for specific purposes. Sisal and other hard fibres face strong competition from synthetic products, such as polypropylene and nylon.

Sisal is more difficult to pulp than abaca, as it requires a higher pressure, longer cooking time and/or more chemicals. Furthermore the pulping yield of sisal is lower. Because sisal fibre cells are shorter and slightly thinner than those of abaca, paper made from sisal has a higher porosity but lower tensile and bursting strength than paper made from abaca. Therefore, sisal is inferior to abaca for the production of specialty papers, except for filtration media.

Description A robust, monocarpic, xerophytic perennial herb, 3–9 m tall when flowering, producing subterraneous stolons (rhizomes) and suckers, and numerous crowded leaves in a rosette. Roots fibrous, originating from the base of the leaf scars at the bottom of the stem, spreading horizontally up to 3(–5) m, and vertically up to 150 cm deep, but concentrated in the upper 30–40 cm of the soil; anchoring or bearer roots, 2–4 mm in diameter, extend horizontally for 1.5–3(–5) m in free range; feeder roots, 1–2 mm in diameter, arise from the bearer roots. Stem short and thick, 120 cm × 20 cm, with an apical meristem and a close rosette. Rhizomes 1.5–3 cm in diameter arise from buds in the axils of leaves below ground level, numbering 5–10 at one time and about 20 in the total life span, grow about 2 m in length before coming to soil surface and producing suckers used as propagation material. Leaves succulent, sessile, arranged in an ascending spiral, linear-lance-



Agave sisalana Perrine – 1, habit flowering plant; 2, apical part of leaf; 3, flower bud; 4, flower.

olate, 75–185 cm × 10–15 cm × 2–4.5 cm, base fleshy, bulbous, triangular in cross section, margin usually spineless, blade gradually broadening to middle and narrowing towards terminal sharp, lignified, dark brown spine up to 3 cm long, concave above and convex below, dark green but covered with a white waxy layer. Inflorescence a panicle on long peduncle, 2–8 m tall, branches widely patent, 30–100 cm × 2 cm, apically 5–6 times branched trichotomously, bearing about 40 flowers per branch; pedicel short; flowers erect, protandrous, containing much nectar; perianth tubular, 6-lobed, 5–6 cm long, pale green; tube 1–2 cm long, lobes oblong, on inner side of the top with a tuft of hairs; stamens 6, attached above the middle of the perianth tube, accrescent during anthesis, finally 6–8 cm long; pistil with inferior, 3-locular ovary containing numerous ovules, style much accrescent during anthesis and finally 6–8 cm long, stigma 3-lobed. Fruit (rarely produced) an ellipsoid capsule, tapering at base, green and fleshy when young and black and dry when ripe, with about 150 seeds. Seed rounded-triangular, thin, flat, papery, black. Bulbils copiously produced on the inflorescence branches, consisting of a meristem, 6–8 reduced leaves and a rudimentary stem with rudimentary adventitious roots. Seedling with epigeal germination.

Growth and development Sisal plants have a short stem or bole on which the leaves and the central bud (often called 'spike') are borne. In the central bud immature white leaves are packed tightly around the meristem until they are pushed outwards by the growth of succeeding leaves and unfurl. The angle between unfurling leaves and stem gradually widens until the lower leaves are almost horizontal. After having produced (180–) 200–250(–300) leaves, which may be up to (3–) 6–9(–20) years after planting depending on climate and soil conditions, a long flowering shoot ('pole') is produced. Its initial growth rate is 10–12 cm per day. In Java poles are formed throughout the year, but in more seasonal climates there is usually a flush of pole formation after the rainy season. After the pole has reached its final length, flowering branches are produced. Flowering starts on the lowest branch and proceeds upwards, taking several weeks until all branches have flowered. The stamens dehisce 2–3 days before the style is fully elongated and the stigma is sticky and receptive. When female flowering takes place on a branch, the stamens on the branch above shed pollen. Pollination is mostly by insects, mainly bees, but wind-pollination can also occur. Although the pollen is viable, the flowers usually abscise. Where sisal has produced seed, this may have been due to contact with pollen from *A. vivipara* L. or related species. It has also been suggested that fruiting in sisal depends on external conditions. Seeds have been obtained in the Kenyan highlands, Indonesia and Brazil by cutting back the inflorescence in an early stage of its development, but this technique was not successful at lower altitudes in East Africa. Bulbils are normally formed on the panicle after the flowers abscise and usually appear in the bottom branches of the pole before the upper flowers have finished flowering. The bulbils grow to a length of 6–10 cm in about 3 months, after which they are shed. One plant can produce up to 4000 bulbils. After the production of flowers and bulbils the entire plant dies. However, a sisal plant may produce 20 or more suckers during its life cycle. Suckers normally start to form when plants are about 1 year old, are most prolific in the 2nd and 3rd year and become fewer as the plants age.

During the initial vegetative phase of the sisal plant each new leaf is 0.6–0.8 cm longer than the preceding leaf. When leaves are regularly harvested the leaf length increase is less, but the rate of leaf unfurling remains almost the same. When sisal becomes reproductive, each new leaf is shorter than the preceding. Based on these characteristics the life cycle can be divided into 4 phases:

- the immature period from planting to first cut;
- the period during which relatively short leaves are cut (usually the 1st and 2nd cut);
- the period during which long leaves (about 120 cm) are harvested;
- the period just before poling, when leaves are becoming shorter.

Sisal follows the Crassulacean Acid Metabolism (CAM) pathway. CAM plants are able to fix CO_2 at night and photosynthesize with closed stomata during the day, thus minimizing water loss. A mature sisal plant, excluding roots, weighs about 60 kg. On a dry weight basis the leaves constitute 70%, the roots 22% and the bole 8% of an unharvested plant. An average leaf weighs about 0.7 kg.

Other botanical information *Agave* L. comprises about 200 species distributed mainly in arid and semi-arid regions from the south-western United States to western Panama, the Caribbean and Venezuela. However, the taxonomy of the genus is very complicated and different views exist on its delimitation and classification. The basic chromosome number of the genus is $x = 30$, and it contains diploids, triploids, tetraploids and pentaploids. In Central America, where the genus probably originated, *Agave* has been used by humans as a source of food, drink and fibre for at least 9 000 years. *A. sisalana* is probably of hybrid origin, with *A. vivipara* (synonym: *A. angustifolia* Haw.) and *A. kewensis* Jacobi as possible parents. Several *Agave* spp. are cultivated for their long fibres, which form about 85% of the hard fibres of commerce. *A. sisalana* is the most important of these on a world scale, followed by henequen (*A. fourcroydes*), which is only grown in Mexico and some Central American and Caribbean countries, with Mexico and Cuba as main producers. Other long-fibre agaves are *A. cantala* and *A. vivipara* L. var. *letonae* (Taylor ex Trel.) P.I. Forst., which are cultivated to a limited extent, the former being of some importance in South-East Asia (see separate article). Hybrid 11648, obtained in East Africa by backcrossing a hybrid of *A. amaniensis* Trel. & W. Nowell and *A. vivipara* with *A. amaniensis*, has largely replaced *A. sisalana* in Tanzania. However, its fibre is similar to that of *A. sisalana* and commercially no distinction is made. No information exists on the extent to which this hybrid has replaced *A. sisalana* in South-East Asia.

A. lurida Ait. (synonym: *A. vera-cruz* Miller) gives an inferior fibre used in the 'longyi' (a garment) industry in Burma (Myanmar) and it is sometimes grown in Malaysia.

Ecology Sisal is a hardy tropical plant needing full sunlight and moderate relative humidity. It grows best in regions with an average annual rainfall of 1000–1250(–1800) mm, but is often grown with less. The maximum temperature should be 27–32°C, with minimum temperatures of 16°C or higher and daily fluctuations not exceeding 7–10°C. Sisal is damaged by frost and hail. Under dry conditions or at low average temperatures it forms fewer leaves per year and has a longer life cycle. In Java it is grown up to about 600 m altitude. Sisal prefers sandy-loam soils but can be grown on a range of soils, provided they are rich in bases, especially Ca, and well drained, as sisal does not tolerate waterlogging. The pH should be between 5.5 and 7.5, though sisal has been grown on soils with pH 4–5 in Indonesia.

Propagation and planting Sisal is propagated vegetatively with bulbils or suckers. Though suckers are directly available from the field, bulbils are more often preferred, because they are produced in greater numbers, making selection possible and thus a more uniform crop. Bulbils may be collected from the ground after they have fallen or the pole may be cut and the bulbils shaken into sacks. In very dry years bulbils may be in short supply. Bulbils at least 10 cm long are planted in nurseries at a spacing of about 50 cm × 25 cm at a depth of 1.3 cm. Application of sisal waste in the nursery is beneficial to plant growth. After 12–18 months the plants are ready to be planted out into the field. At transplanting the fibrous roots around the base of the plantlets are usually cut off and the lower leaves may be pulled off.

Before planting in the field, the soil is cleared mechanically or by hand and it may be ploughed shallowly. The optimum density ranges from 4000–6000 plants/ha, depending on climate and soil. Most sisal estates in East Africa have a density of 5000 plants/ha, obtained by a spacing of 2.5 m × 0.8 m between plants or by double rows 3.5–4 m apart, with 1 m between the rows of each pair and (0.75–)0.8(–1) m between plants within each row. In Indonesian estates the usual density is 7200 plants/ha, obtained by planting in double rows 2.7 m apart, with 0.9 m between the rows of each pair and 0.75 m between plants within the rows. A density of 7000 plants/ha has been mentioned for sisal grown for pulping in Brazil. The planting depth is 5–8 cm.

In vitro propagation of sisal is possible, as complete plants have been regenerated from rhizome and stem explants on various growth media, supplemented with different concentrations of benzyladenine (BA), kinetin, naphtalene acetic acid (NAA), indolacetic acid (IAA), indolylbutyric acid (IBA) and 2,4-D, either alone or in combination. Shoot regeneration may occur either directly or from callus, and regenerated shoots root readily.

Sowing of legume cover crops such as *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth. is recommended. On fertile soils or with proper fertilization young sisal may be interplanted with maize, beans or cotton without adverse effects on the sisal crop unless the other crops are planted very close to the sisal rows. In Indonesia sisal has been grown in rotation with, for instance, cassava (East Java) and abaca (Sumatra), but rotation is not necessary if sisal processing waste is returned to the field.

Husbandry Weeds should be controlled in the first 2–3 years after transplanting sisal, by hand, or by mechanical or chemical means. Later, weeds may be allowed to grow during the rains and cut down at the beginning of the dry season to conserve moisture and provide mulch. The nutrient removal per t of fibre is about 27–33 kg N, 5–7 kg P, 59–80 kg K, 42–70 kg Ca and 34–40 kg Mg, but the majority of the removed nutrients can be returned to the field with the waste material after fibre extraction. Fertilizer recommendations depend on soil characteristics and cropping history. Lime application is recommended in highly acidic soils. 'Purple leaf tip', in which the leaf tip becomes reddish-purple and the leaf margins curve upwards, is associated with exhausted acid soils and a shortage of calcium, but other factors may also be involved. Potassium deficiency causes 'banding disease', characterized by 10–15 cm wide horizontal bands of purplish-brown necrotic tissue, especially at the transition between the leaf base and the leaf blade, resulting in wilting and bending over of the leaf blade. Nitrogen application tends to shorten the crop cycle, but the total number of leaves is not affected. Care should be taken in using ammonium sulphate which may increase soil acidity. Suckers should be removed and may be used for propagation. Old sisal fields are sometimes kept in production by maintaining selected suckers, but this method is not recommended as it is better to replant the field.

Diseases and pests The most serious disease of sisal is bole rot caused by the fungus *Aspergillus niger* entering through the leaf bases after leaves are cut. It causes a wet rot which becomes yellowish-brown and soft, with a pinkish margin, and it may lead to plant collapse and death. The incidence can be reduced through removal of infested material and harvesting under dry conditions. The fungus also causes a basal dry rot when it enters the base of the bole through an injury.

The only serious insect pest of sisal is the Mexican sisal weevil (*Scyphophorus interstitialis*), first recorded in Tanzania in 1914 and in Java in 1916. The larvae damage the subterranean parts of young plants and may cause substantial losses. They also feed on leaves in the central bud, giving a shothole effect, whereas the adult weevil damages the crop by feeding on the youngest leaves before and shortly after unfurling. Planting before or in the early rains and the application of insecticides in the soil around young plants can control the insect.

Harvesting Sisal leaves are harvested at regular intervals during the life cycle of the crop. As the total number of leaves produced during the life of the plant is constant and the rate of leaf emergence is affected by temperature and rainfall, the time from planting to the first harvest, the total production period and the number of cuttings depend on environmental conditions. An early start with cutting is conducive to better yields, if the plants are not cut too severely. If cutting is delayed, plants pole earlier and heavy leaf losses occur through withering. Overcutting results in the formation of more but smaller leaves with a lower fibre content, leading to reduced fibre yields and higher cutting costs. In general the first harvest takes place when leaves over 60 cm long start to touch the ground. Leaves shorter than 60 cm are normally not used for fibre extraction, because mechanical decorticators cannot handle them. The time from planting to the first harvest depends on the rate of leaf production, which in turn depends on climate and soil conditions. Under East African lowland conditions (high temperature) cutting usually starts 2–3 years after planting and cutting is then repeated annually. In the Kenyan highlands (lower temperature) cutting usually starts 4 years after planting. On estates in Indonesia (high temperature, high soil fertility) it was common practice to have the first cutting at 1.5–2 years after planting with 12–13 further cuttings until the plants were 6–8 years old. In Brazil (low rainfall, low soil fertility) the first harvest usually takes place when the plants are 3 years old and subsequent harvesting is twice a year. Generally harvesting continues for about (5–)8(–12) years. At the last cutting, when about 80% of the plants are poling, all suitable leaves (more than 60 cm long and sufficiently succulent) are cut. Harvesting is usually done throughout the year.

Usually the leaves are cut manually at 2.5–5 cm from the bole. It is essential to leave sufficient leaf area at each cutting to enable the plant to continue growing. About 20–25 leaves are left on the plant at the first cutting, and this number is usually decreased to 15–20 leaves at subsequent cuttings. The terminal spines are removed before or after the leaves have been cut. The leaves are tied in bundles and transported to the processing site, which must be done as soon as possible after harvesting, because cut leaves deteriorate rapidly if exposed to the sun.

Yield From 100 kg sisal leaves about 3.5 kg extractable fibre is obtained, of which about 92–96% is line fibre and 4–8% tow. On the best Indonesian and East African plantations annual fibre yields of 2.0–2.8 t/ha have been obtained, whereas on poorer soils annual yields were about 1 t/ha. However, yields in Tanzania have shown a strong downward trend since the 1960s. Present yields in Madura (Indonesia) are less than 0.5 t/ha per year, with a fibre recovery from the leaves of only 2–2.5%. Sisal processed for pulp production in Brazil yields about 5.5 t of dried fibre per ha per year, with 6 kg of fibre obtained per 100 kg fresh leaves.

Handling after harvest Fibre extraction of sisal should be carried out as soon as possible after cutting, because leaf juices tend to harden, making fibre extraction more difficult. Where sisal is grown for local use in Indonesia, the fibre is manually extracted by scraping away the leaf parenchyma with a stump knife or piece of wood. Retting is also done, e.g. in India, where the leaves are immersed in water for about a week, after which the leaves are beaten on a stone to remove the remaining extraneous matter, and the separated fibre is washed, dried in the sun and baled. In commercial production, decortication is usually mechanical. Before the advent of high-speed automatic decorticators this was done by semi-automatic raspadors, consisting of 1–4 open rotating drums with blades or bars on the periphery, into which the leaves are fed manually and end-on. Decorticators consist of decorticating drums, chains or rope for leaf-gripping and belts, into which the leaves are fed sideways, and have a much higher productivity than the raspador. Extraction with decorticators involves crushing and scraping, removing and washing away the parenchymatous leaf tissue and leaving the fibre strands to continue through the machine. During decortication 15–20% of the total leaf fibre ('flume tow') is lost and enters the waste effluent. Mobile decorticators have been introduced into Tanzania. After decortication and washing, the fibre is dried, either in the sun or in drying machines, the latter giving fibre of a more uniform quality. Excessive drying in the sun may lead to deterioration in colour. The dried fibre, which has become stiff and congealed, may be beaten lightly by metal beaters ('brushing') to free the individual bundles and to remove dirt and other extraneous matter. This process also combs out the shorter fibre strands, 7.5–12.5 cm in length, which constitute the 'brush tow'.

Sisal fibre is mainly graded according to length, colour and presence of impurities, but designations vary by country and even within countries. The moisture content of packed fibre should not be more than 10–12%. If it is too wet, it becomes stiffly matted and there is a danger of spontaneous combustion in the bales. The fibre is baled in hydraulic presses to produce unwrapped bales of the desired size. Spinning of yarn is usually done on special machines able to cope with the long fibres. The yarns produced are coarse, spiky and harsh to the hands. They are used singly as harvest twine, 3-folded into packaging twine or further multiplied into ropes of different sizes.

For paper production in Brazil, the leaves, with the terminal spine removed, are transversely cut into pieces about 5 cm long and passed through a hammer mill. The juice and other residues are removed through vertical screens, the fibres are passed through a drier and pulped using an alkaline soda process.

To obtain hecogenin, sisal leaf juice collected from the decorticator is allowed to ferment for several days, after which the sludge is hydrolysed into a dark brown solid ('coffee grounds') with a hecogenin content of 10–20%. Alternatively, air is blown upwards through a tank containing fresh juice, and the resulting foam, containing most of the saponins, is transferred to a vessel for immediate hydrolysis to hecogenin.

Genetic resources About 70 sisal accessions are kept at the Centro Nacional de Pesquisa de Algodão (CNPA), Campina Grande, Brazil. The Instituto Agronômico de Campinas (IAC), Campinas, São Paulo, Brazil, maintains a collection of about 300 *Agave* accessions. Germplasm is also kept at the Mlingano Agricultural Research Station in Tanzania.

Breeding Sisal has a narrow genetic base and offers little opportunity for breeding and selection. Furthermore, the plants have a long life cycle and it is almost impossible to synchronize flowering of prospective parents. Most breeding work has been carried out in East Africa, where it focused on developing a long-fibre agave with a more rapid growth and higher leaf number potential than sisal, but resembling sisal in other respects (non-spiny leaf margins; long, heavy and rigid leaves of good configuration; good fibre yield per leaf; resistance to diseases and pests; good fibre quality). Several other *Agave* spp. have been incorporated in sisal breeding. Examples are the diploids *A. amaniensis*, which has smooth margins and finer and more numerous fibre bundles in its leaves than *A. sisalana* but has leaves tending to be corrugated, making mechanical processing difficult, and *A. vivipara*, which produces many but short leaves with spiny margins. Crosses between *A. sisalana* and these species resulted in progenies with spiny margins, but crosses between *A. amaniensis* and *A. vivipara* are fertile and combine a high number of leaves with a good leaf size, some of them having smooth margins. Backcrossing of these hybrids with *A. amaniensis* gave very good results, in particular Hybrid 11648, which may produce more than 600 leaves and give annual fibre yields twice as high as sisal, with a longer life cycle. The leaves are of good configuration and have smooth margins, and the fibre is as strong as sisal fibre, though finer. However, Hybrid 11648 is susceptible to 'zebra disease' caused by *Phytophthora* spp., to which *A. sisalana* is mainly resistant. At altitudes higher than 600 m the leaves are short and the leaf-number potential is not realized because of early poling. Breeding work in Brazil also focussed on backcrosses between *A. amaniensis* and hybrids of *A. amaniensis* and *A. vivipara*. Successful crosses between sisal and cantala have been made, e.g. in Indonesia, but usually seed set is poor and the progeny has spiny leaf margins.

Prospects There is scope for increased utilization of sisal and sisal-like agaves such as Hybrid 11638, in view of the resurgence of demand for natural fibres for their biodegradability and unique appearance and texture. Non-traditional uses of sisal and sisal-like fibre, especially for the production of pulp, offer promising new possibilities for producers. The development of highly productive cultivars suited to local needs, improved management practices, efficient fibre extraction and pulping technologies and further promotion of the use of natural fibres may open a new frontier to the profitable cultivation of sisal and sisal-like agaves in South-East Asia. The development of mechanical harvesting methods would enhance their prospects as fibre crops, especially if it could be combined with fibre extraction. Better utilization of the by-products (e.g. short fibres, poles and boles for pulping; leaf waste for feed or hecogenin extraction) would help to make their cultivation more profitable.

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Anodendron A. DC.

Prodr. 8: 443 (1844).

APOCYNACEAE

x = unknown; $2n$ = unknown

Major species and synonyms

- *Anodendron candolleanum* Wight, Icon. pl. Ind. Orient. 4: t. 1309 (1848), synonyms: *A. rubescens* (Teijsm. & Binnend.) Teijsm. & Binnend. (1866), *A. scandens* (Hassk.) Pichon (1948), *A. tenuiflorum* auct. non (Miq.) Miq. (1965).
- *Anodendron oblongifolium* Hemsl., Ann. Bot. (Oxford) 5: 504 (1889).
- *Anodendron paniculatum* A. DC., Prodr. 8: 444 (1844), synonyms: *A. moluccanum* Miq. (1869), *A. tenuiflorum* (Miq.) Miq. (1869), *A. manubriatum* Merr. (1912).

Vernacular names

- *A. candolleanum*: Malaysia: akar katam, akar tingam. Thailand: yaan tum (Trang).
- *A. oblongifolium*: Papua New Guinea: kapi, karge (Bougainville Island).
- *A. paniculatum*: Andamanese bowstring plant (En). Indonesia: gambi (Javanese), bikat (Dayak), upapi (Ambon). Thailand: thao yaang nong (Trat), phi-pha-du (Chiang Mai), yaang nong thao (Prachin Buri).

Origin and geographic distribution *Anodendron* comprises 17 species and is distributed from India, Sri Lanka and China eastwards to Japan and southwards and eastwards through South-East Asia to the Solomon Islands and Vanuatu. From South-East Asia 15 species are recorded. *A. candolleanum* is found in Thailand, Malaysia, Indonesia and the Philippines. *A. oblongifolium* occurs in Peninsular Malaysia, Borneo, the Moluccas, the Philippines, Papua New Guinea, the Solomon Islands and Vanuatu. *A. paniculatum* is distributed from India and Sri Lanka through Bangladesh, Burma (Myanmar), Thailand, Cambodia, Laos, Vietnam and Malaysia to Indonesia and the Philippines.

Uses In the Moluccas the bast fibre of *A. paniculatum* is made into fishing nets and it has been used for bow-strings. In Kalimantan the main application of the fibre is also for fishing nets. Twisted stems are used as coarse tying material in Java. In Malaysia the bast has been used for tying. In Indo-China fibre from *A. paniculatum* serves as sewing-thread. On the Andaman Islands bast fibre of *A. paniculatum* is made into string, harpoon lines, bowstrings and turtle nets. The fibre is also used in India and Sri Lanka. The bast fibre of *A. oblongifolium* is applied similarly in Bougainville Island (Papua New Guinea) and the Solomon Islands for making strings for tying, fishing gear and bows, but also for custom clothing. Formerly *A. candolleanum* was the principal fibre in lower Perak (Malaysia), where it was probably used and prepared in the same way as *A. paniculatum* elsewhere. In the Philippines *Anodendron* stems serve for tying as well.

Anodendron latex is said to have been used as a poison on Ambon. The latex of *A. oblongifolium* is known as an antidote in case of poisoning by snakes or centipedes. The Dayak in Kalimantan boil the bast of old *A. paniculatum* plants to obtain a medicine against ulcers.

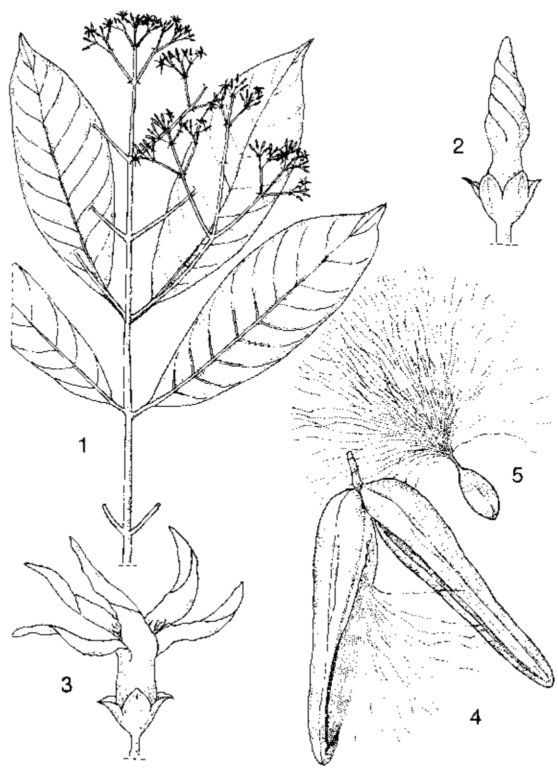
Production and international trade No production statistics of *Anodendron* are available. It does not enter international trade.

Properties Fibre from *A. paniculatum* is fine, strong and durable. That of *A. oblongifolium* is said to be tough and to last for a decade. However, detailed and quantitative information on *Anodendron* fibre properties is lacking.

Several cardiac glycosides (cardenolides), called anodendrosides A–G, have been isolated from *A. paniculatum* branches. Paper chromatography has shown the presence of cardenolides in the bark, leaves and seeds of *A. paniculatum* and the bark and leaves of *A. candolleanum*. Cardiac glycosides have effects on myocardial contraction and atrioventricular conduction, which may account for the toxicity of *Anodendron* latex.

Adulterations and substitutes For the production of fishing gear and other cordage applications *Anodendron* can be replaced by natural fibres, for instance *Colona javanica* (Blume) Burret and *Curculigo* spp., and synthetic materials.

Description Climbers or scramblers, producing latex upon wounding. Leaves opposite, petiolate, coriaceous to papery, entire. Inflorescence consisting of axillary or terminal cymes, often arranged paniculately; flowers regular, 5-merous; sepals free; corolla with a narrow cylindrical tube and spreading oblong to elliptical lobes which overlap to the right in bud; stamens included in corolla tube, attached in a ring around the pistil head; disk annular, 5-dentate or 5-lobed; pistil consisting of an ovary of 2 separate carpels united into a common style ending in an ovoid stigma head with a short sharp projection. Fruit a pair of sub-divergent follicles, wide at base, narrowing to the apex,



Anodendron paniculatum A. DC. – 1, flowering branch; 2, flower bud; 3, flower; 4, fruit (2 follicles); 5, seed.

longitudinally dehiscent. Seed flattened ovoid to ellipsoid, beaked, bearing a tuft of hairs (coma).

- *A. candolleanum*. A glabrous liana. Leaves thickly coriaceous; petiole up to 5 cm long; blade elliptical to oblong, 4.5–25 cm × 1.5–12 cm (1.5–3 times as long as wide), base rounded, apex acuminate to apiculate, with 8–12 pairs of lateral veins. Inflorescence 3–23 cm long; pedicel 2–4 mm long; sepals 0.6–1 mm × 0.3–0.6 mm; corolla pinkish or cream, glabrous outside, pubescent inside, tube 1.5–2.5 mm long, lobes 2–3 mm × 0.5–1 mm; stamens inserted at 0.6 mm from corolla base; disk 0.4 mm in diameter; pistil 1–1.5 mm long. Fruit 10–20 cm × 1–1.5 cm.
- *A. oblongifolium*. A glabrous liana. Leaves with petiole up to 2 cm long; blade elliptical to obovate, 6–16 cm × 2.5–7.5 cm (2–4 times as long as wide), base cuneate to rounded, apex acuminate, lateral veins 9–13 pairs. Inflorescence 2–10 cm long, minutely puberulent; pedicel 1–4 mm long; sepals 1–2.5 mm long, ciliate; corolla white or yellowish, glabrous outside, pubescent inside, tube 1.5–3.5 mm long, lobes 3–6 mm long; stamens inserted at 0.5–1 mm from the corolla base; disk 5-crenate, up to 0.5 mm in diameter; pistil 1–1.5 mm long. Fruit 11–15 cm × 1–2 cm. Seed up to 17.5 mm × 7.5 mm, beak 6–9 mm long, coma up to 9 cm long.
- *A. paniculatum*. A glabrous liana. Leaves with petiole up to 2.5 cm long; blade elliptical to obovate, 14–28 cm × 1–10 cm (2–4.5 times as long as wide), base cuneate to rounded, apex acuminate, lateral veins 8–18 pairs. Inflorescence 5–15 cm long; pedicel 1.5–3 mm long; sepals about 1 mm long; petals whitish-yellow, glabrous outside, pubescent inside, tube 1–3 mm long, lobes 2–4 mm long; stamens inserted up to 1 mm from corolla base; disk 0.3 mm in diameter; pistil 1–1.5 mm long. Fruit 8–16 cm × 1–3 cm. Seed up to 22 mm × 9 mm, beak 6–17 mm long, coma 5–9 cm long.

Growth and development In Java *A. paniculatum* flowers in June and July. In Indo-China flowering is from February to June and fruiting from January to August. In Papua New Guinea and the Solomon Islands *A. oblongifolium* flowers throughout the year.

Other botanical information *A. oblongifolium* is often included in *A. paniculatum*, but in a 1996 revision it was recognized as a separate species. It can be distinguished from *A. paniculatum* by its generally shorter inflorescences, which are more often axillary and puberulent, and larger flowers.

Cardenolide glycosides have also been isolated from the leaves, stems, bark and seeds of *A. affine* (Hook. & Arn.) Druce, which occurs in Bangladesh, Burma (Myanmar), Thailand, Laos, Vietnam, the Philippines, China and Taiwan. Some of these cardenolide glycosides have shown insect growth inhibitory activity. The leaves of *A. coriaceum* (Blume) Miq., found in Thailand, Malaysia and Indonesia, have been eaten as a vegetable in Indonesia. It is probable that fibre is or can be obtained from these and other South-East Asian *Anodendron* species.

Ecology *A. candolleanum*, *A. oblongifolium* and *A. paniculatum* are found in lowland forest.

Propagation and planting No information is available on propagation methods for *Anodendron*. In southern and eastern Borneo *A. paniculatum* is sometimes taken from the forest and planted near the house.

Diseases and pests In India *A. paniculatum* is affected by scab disease caused by *Elsinoe tumifaciens*. Severe infection causes hypertrophy of the leaf and stem and premature dehiscence of the fruits. There is no information on diseases and pests attacking *Anodendron* in South-East Asia.

Handling after harvest In the Moluccas *A. paniculatum* branches not thicker than about 2.5 cm are cut at the nodes to obtain pieces 30–70 cm long, covered by a 3-layered bark, with the outermost layer being grey or brown, the middle layer green and the inner layer white. The outermost and middle layers are scraped off, after which the white layer is removed with a knife and split into threads, of which 5–6 are twisted together into yarn. In Borneo young stems or green branches of *A. paniculatum* are cut into pieces about 40 cm long, which are allowed to wither in the house or in the sun. When the outer bark develops a wrinkled appearance, it is peeled off, the white fibres are exposed, and once removed by hand they are ready for use. In the Solomon Islands and Bougainville Island (Papua New Guinea) string is made from *A. oblongifolium* by removing the bark, drying the fibre in the sun and rolling the fibres end to end.

Genetic resources and breeding No germplasm collections or breeding activities of *Anodendron* are known to exist.

Prospects The role of *Anodendron* will probably remain limited to a local source of good quality fibre, especially useful in the production of fishing gear, with the different species having more or less the same role in various parts of South-East Asia. The presence of a range of natural and artificial substitutes makes an increase in the importance of *Anodendron* very unlikely.

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M. Brink

Artocarpus elasticus Reinw. ex Blume

Bijdr. fl. Ned. Ind.: 481 (1825) (*'elastica'*).

MORACEAE

$2n = 56$

Synonyms *Artocarpus blumei* Trécul (1847), *A. kunstleri* King (1888).

Vernacular names Wild breadfruit (En). Brunei: danging, tebagan, terap hutan. Indonesia: benda (Javanese, Sundanese), teureup (Sundanese), terap (Sumatra, Kalimantan). Malaysia: terap nasi (Peninsular), terap (Sarawak), terap togop (Sabah). Thailand: oh, ka oh, tuka (peninsular).

Origin and geographic distribution *A. elasticus* is native to Burma (Myanmar), Thailand, Malaysia, Brunei, Indonesia (Irian Jaya excluded) and the Philippines (Palawan). It is also cultivated, for instance in Malaysia and Indonesia (Java, Kalimantan).

Uses The bast (inner bark) of *A. elasticus* is traditionally made into cloth ('barkcloth'), for instance by aborigines in Sarawak. This cloth has been used to make shirts, loincloths, jackets, blankets and house walls. The bast also serves for making string, fishing nets and lines, carrying straps on baskets and mats. In Indonesia it has been made into bandages. It has been suggested as a raw material for paper making. The leaves are used for thatching and for making partitions in longhouses and temporary huts. In Malaysia *A. elasticus* fibre is an attribute in rice- and wedding-ceremonies and healing rituals.
Peeled shoot tips may be eaten raw or cooked and the fleshy perianth is edible as well. Ripe fruits are sometimes eaten, but they often have a bad smell. The seeds are eaten roasted or fried. The latex is used as birdlime. In Indonesia the leaves mixed with rice are taken against tuberculosis, and the latex against dysentery. The timber is used for light construction and for making boats, for instance in Java and Brunei.

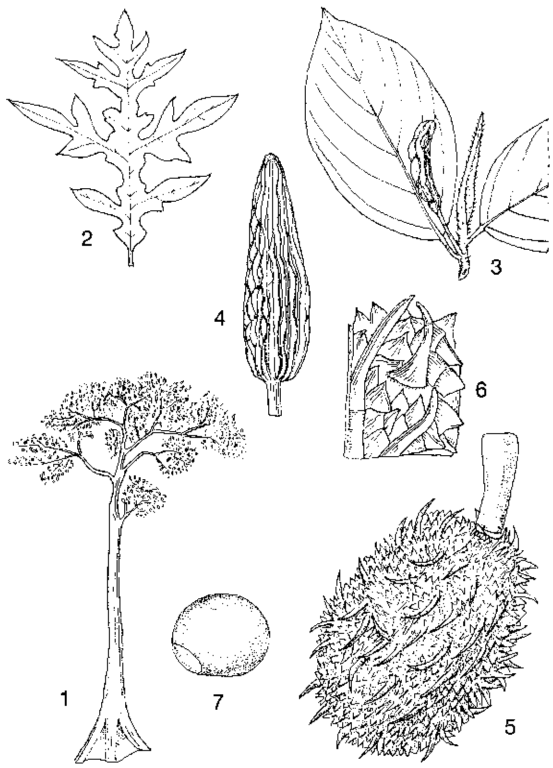
Production and international trade *A. elasticus* fibre and its products are used and sold locally and seldom traded on a large commercial scale; production and trade statistics are not available.

Properties The ultimate fibres in the bast of *A. elasticus* are (9-)18(-27) mm long, which is comparable to hemp (*Cannabis sativa* L.), and about 33(-44) µm wide. The cellulose content (Cross and Bevan method), calculated on a moisture-free base, is about 64%. The bast of old trees is less pliable than that from young ones, and therefore they have different names. In Malaysia young trees are called 'kelabit' and old trees 'talm'. In Tapanuli (Sumatra) young trees are called 'uwalang' and old trees 'torop'.
The average length of the ultimate fibres in the wood is 1.7 mm. The wood contains 59% holocellulose, 41% α-cellulose, 13% pentosans, 28% lignin and 1% ash. The solubility is 6.4% in alcohol-benzene, 6.2% in hot water and 16.9% in a 1% NaOH solution. It has a density of 365–545 kg/m^3 at 15% moisture content. With 15% active alkali a sulphate pulp yield of 51% has been obtained, with a kappa number of 20.6 and good paper making properties. The paper made from this pulp had a bulk density of 1.3–1.4 cm^3/g, a tear index of 11.8 mNm^2/g, a breaking length of 9.1–11.9 km and a stretch of 4.0–4.7%.
Seven prenyl flavonoids (artelastin, artelastochromene, artelasticin, artocarpesin, cyclocommunin, artelastocarpin and carpelastofuran) have been isolated from the wood of *A. elasticus*. They have shown moderate to strong in vitro activity against 3 human cancer cell lines (MCF-7, TK-10 and UACC-62), with artelastin having the most potent activity. Artelastin, artelastochromene,

artelasticin and artocarpesin have also shown anticomplementary activity.
The 1000-seed weight is 500–850 g.

Adulterations and substitutes To obtain barkcloth or cordage other *Artocarpus* species may be used in place of *A. elasticus*, such as *A. blancoi* (Elmer) Merr., *A. rubrovenius* Warb. and *A. tamaran* Becc. (see minor species). Barkcloth has also been obtained from *Antiaris toxicaria* Lesch. and *Broussonetia papyrifera* (L.) L'Hér. ex Vent. Nowadays barkcloth has almost entirely been replaced by cotton (*Gossypium* spp.). In Sarawak *A. elasticus* string is replaced by string made from the leaves of *Curculigo latifolia* Dryand., but the latter is less strong and durable.

Description An evergreen, monoecious tree, up to 45(–65) m tall; bole branchless for up to 30 m, up to 1.2(–2) m in diameter, with buttresses up to 3 m high; outer bark dark grey, smooth to slightly scaly, upon wounding exuding a white, thick latex; inner bark (bast) yellowish to pale brown; sapwood yellowish-white; twigs 1–2 cm in diameter, bearing ring-like stipular scars, short hispid. Leaves spirally arranged, stiffly leathery, in juvenile trees 2–3-times pinnatifid and up to 2 m long, in adult trees simple; stipules amplexicaul, lanceolate, 6–20 cm long, hispid-pubescent with yellow to red-brown hairs; petiole 4–10 cm long; blade ovate to elliptical, 15–60 cm × 10–35 cm, base rounded or cuneate, margin entire or shallowly crenate, apex acuminate; midrib raised above, lateral veins 12–14 pairs and flat and distinct above but prominently raised below, upper surface appressed hispid, lower surface bullate and hispid-pubescent. Inflorescence unisexual, capitate, solitary, axillary; numerous flowers densely packed together, embedded in the receptacle, the perianths enclosing a single stamen or ovary, usually mixed with abundant, stalked, interfloral bracts. Male head on peduncle 4–7.5 cm long, cylindrical, 6–15(–20) cm × 1.5–2.5 cm, with distinct deep grooves, yellow; perianth tubular, 0.8 mm long, bilobed at apex, appressed pubescent; stamens up to 0.9 mm long. Female head with bifid styles exserted to 1 mm. Fruit a syncarp on a 7–12 cm long peduncle, cylindrical, up to 17 cm × 10 cm, yellow-brown, covered by closely set, fleshy, whitish, short-hispid processes ('spines') of 2 lengths, the longer flexuous and solid, 10–18 mm × 1–1.5 mm, the shorter ones narrowly conical, perforate, 4 mm × 1 mm; interfloral bracts scattered between the processes, slenderly stalked and with funnel-shaped upper parts; fruiting perianths numerous, the proximal free region fleshy and white. Seed (the thin, horny pericarp) ellipsoidal, 10 mm × 6 mm. Seedling with hypogeal germination.



Artocarpus elasticus Reinw. ex Blume – 1, habit; 2, leaf of juvenile tree; 3, branch with leaves of adult tree; 4, male head; 5, fruit; 6, part of surface of fruit; 7, seed.

Growth and development Germination of *A. elasticus* starts in the third week after sowing and growth is relatively fast. The average height after 2 years of growth is 6–7 m, and after 7 years 11–12 m, with an average diameter of about 15 cm, i.e. a mean annual diameter increment of over 2 cm. Juvenile plants have deeply-lobed leaves (twice or thrice pinnatifid); as the tree grows the new leaves are less deeply cut until only simple adult leaves are produced. *A. elasticus* may be deciduous in regions with a dry season, such as the eastern coast of Peninsular Malaysia and its northern region. In Java flowers have been collected in January, August and November, and fruits in January. *A. elasticus* is probably wind-pollinated, the male inflorescences producing clouds of pollen. The fruits are eaten by monkeys and squirrels, which probably play an important role in seed dispersal. *A. elasticus* coppices freely, with the leaves on the coppice shoots having lobed leaves like those produced on juvenile trees.

Other botanical information *Artocarpus* J.R. Forster & G. Forster contains about 50 species and is distributed from Pakistan, India and Sri Lanka throughout South-East Asia to southern China, Taiwan, the Solomon Islands and Australia. It is divided into subgenus *Artocarpus*, with spirally arranged leaves having large amplexicaul stipules, and subgenus *Pseudojaca* Trécul, with alternate and distichous leaves having small non-amplexicaul stipules. *A. elasticus* belongs to subgenus *Artocarpus*.

A. elasticus is the most important source of fibre in the genus, not because its fibre is the best, but because it is good enough and readily available from the forest. Fibre for cordage and cloth is also obtained from several *Artocarpus* species treated in the PROSEA volumes 2 and 5(2): *A. altilis* (Parkinson) Fosberg (synonym *A. communis* J.R. & G. Forster), *A. heterophyllus* Lamk, *A. integer* (Thunb.) Merr. (synonyms: *A. champeden* (Lour.) Stokes, *A. integrifolia* L.f.), *A. scortechinii* King and *A. sericicarpus* Jarrett. *A. lakoocha* Roxb. is used for cordage in India.

A. elasticus is absent in the Philippines except for in Palawan and published information on *A. elasticus* in other parts of the Philippines probably refers to *A. sericicarpus* (some major differences with *A. elasticus* are: leaves are more thinly coriaceous and sometimes slightly scabrid above, never short-hispid; male head 3.5–10 cm × 1.5–2 cm; female head subglobose, 4.5 cm × 4 cm; syncarp ellipsoidal to cylindrical, 8.5 cm × 5 cm, with long processes 20–35 mm × 0.5–1 mm, short ones 3–6 mm × 1 mm). Some authors, however, consider *A. sericicarpus* to be a synonym of *A. elasticus*. Some information published on *A. elasticus* in Borneo seems to refer to *A. tamaran* Becc. (characteristics: leaves with 17–23 pairs of lateral veins; juvenile leaves deeply pinnatifid with sessile pinnae and narrowly winged rachis; surface of the male head bears short, irregularly cylindrical projections with pilose tips; processes on the syncarp up to 10 mm × 0.5 mm and covered by recurved hairs), and is therefore not included in the present treatment.

Ecology *A. elasticus* is found in evergreen and semi-deciduous forest, both primary and secondary, up to 1500 m altitude.

Propagation and planting *A. elasticus* can be propagated by seed. Seeds germinate readily (85%) when sown fresh, but germination decreases to 60% for seeds stored for 1 week and to 0% for those stored for 2 weeks. Seeds remain viable when kept inside the fruit, so storage may be slightly prolonged in this way. *A. elasticus* is sometimes planted in villages, for instance in Indonesia, but more often wild plants are utilized.

Harvesting *A. elasticus* trees usually have a diameter at breast height of more than 10 cm when they are cut to obtain the bast. For the production of string the Kenyahs in Sarawak fell young saplings or coppice shoots. To obtain latex the trunks are commonly scored in herring-bone fashion.

Handling after harvest In Sarawak the bast of *A. elasticus* is separated from the tree and outer bark, and then soaked in clean water to make it supple, after which it is stretched and dried. Next it is repeatedly pounded with a wooden beater (called 'tutuk' or 'pemalu' in Sarawak), rolled up first on one side and then on the other. It is soaked in clean water again and the whole process may be repeated. Most often, however, once is enough. The resulting coarse blanket is made into cloths. To make cordage, bast strips are usually pounded and twisted. To obtain string, the Kenyahs in Sarawak cut the felled stems into pieces 1.5–2 m long and the bark is stripped off in pieces 2–3 cm wide or more. The bast is peeled from the outer bark and dried in the sun for 2–3 days, after which it is reddish-brown. The material can be stored in this form. When string is needed, the bast material is divided into fine strands for plaiting. For mat-making in Tapanuli (Sumatra) the bark is removed from felled trees, after which the outer bark is removed and the bast is pounded until it is supple. Then it is dried and cut into strips, which are woven into mats, together with split rattan. In Padang Lawas (Sumatra) the bast is pounded, dried, submerged in water for 5 minutes, folded, pressed between 2 planks and cut into strips. Alternatively, the pounded bast is submerged in running water for one night, dried and then cut into strips.

Genetic resources and breeding No germplasm collections or breeding programmes of *A. elasticus* are known to exist.

Prospects Though *A. elasticus* is at present only locally used as a source of cordage and cloth, there is some prospect for an increase of its importance, because the long ultimate fibres make the bast fibre useful (e.g. as a substitute for hemp), the wood has good pulping and paper making characteristics, and compounds isolated from the wood have shown anticancer activity.

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S.P. Teo & R.E. Nasution

Arundo donax L.

Sp. pl.: 81 (1753); Gen. pl. ed. 5: 35 (1754).

GRAMINEAE

$2n = 100, 110, 112$

Synonyms *Arundo sativa* Lamk (1779), *Donax arundinaceus* P. Beauv. (1812), *Scolochloa donax* (L.) Gaudin (1828).

Vernacular names Giant reed, Spanish reed, bamboo reed (En). Canne de Provence, grand roseau (Fr). Burma (Myanmar): alokyu. Laos: khem. Thailand: o (general), o luang (northern), o yai (central). Vietnam: s[aaj]y, lau.

Origin and geographic distribution *A. donax* is distributed from the Mediterranean region to southern Asia. It has been cultivated in southern Europe and elsewhere since antiquity and has been introduced into many other parts of the world, including South-East Asia, Australia, southern Africa and America. It is widely naturalized in many countries and is sometimes considered a noxious weed, for instance in the United States.

Uses Split young culms of *A. donax* are widely employed for weaving articles such as baskets, mats, trays, lattices and chair-seats, for instance in Europe and India. Unsplit culms are made into a number of items including fishing rods, umbrella-handles, walking-sticks and fish traps. They are also used for light construction work, fences and as supports for plants. The leaves have been employed for tying and for thatching. In Mexico *A. donax* is woven into various types of baskets, cradles and mats. *A. donax* can be utilized, alone or in combination with *Eulaliopsis binata* (Retz.) C.E. Hubbard, *Phragmites vallatoria* (Pluk. ex L.) J.F. Veldkamp, or bamboos, for the production of printing, writing and wrapping paper. It can also be used for fibreboard manufacture. In Italy it is a source of cellulose for rayon production.

A. donax canes have long been made into musical instruments, such as flutes and are still the main source of reeds for clarinets, oboes, bassoons, saxophones and bagpipes. It is cultivated for this purpose in south-eastern France and, to a small extent, the United States (Texas and California).

The young shoots of *A. donax* are sometimes eaten. It has little importance as forage, but is grazed by cattle when other fodder is scarce. *A. donax* is widely grown as an ornamental, for instance in Java. It is planted for erosion control, for instance for dune stabilization (e.g. in Pakistan and Tunisia) and in windbreaks. Because of its high biomass production *A. donax* is under investigation as a renewable and CO_2-neutral source of energy in Europe and elsewhere. It is also being investigated as an element of plant-based systems for wastewater treatment.

The role of *A. donax* in South-East Asia is still limited. It has been introduced into Peninsular Malaysia, where it is occasionally cultivated as an ornamental (the variegated form) and for stabilization of embankments (the non-variegated form). In Indo-China tall stems are made into fishing rods and medicinally the rhizomes are considered to have lactifugal properties. In Burma (Myanmar) the root is used as a diuretic.

Production and international trade In the late 1950s, the annual production of *A. donax* cane for the manufacture of reeds for musical instruments was estimated at 90–140 t in France and 10 t in the United States. An estimated 15–20 million reeds were produced in France and 5–7 million in the United States. No recent production or trade statistics for *A. donax* are available.

Properties Mature culms of *A. donax* are hollow, with a diameter of 1–4 cm and walls 2–7 mm thick. Young culms have a diameter similar to that of mature ones, but their walls are thinner. The culms are divided by partitions at the nodes. The nodes form 10–25% of the stem mass, depending on the length of the internodes. The nodes and internodes contain 38% and 34% fibre, respectively. The outer stem tissue is very hard and brittle, with a smooth, glossy surface, which turns pale golden-yellow when the culm is mature. The collateral vascular bundles are freely distributed through the cross-sectional area of the parenchymatous inner ring, but those near the periphery are smaller and more numerous. The bundles in the interior are normally enclosed by a single row of fibres, but the number of rows of fibres increases towards the periphery, until they form a continuous ring of structural tissue with scattered vascular elements. *A. donax* culms are stronger than those of other *Gramineae*, but less strong than bamboo. For the production of articles such as baskets and lattices, young canes are preferred because they are more supple and thus more easily worked than older ones.

The ultimate fibre cells in *A. donax* culms are (0.1–)1.2–1.5(–5.4) mm long and (7–)15–17(–41) μm wide, with an average wall thickness of 5 μm. On average the ultimate fibre cells of the nodes are 1.2 mm long and 16.9 μm wide, with a cell wall thickness of 5.3 μm, whereas those of the internodes are 1.2 mm long and 14.6 μm wide, with a cell wall thickness of 4.6 μm. Information on the chemical composition of *A. donax* varies widely. Dry *A. donax* culms contain approximately 44–46% α-cellulose, 26–29% hemicelluloses, 22–24% lignin, 2–7% ash and 1–2% lignin. In Portuguese studies in the 1990s, however, lower cellulose contents were found: the nodes contained 28–34% α-cellulose, 22–32% hemicelluloses, 16–22% lignin and 3–5% ash; the internodes 32–36% α-cellulose, 21–30% hemicelluloses, 16–22% lignin and 4–6% ash. The lignin content of nodes and internodes decreased from the base (20–22%) to the top (16%) of the stem. The foliage contained about 35% α-cellulose, 26% hemicelluloses, 17% lignin and 6% ash.

The absence of pith in the stems, in contrast to e.g. *Miscanthus* Anderss., makes pulping easier. In experiments using the kraft (sulphate) and soda processes, unbleached pulp yields of about 35% have been obtained when air-dry culms with leaves were used, and 40–45% when culms without leaves were used, but the strength of both pulps was rather low (breaking length 6300–7000 m). Leaves alone give lower pulp yields and poorer strength. In France it has been recommended not to use the leaves for pulping because of their high silica content, but in India the use of culms with leaves for pulp production proved more economical. Large-scale tests in the United States led to the conclusion that *A. donax* is not a satisfactory source of pulp if strength is important, but it may serve for the production of special papers. Studies using kraft pulping have shown that the internodes are more suitable for pulping than the nodes, with the latter having an adverse effect on pulp yield and properties. Screened pulp yields of 42%, 45% and 39% were obtained for whole stems, internodes and nodes, respectively. Pulp of internodes had lower residual lignin contents and better strength properties, brightness and viscosity than that of nodes. The strength properties of whole stem pulps are similar to or lower than those from internodes. Beaten kraft pulps from *A. donax* showed paper making properties comparable to hardwood kraft pulps, and their properties can be improved by removing nodes from the crushed stems before pulping. Pulps with high yield and low residual lignin content, comparable with kraft pulps from hardwoods, have been produced from *A. donax* using various organosolv processes. The main disadvantages of kraft and organosolv pulps of *A. donax*, compared to wood pulps, are the fast response to beating and drainage problems.

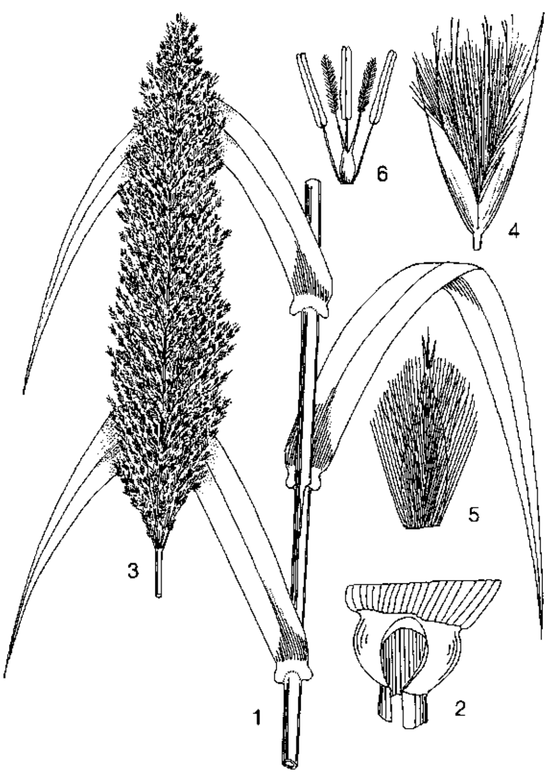
The suitability of reeds from *A. donax* canes for woodwind instruments is due to their resilience, elasticity and resistance to moisture. They respond instantly to minute changes in pressure and do not crack or split easily.

Defatted ethanolic rhizome extracts of *A. donax* have shown hypotensive and antispasmodic action against histamine-, serotonin- and acetylcholine-induced spasms. The rhizome contains the alkaloids gramine (donaxine), bufotenine and bufotenidine. Gramine has shown weak parasympathomimetic action. Small doses raise blood pressure in dogs and cats, but larger doses lower it. The same effects were found with gramine hydrochloride in anaesthetized cats. The leaves and flowers also contain gramine. Crude whole plant extracts of Thai *A. donax* and several isolated compounds, including triacontanol and tricin, have shown antifeedant activity against the boll weevil *Anthonomus grandis*, an important cotton pest. The energy content of *A. donax* is about 15–17 MJ/kg dry matter.

Adulterations and substitutes As a source of pulping material, *A. donax* mainly competes with hardwoods. Compared with hardwoods, it has some disadvantages, such as a relatively low fibre content (30–36%) and high parenchyma content (around 60%), and higher silica and ash content. The advantages include high biomass productivity, annual harvesting, and tolerance to a wide range of ecological conditions. It also has a lower lignin content, making simple pulping methods with reduced chemical charge possible.

As a source of reeds for musical instruments *A. donax* has no satisfactory natural substitutes, the exception being bagpipe reeds, which can be made of elder stems and goose quills as well. Synthetic reeds are available but are usually unacceptable to professional musicians.

Description A robust, strongly tufted, rhizomatous, perennial grass up to 8 m tall. Rhizome often far creeping, fleshy to woody, forming compact masses from which tough fibrous roots arise that



Arundo donax L. – 1, part of culm with leaves; 2, part of sheath with ligule; 3, inflorescence; 4, spikelet; 5, lemma; 6, floret.

penetrate deeply into the soil. Culm terete, 2–8 m × 1–4 cm, with solid nodes and hollow internodes 12–30 cm long, erect or nodding, often copiously branched, pruinose below the nodes, outer tissue very hard and brittle with a smooth glossy surface that turns pale golden-yellow upon maturity. Leaves conspicuously distichous, sheathed; sheath at first ciliate along the margins and with long hairs at the mouth, afterwards glabrous; ligule a short scarious membrane; blade linear-lanceolate, 15–75 cm × 1–8 cm, base rounded or cordate, margins very rough, apex long-attenuate, on the lower surface with a few shallow depressions caused by the pressure of the mouths of older sheaths, in wild specimens subglaucous, in cultivated plants often with yellowish-white longitudinal stripes or the smaller blades often entirely pale yellow, glabrous and smooth. Inflorescence an open or contracted, repeatedly branched panicle, 30–75 cm long, with scabrid axis and fascicled branches, silkily hairy but glabrous at the bases of the lowest branches; spikelets 3–4-flowered, 10–15 mm long, yellowish-green or tinged with purple; glumes subequal, lanceolate, 8–13 mm long, the lower a little shorter than the upper; lemma lanceolate, 6–13 mm long, 3–5-veined, 3 of the veins produced as short awns, hairy all over the back below the middle with hairs up to 8 mm long; palea 5–6 mm long, with 2 densely ciliate keels; stamens 3; pistil with glabrous ovary, 2 free, short styles and 2 plumose stigmas. Fruit (often not produced) a cylindrical caryopsis.

Growth and development The growth of *A. donax* is rapid, with a height increase of up to 7 cm per day under favourable conditions. In southern France the culms normally branch during the 2nd year of growth and die the following winter, but some culms may survive and branch further in the 3rd growing season. During each growing season new culms arise from the rhizomes, giving the crop a perennial character. In Java (Indonesia) *A. donax* flowers in February and March, but in Bogor it has never been found flowering. It rarely produces viable seed, but plants have been grown from collected seed in western Asia. Under natural conditions *A. donax* usually spreads through rhizome growth. In natural stands near Jaipur (India) the standing aboveground dry biomass was 3.6–5.7 kg/m^2, and the belowground biomass 4.8–5.2 kg/m^2.

Other botanical information Opinions about the number of species in *Arundo* L. vary from 1 to 12, but the most commonly accepted number is 3, occurring in tropical and temperate regions.

Though *A. donax* is rather uniform, several ornamental forms have been distinguished, mainly differing in their variegated leaves. The best-known is *A. donax* 'Variegata' (also known as *A. donax* 'Versicolor' based on *A. versicolor* Miller), with white-striped leaves, usually with broad white bands at the margins. It may reach a height of 4–5 m, but is often not taller than 0.6–1 m, with culms up to 1.5 cm in diameter. Its growth is denser than that of typical *A. donax* due to greater culm and leaf production, and it is less hardy. It is occasionally cultivated in Peninsular Malaysia, where it is called 'tebrau gading'.

A. donax is often confused with *Phragmites vallatoria* (synonym: *P. karka* (Retz.) Steud.), from which it can be distinguished by its membraneous ligule and its generally broader leaves, which are cordate at the junction with the sheath.

Ecology *A. donax* is a plant of warm-temperate and subtropical regions, but tolerates a wide range of ecological conditions. It grows in regions with a rainfall between 300–4000 mm and average annual temperatures of 9–29°C, and normally survives prolonged periods of severe drought or excessive rain. During the first year of growth, however, growth can be seriously retarded by drought. The ability to tolerate extreme drought is due to the presence of rhizomes and a deeply penetrating root system. *A. donax* can survive very low temperatures when dormant but is seriously damaged by frost after growth has started. Young culms have little wind resistance. *A. donax* grows on many soil types, from heavy clay to loose sand and gravelly soils, but prefers well-drained soils with ample moisture. Salt or brackish conditions affect growth negatively. It favours wet habitats, such as lake borders or along ditches and canals, but once established it will also grow in drier locations. It does not grow in swamps, as the rhizomes do not withstand prolonged submersion in water. In East Java *A. donax* grows wild at 1000–1800 m altitude.

The ecological requirements for the production of reeds for musical instruments are often considered to be more rigid: low relative humidity and deep light soils with sufficient but not too much moisture prevent highly vigorous growth which would result in soft, porous canes.

Propagation and planting *A. donax* is normally propagated by rhizome division. It may also be propagated by stem cuttings placed horizontally in moist soil, with young plants developing on the nodes. Stem pieces as short as 2 cm may be used. In storage the viability of rhizome and stem parts decreases, but rhizomes and stems kept for 16 weeks under cool (9–10°C) and moist conditions (plastic bag with moist soil) still produced about 75% and 70% sprouting, respectively. Rhizome parts planted as deeply as 25 cm readily sprout, but sprouting of stem parts is hindered by planting deeper than 10 cm. Stem cuttings may be directly planted in the field or they may first be placed in plastic bags and transplanted later. In southern France rhizomes or rooted stem cuttings are placed at a depth of about 10 cm, in rows 2–3 m apart, to enable mechanized operations. Until the soil becomes covered with *A. donax*, the space between rows may be utilized for the cultivation of other crops. When *A. donax* is grown as an energy crop, spacings of 0.7 m between rows and 0.5 m within rows may be applied when rhizome cuttings are used. When stem cuttings are planted, the within-row spacing may be closer, because they are cheaper and initial growth is slower.

Husbandry During the first year in southern France *A. donax* is irrigated when necessary and weeded once or twice. During early development, the canes are cut periodically to encourage spreading of the rhizomes and to increase the density of the stand. Established plantings effectively suppress weeds and receive little attention other than the periodic removal of large weeds and small or inferior canes. Removal of *A. donax* where it is a weed requires treatment with systemic herbicides. For the cultivation of *A. donax* as an energy crop in Europe it is recommended that phosphorus be incorporated in the soil before establishing a plantation.

Diseases and pests Little is known about the effects of diseases and pests on the growth and reproduction of *A. donax*, though numerous insects are known to feed on it. *A. donax* is a host of the root-knot nematode *Meloidogyne incognita*.

Harvesting *A. donax* to be used for paper making or energy production can be harvested yearly from 2 years after planting onwards. Mechanical harvest is possible with forage harvesters or machines devised for sugar-cane harvesting. The culms have to be transported to the processing factory immediately to prevent deterioration of pulping quality. Plantings require up to 5 years before producing the first full crop of good-quality cane for musical instruments; in established plantations the canes to be used for reeds are selectively cut during the winter months when they are 2–3 years old.

Yield Estimates of average annual dry matter yields of *A. donax* vary from about 7 t/ha for wild stands in India up to 43 t/ha for Italian plantings. In southern France annual dry biomass yields of 20–25 t/ha are obtained, but potential production estimates are as high as 100 t/ha. About 15% of the dry matter produced consists of leaves. Normally, less than 5% of the total dry matter production is suitable for the production of reeds for musical instruments. No information exists on yields in South-East Asia.

Handling after harvest *A. donax* material to be used for paper making has to be dried, preferably artificially, because fermentation may occur during the slow process of natural drying. *A. donax* for rayon pulp in Italy is harvested during the winter and dried in the open for several months. The dried material is collected, placed in piles, and seasoned for some months. After this, the culms are crushed and cut into pieces about 2 cm long, the leaves and sheaths are removed, and the chips are processed into pulp.

For mat-making in Mexico the canes are soaked in water and crushed with a rock before being woven. In the Toluca region of Mexico baskets are made with the warp elements (vertical strands) made from split stems of *A. donax* and the weft elements (the horizontally woven strands) from narrowly cut strips of the same material.

Textile fibre has been made from *A. donax* by splitting the culms into long strips, treating them with a caustic solution and separating fibres suitable for spinning by beating the material. The fibres obtained were about 35 cm long and could be processed like hemp.

Canes intended to be used for reeds for musical instruments are traditionally tied in large bundles, often with leaves and branches intact, stacked and dried for at least 2–4 months, in which period the leaf sheaths rot. After this, the upper branching portions of the canes and the remaining leaves and sheaths are removed, and the canes are cut into pieces about 1.2 m long. Spoiled or cracked canes are discarded and the remaining material is cured in the sun for at least 3 weeks. As soon as the exposed surface turns to a creamy colour, the canes are turned so that another surface is exposed to the sun. Cured canes are stored in sheds, where they may be retained for a further period of curing or immediately marketed. By the time properly seasoned cane is ready for use, which may be 3–5 years after harvesting, its colour has become a rich golden-yellow. The cane is divided into tubes by cutting about 1 cm on either side of the nodes. Tubes of inferior quality are discarded. Reeds are frequently made of canes harvested when only a few years old and dried artificially, probably resulting in a lower quality.

Genetic resources As *A. donax* has a wide distribution, it does not seem liable to genetic erosion. No germplasm collections are known to exist.

Breeding Breeding efforts in *A. donax* are hampered by the fact that it seldom produces seed. Therefore it is recommended that any breeding programme be preceded by a study into the possibilities of overcoming this sterility, which would result in broader genetic variability.

Prospects Although *A. donax* occurs in South-East Asia, it is not much used there. There may be some prospect in promoting its use as weaving material and for thatching, because of its high productivity. Furthermore, *A. donax* is a promising raw material for the production of paper.

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Boehmeria nivea (L.) Gaudich.

Voy. Uranie, Bot.: 499 (1830).

URTICACEAE

$2n = 24$ (cv. group Green Ramie), 28 (cv. group White Ramie).

Synonyms *Urtica nivea* L. (1753), *Boehmeria tenacissima* Gaudich. (1830), *B. utilis* Blume (1853).

Vernacular names Ramie, rhea, China grass (En). Ramie (Fr). Indonesia: rami (Indonesian), haramay (Sundanese). Malaysia: rami, rami-rami. Philippines: amirai (Tagalog), labnis (Ilokano), lipang-aso (Tagalog). Cambodia: thmey. Laos: pan. Thailand: po-paan (central), po-bo (northern), taan khamoi (southeastern). Vietnam: c[aa]y gai.

Origin and geographic distribution Ramie probably originated in western and central China and has been cultivated in China since antiquity. Cultivation spread from China to other Asian countries. Ramie plants and products were brought to Europe in the 18th Century and experimental plantings were established in many tropical, subtropical and temperate countries. With the advent of synthetic fibres, however, the cultivation of ramie plummeted, though it is still grown in many tropical and subtropical countries, including the Philippines, Indonesia, Malaysia, Thailand, Vietnam, Cambodia and Laos. It has occasionally escaped from cultivation and naturalized.

Uses Fibre from the stem of ramie is one of the oldest textile fibres, used since prehistoric times in China, India and Indonesia, and mentioned and praised in Sanskrit poems. In China it has been used for paper making for many centuries. Nowadays ramie fibre serves locally for the production of ropes, strings, fishing lines and nets, sewing thread and fabrics. Its traditional use in South-East Asia is mainly for fishing lines and nets which are durable in sea water. The fibre can be spun and the cloth ('grass cloth', 'grass linen' or 'Chinese linen') is used for clothing, tablecloths, napkins, sheets, pillow cases, towels, handkerchiefs, mats, sails, etc. Ramie fibre is processed into a range of other products, including canvas, mosquito nets, fire-hoses, upholstery, filter cloths, gas mantles, shoe laces, marine packings and carpet backing. Ramie is often blended with polyester, wool, silk or cotton. In Brazil undegummed ramie serves as a substitute for jute, e.g. for sacks. Residues remaining after fibre extraction, and also the short fibres, are used for the production of high-quality paper, such as banknotes and cigarette paper. Processing waste is also blended with cotton or rayon and made into lower-grade fabrics. Ramie may be fed to cattle, sheep, goats, pigs, rabbits and chickens. The main parts used as fodder are the leaves and stem tops that are by-products of fibre extraction. Ramie may also be grown specifically for forage, in which case it is harvested before the fibres have fully developed. It can be given fresh, dried as a hay, ensiled with molasses or as a dried meal. The leaves and tops are also applied as green manure. In Vietnam ramie leaves are utilized in the preparation of a cake ('banh gai') which is considered a delicacy. In Malaysia ramie leaves are used to poultice boils and against flatulence; a decoction of roots and leaves is taken as a tonic in the case of dysentery and the root is applied on ulcers. In Indo-China the roots and leaves are considered to be cooling, diuretic, emollient and resolvent, and are prescribed in a number of disorders including dysuria, urogenital inflammation and prolapse of the uterus.

Production and international trade Despite its high fibre quality and diverse uses, ramie has not become a major world textile, because the difficulties and high costs of production and processing lead to irregular supply, uneven quality and high prices. Commercial production in the Philippines started in the 1930s, when China prohibited ramie exports temporarily, and peaked at about 5500 t per year in the 1960s. In the late 1960s and 1970s Brazil expanded its production, reaching a peak of about 30 000 t from about 20 000 ha in 1970 and 1971. Production in the Philippines declined to about 3000 t per year in the early 1970s, but recovered in the 1980s; in the late 1980s up to 10 000 ha were planted with ramie there. According to FAO estimates the world ramie fibre production in the period 1996–2000 was about 140 000 t per year, cultivated on about 90 000 ha, with more than 90% produced in China. In this period Brazil produced 2400 t per year, the Philippines 1600 t and Laos 1400 t.

Most of the ramie produced is used in the producing countries and only a small proportion enters international trade (on average about 3000 t per year for the period 1996–2000). The main exporters in this period were China (about 2000 t per year), Indonesia (300 t/year) and Brazil (100 t/year). The major importer is Japan (1800 t per year in 1996–2000). The highest quality ramie available on the world market is produced in the Philippines, mainly because of the superior processing equipment employed.

Properties Ramie fibres, classified as nonlignified soft fibres, lie in bundles in the bast layer of the stem and can be stripped in the form of ribbons. The ultimate fibre cells are (10–)40–250(–600) mm long and (10–)25–60(–100) μm wide. They are flattened in cross-section, irregular in shape, have thick walls and a well-defined lumen, and taper to rounded ends. The fibre walls show pronounced longitudinal striations. The fibres contain 69–91% α-cellulose, 5–13% hemicelluloses, 1% lignin, 2% pectin and 2–4% ash. Fibres extracted from ramie stems by decortication contain a high amount of gums, so special methods must be used to separate them. The gums are mainly composed of hemicelluloses and pectin, which are relatively insoluble in water but fairly soluble in alkaline solutions. Properly degummed fibres contain 96–98% α-cellulose.

Ramie fibre is strong, lustrous and durable. The tensile strength, absorbency, drying properties and dyeing qualities of ramie fibre are often indicated as being superior to those of cotton and flax fibre, but measured values vary widely and with respect to these characteristics ramie is rather similar to cotton and flax. However, wetting does cause less shrinkage in ramie than in other fibres, and a mixture of wool and ramie shrinks much less than pure wool. On the other hand ramie lacks the elasticity of wool and silk and the flexibility of cotton, which makes ramie cloth rather harsh, with a tendency to crease and to crack and break when bent. Typical values of the tensile strength, elongation at break, and Young's modulus of ramie fibre are 400–940 N/mm^2, 3.6–3.8% and 61.4–128.0 GPa, respectively. Its resistance to bacterial action and its increased strength when wetted make ramie fibre particularly suitable for marine applications.

The nutritional value of ramie as fodder is high. Per 100 g dry weight the whole aboveground plant contains: crude protein 11–28 g, crude fibre 9–29 g, ash 15–17 g, Ca 3.7–4.5 g and P 0.13–0.31 g. The leaves contain about 25 g protein per 100 g dry weight, whereas total plant residues after fibre extraction contain about 13 g. The digestible protein contents of 4- and 6-week-old ramie (stems and leaves) in Thailand were 86 g and 52 g per kg dry matter, respectively. The net energy contents of 4- and 6-week-old plants were 381 and 331 starch equivalent per kg dry matter. Meal made of ramie leaves and tops contains 21–22% crude protein.

Adulterations and substitutes Because of its high price ramie may be adulterated with other fibres, e.g. flax (*Linum usitatissimum* L.) or cotton (*Gossypium* spp.).

Description A monoecious, erect, fast-growing perennial herb or small shrub, 1–2(–3) m tall, with long rhizome and tuberous storage roots. Stem usually unbranched and hollow, 8–16 mm in diameter, initially green and hairy, turning brownish and woody, the bast layer yielding the ramie fibre. Leaves alternate, simple, with 3 prominent basal veins; stipules axillary, connate at base, linear-lanceolate, up to 1.5 cm long; petiole 6–12 cm long, pubescent; blade broadly ovate, triangular to suborbicular, 7–20 cm × 4–18 cm, base cuneate to

Boehmeria nivea (L.) Gaudich. – 1, flowering and fruiting stem; 2, male flower; 3, female flower cluster; 4, female flower; 5, fruit.

subcordate, margin coarsely dentate to dentate-serrate or crenate, apex usually abruptly long-acuminate, green and scabrid above, glabrous and green or white appressed-pubescent below. Inflorescence axillary, racemose, paniculate, 3–8 cm long, each branch bearing several crowded or well-separated clusters of unisexual flowers, mainly female with a few male branches towards base; male clusters small, usually with 3–10 flowers, female clusters larger, usually with 10–30 flowers; male flower shortly pedicelled, perianth 3–5-lobed, stamens as many as lobes and incurved with persistent rudiment of pistillode; female flower sessile, perianth tubular, 2–4-lobed, greenish to pinkish, pistil with 1-celled ovary with one ovule, style exserted, slender and hairy on one side, stigma filiform. Fruit a subglobose to ovoid achene, about 1 mm in diameter, enclosed by the persistent perianth, hairy, crustaceous, brown-yellow. Seed subglobose to ovoid, slightly less than 1 mm in diameter, dark brown.

Growth and development The rhizome of ramie starts to grow 5–20 days after planting. The storage roots are produced in early stages of growth. Harvesting may start 3–10 months after planting out the rhizomes, but the first harvest of a new plantation is often not used for fibre because of uneven growth and low fibre quality. Ramie is cross-pollinated. The male flowers open first and pollination is by wind. In Java flowering is year-round.

Other botanical information Considerable variation exists within *B. nivea* and this variation has been described as different species, subspecies, varieties or forms. For the cultivated forms it is, however, most appropriate to distinguish the following 2 cultivar groups:

- cv. group White Ramie (also named *Boehmeria nivea* (L.) Gaudich. var. *nivea*, Chinese ramie or China grass). This group, originating from China and Japan, is characterized by a thick, white felt of hairs on the lower surface of the leaves. It appears better suited to temperate and subtropical climates. This group is cultivated on a commercial scale.
- cv. group Green Ramie (also named *Boehmeria nivea* (L.) Gaudich. var. *tenacissima* (Roxb.) Miq., *B. tenacissima* Gaudich., *B. utilis* Blume, Indian ramie or rhea). This group, believed to originate from Peninsular Malaysia, has smaller leaves which are green on both sides. It appears better suited to tropical climates. Green ramie might be a derivative of a cross between a White Ramie cultivar and an unknown species.

There are numerous ramie cultivars, many originating from Japan, where ramie research started in the early 1900s. The most popular and widely used cultivar in the Philippines is 'Seikeiseishin', introduced from Japan, maturing in 45–60 days and yielding on average 3 t/ha of a strong, fine fibre, suitable for spinning fine yarns. Other cultivars grown in the Philippines are 'Miyazaki 112', 'Chuma', 'Everglades', 'Formosa' and 'Guiran Taipan No 1'. Indonesian cultivars include 'Pudjon 10', 'Bandung A', and 'Lembang A', developed in Java, and 'Pantjur Batu', developed in Sumatra.

B. holosericea Blume is occasionally grown as a fibre plant in Korea, whereas *B. grandis* (Hook & Arnott) Heller has been cultivated in Hawaii as a source of barkcloth.

Ecology Ramie is found from almost equatorial conditions in Indonesia and the Philippines to about 38°N in Japan and South Korea. It is grown at average temperatures ranging from 20°C during the cropping season in temperate regions to 28°C in the tropics. Frost may destroy the rhizomes; this can be prevented by mulching with leaves or compost. To grow properly, ramie requires a minimum of 100–140 mm rainfall per month. Short days promote flowering and ramie tolerates partial shade.

For optimal fibre production ramie requires rich, well-drained, sandy loams, with a pH of 5.5–6.5 (4.8–5.6 for peat soils). With heavy manuring it can also be grown on less favourable soil types. Ramie is extremely sensitive to waterlogging. In Philippine experiments it was most sensitive to flooding immediately after cutting and least sensitive during the middle vegetative stage (20 days after cutting). The duration of flooding significantly affected the height, stem weight and dry fibre yield, but had no significant effect on the fineness or diameter of the fibre.

Propagation and planting Ramie can be propagated by seed, but the resulting plants take 1–2 years to become productive and are often inferior to their parents. Therefore, ramie is usually propagated vegetatively by means of rhizome cuttings, 15–30 cm long, taken from plants at least 3 years old. To ensure optimal growth, the rhizomes should be planted out as soon as possible after being cut. If immediate planting is impossible, they should be kept moist and covered and in a shaded place. The rhizome cuttings are usually planted manually in a well-prepared seed-bed at a depth of 5–7.5 cm. Planting distances vary widely, depending on soil fertility, cultivar and availability of planting material. The spacing between rows ranges from 25–140 cm and that within the row from 5–60 cm. Ramie can also be propagated by division, air layering and stem cuttings. In vitro propagation is possible, as complete plants have been regenerated from callus produced from ramie cotyledons, leaves, stem segments, leaf segments and hypocotyls.

Except for the large estates in the Philippines and Brazil, ramie plantings are usually small family plots.

Husbandry Ramie needs regular weeding until the canopy is closed. Weeding of ratooned crops usually starts during the harvest of the preceding crop, when not only the ramie but also the weeds are cut. In the Philippines the crop is sometimes irrigated. Because of its high productivity ramie rapidly depletes soil nutrients. Fertilization with manure or inorganic fertilizer, especially with nitrogen, is important for satisfactory yields. Leaving or returning leaves and other residues on or to the field is beneficial, because these materials contain a large proportion of the nutrients removed. The production of 45 t fresh plant material (1.5 t fibre) on a peat soil results in the removal of about 206 kg N, 19 kg P, 100 kg K, 230 kg CaO and 52 kg MgO. A general recommendation in the Philippines is to fertilize a plantation of 50 000 plants/ha with 90 kg N, 26 kg P and 50 kg K per harvest per ha on sandy or clay loams and with 60 kg N, 13 kg P and 25 kg K on soils rich in organic matter, and to return all plant waste to the field after fibre extraction.

Diseases and pests The most serious disease of ramie is 'white fungus disease' caused by *Rosellinia necatrix*. It occurs in the Philippines, Vietnam and Japan. By the time the symptoms of wilting leaves are visible, the root system has been destroyed and the dead roots are covered with a white veil of thread-like forms. Infested areas should be dug up, burned and disinfected (e.g. with a chloropicrin solution). In Indonesia angular leaf spot caused by *Pseudocercospora boehmeriae* is a serious disease that retards growth. Other diseases known to attack ramie include stem rots caused by *Phoma boehmeriae*, *Rhizoctonia solani*, *Macrophomina phaseolina*, *Sclerotium rolfsii* and *Corticium rolfsii*, and leaf spots caused by *Cercospora* spp.

Many insects feed on ramie leaves, but there are few serious pests. The most serious and widespread are leaf rollers (*Sylepta* spp.), found in almost every country where ramie is grown. The larvae feed on the leaves, roll them up and pupate in the rolled leaves. Heavy infestation results in complete defoliation, growth cessation and undesirable secondary growth. In the Philippines, Indonesia and Japan ramie is attacked by the black caterpillar *Cocytodes coerulea*, which may defoliate large patches in the field. The larvae are removed either manually or by spraying. In the Philippines ramie is one of the crops damaged by the golden apple snail (*Pomacea* sp.).

The root-knot nematode *Meloidogyne incognita* occurs regularly in ramie, e.g. in the Philippines and in India. It can be detected by the presence of galls on the roots. Severely infected plants are stunted and have yellow leaves. Other nematodes harming ramie include the lesion nematode (*Pratylenchus* sp.), stunt nematode (*Tylenchorhynchus* sp.) and reniform nematode (*Rotylenchulus* sp.). Nematode control is difficult; sometimes the fungus *Paecilomyces lilacinus* is used as a biological control agent.

Harvesting The timing of the harvest of ramie is crucial: if stems are immature, the fibre yield is reduced; if stems are too mature, it is difficult to remove the fibre. Harvesting is usually carried out when the stems start turning brown and growth slows down. In temperate regions ratoon crops can be harvested 2–3 times a year, in subtropical areas 4–5 times, and in tropical areas up to 7 harvests a year are possible. However, the yield per harvest is usually higher in temperate regions, and it is possible that more fibre is obtained per ha per year from 2–3 harvests in temperate regions than from more harvests in tropical areas.

The plants are usually harvested manually with a sickle close to the ground to prevent new stalks arising from the old stump. In some areas the stems are bent over to break the core and the cortex is stripped from plants in the field. Mechanical harvesters have been developed but are not used commercially. At harvesting, the tops and the leaves may be removed from the stems and used as animal feed or green manure.

Yield The fresh stem yield of ramie is normally 45–60 t per ha per year, giving 1000–1600 kg dried fibre and 500–1200 kg degummed fibre. For the Philippines yields have been recorded of 2000 kg dried fibre per ha in the first year after planting and 3500 kg in subsequent years. Yields start to decline when plantings become overcrowded; at this point the rhizomes may be pruned, e.g. by ploughing, or the area may be replanted. In some countries, replanting is done every 7 years whereas in parts of China the crop is maintained as long as 20 years.

When grown for fodder, the yield may amount to

300 t fresh material or 42 t dry matter per ha per year in up to 14 cuts.

Handling after harvest Ramie is processed into fibre in one or two steps: the first being extraction, the second being degumming.

Extraction is usually done manually by defoliating the stems and removing the entire raw bast ribbon, which is then scraped to remove the outer bark, non-fibrous parenchyma and much of the gummy material. In Indonesia the outer bark may be scraped from the over-mature stalk, leaving the fibre, The stalk is washed and dried for several days, after which the fibre is peeled off in strands. Manual extraction is very labour intensive, and in Brazil, Japan and parts of the Philippines ramie is decorticated mechanically using machines based on the same principles as those used for kenaf (*Hibiscus cannabinus* L.) or sisal (*Agave sisalana* Perrine). Ramie fibre cannot be extracted satisfactorily by retting, because of the presence and nature of large amounts of gums in the bark, though some bacteria have been found to decompose the gums. The fibres are extracted when the stems are still fresh, because the bark is more difficult to remove when the plant dries. If extraction cannot be done immediately after harvesting, the stems are kept in water to keep them fresh. Extracted fibres are hung over poles for 1–3 days to dry and bleach in the wind and sun. Drying is done as soon as possible, to prevent attack by fungi and bacteria. After being dried, the fibres may be brushed to reduce the gum content. Undegummed ramie fibre may be used for coarse ropes for marine applications, sacks and other containers and rugs and carpets. There are no universally accepted grades, and each country has its own way of grading. The main Philippine grades are RD-A ('Ramie Special'; fibres 80 mm or longer; well cleaned; colour straw to creamy), RD-1 ('Ramie Good'; fibres 80 mm or longer; well cleaned; colour brownish), RD-2 ('Ramie Fair'; fibres 80 mm or longer; fairly cleaned; colour light brown and RD-3 ('Ramie Short'; fibres 40–80 mm long). Minor Philippine grades include RD-O (string), RD-T (tow) and RD-W (waste). Most farmers in the southern Philippines produce RD-1 and RD-2, because the leaves and tops are not removed before decortication.

Degumming is necessary to remove the gums contained in the raw ramie fibre. The presence of gums makes the fibre stiff and brittle, and they must be removed before the fibre can be combed and spun into fine yarns. In areas where processing is manual, this may be done by repeated soaking, scraping, washing and sun-drying. Other methods include treatment with soap solution, lime or chemicals. Many chemical degumming methods have been developed, but they are usually kept secret by the textile mills using them. Usually they contain the same basic steps: boiling in an aqueous alkaline solution; washing with water; bleaching with an oxidizing agent; washing with water; and oiling with a sulphonated hydrocarbon. If carried out incorrectly, degumming can reduce the strength of ramie fibre and increase its brittleness. Furthermore, the chemical degumming process produces polluting effluents. Combined microbial and chemical degumming processes have been proposed to reduce the use of chemicals and energy and improve the resulting fibre quality, but they have not yet been applied on industrial scale.

In industrialized regions, ramie is commonly spun on machinery developed for silk, wool or cotton. The results are often less satisfactory, however. When a short-fibre spinning system like the one used for cotton is used, ramie fibre has to be cut short ('stapling').

Genetic resources The Institute of Bast Fiber Crops of the Chinese Academy of Agricultural Sciences (CAAS) in Yuanjiang, China, has a collection of about 1300 ramie accessions, and characterizes and evaluates botanical and agronomical characters, fibre yield, quality and stress resistance. In total, 1017 indigenous accessions and 10 other accessions have been planted in the field in Yuanjiang to create the 'National Ramie Germplasm Field Genebank'. Germplasm collections are also available at the Instituto Agronômico de Campinas (IAC), São Paulo, Brazil (460 accessions) and the Institute of Plant Breeding of the University of the Philippines Los Baños (56 accessions).

Breeding Ramie is a clonal crop, so the breeding methods applied are similar to sugar cane or potato. Seedlings are mostly very inferior in quality and to obtain improved cultivars initial recombination crossing has to be followed by a long programme of clonal selection. Selection work on ramie has been carried out in various countries, including the Philippines and Indonesia. In China, the Institute of Bast Fibre Crops has selected and distributed more than 30 elite accessions. In India 5 cultivars were selected on the basis of yield, gum content, fertilizer response and resistance to stress, and the most popular of these ('R 67-34') has been released. Important considerations in ramie selection are: adaptation to ecological conditions, decortication characteristics, leafing and branching characteristics, resistance to diseases and pests, tendency to lodge and fibre characteristics (uniformity, strength, fineness and colour).

In Brazil a protocol has been developed for the genetic modification of ramie and experiments are being carried out to improve the amino acid composition and thus the fodder value of ramie through genetic modification.

Prospects Because of the difficulties and costs involved in the production and processing of ramie, it is unlikely that the crop will become a major trade commodity and challenge the established major natural and synthetic fibres. However, the excellent properties of its fibre and the wide range of possible uses make ramie a promising cash crop for the local market in many tropical and subtropical countries. The development of new technologies such as decorticating and stripping machines and degumming processes suitable for medium- and small-scale operations, may improve the chances of ramie becoming more important as a fibre crop.

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R.P. Escobin

Broussonetia papyrifera (L.) L'Hér. ex Vent.

Tabl. règn. vég. 3: 547 (1799).
MORACEAE
$2n = 26$

Synonyms *Morus papyrifera* L. (1753), *Smithiodendron artocarpioideum* Hu (1936), *Broussonetia papyrifera* (L.) L'Hér. ex Vent. var. *sumatrana* (Miq.) Bur. (1873).

Vernacular names Paper mulberry, paper mulberry tree, tapa-cloth-tree (En). Mûrier à papier (Fr). Indonesia: saeh (Sundanese), galugu (Javanese), dhalubang (Madurese). Burma (Myanmar): malaing, thale, dalaing. Cambodia: rong. Laos: po sa (Vientiane), sa lè (Xieng Kouang), may sa. Thailand: po krasa (central, northern), momee (central), po faai (peninsular). Vietnam: (c[aa]y) d[uw][ows]ng, ch[uwr], ch[uwr] d[af]o ph[uj].

Origin and geographic distribution The natural range of distribution of paper mulberry comprises Japan, China, Indo-China, Thailand, Burma (Myanmar) and India (Assam). It has been introduced into the Ryukyu Islands, Taiwan, the Philippines, Indonesia (Sumatra, Java, Sulawesi, the Lesser Sunda Islands (Flores, Timor, Alor and Wetar) and the Moluccas), New Guinea and Polynesia. It is found in the collections of many botanical gardens in subtropical and temperate regions. It is naturalized in some areas, for instance southern Europe and the southern United States. It has been cultivated in East Asia, Indonesia and Polynesia since early times.

Uses For centuries the tough and interlacing bast fibre from the inner bark of paper mulberry has been used to make paper and textile fabric for clothing. The former application is found in Japan, China, Indo-China, Thailand, Burma (Myanmar), the Philippines, Java and Madura, although with different production methods, and the latter in, among others, Indonesia, New Guinea and Polynesia, where the fabric is known as 'tapa' cloth. Around 100 AD paper mulberry fibre was made into a form of paper in China, although the sheets made were not paper in the usual sense. They consisted of strips cemented together instead of liberated fibres deposited randomly. Around 600 AD paper manufacturing from paper mulberry reached Japan, where a high-quality paper industry became established. In general, paper mulberry paper made in Japan, mainland China and Taiwan is of higher quality than that made elsewhere, e.g. in (northern) Thailand and Indonesia. The very strong paper made of paper mulberry bast fibre in Japan is used for writing and the construction of lanterns and umbrellas, whereas paper made in Thailand often serves for wrapping, e.g. the Shan people used it to wrap raw opium. Both the bark and the wood can be used for paper pulp production, making it possible to utilize the whole stem. Textile fabric from paper mulberry is used to make items such as sarongs, head-cloths, bed clothing and bags. The fibres are sometimes made into rope or cord, e.g. in Indonesia. The Lahu people in northern Thailand also use the roots for this purpose.

In Indonesia the steamed young leaves are eaten as 'lalab'. The sweetish infructescences ('fruits') are edible as well. The leaves are fed to pigs in Indo-China and to silkworms in China. In Indo-China the leaf of paper mulberry is considered a laxative for children and a diaphoretic, and the fruit a pectoral, stomachic and tonic, whereas the bark is taken against dysentery and haemorrhage and the latex applied externally against snake- and dog bites and bee stings.

Production and international trade In South-East Asia paper mulberry fibres are mainly used locally, and paper making is usually a home industry. In the Philippines handmade paper is produced for domestic use as well as export markets, but production statistics are not available. Research on commercial paper production at the beginning of the 20th Century indicated that the quality of the paper based on raw material from Java (Indonesia) and the production methods applied were too poor to create a suitable market.

Properties Paper mulberry bast fibres are soft, lustrous and very strong. The inner bark is about 2 mm thick and dense and homogeneous because of the minute pith rays. The fibre cells are (6–)10–15(–25) mm long and (12–)25–30(–36) μm wide. Their walls are often thick and their ends are usually pointed or blunt, though other shapes may also occur. Dislocations and cross-markings are frequent but finer than those in flax (*Linum usitatissimum* L.) and hemp (*Cannabis sativa* L.) fibre. The bark also contains a second type of fibre cells, which are wide, thin-walled and ribbon-like, with rounded ends. Paper mulberry fibres are often enveloped by a transparent membrane (the loosened primary wall), which distinguishes the fibres of this species from those of many other bast fibre species. Parenchyma with cells containing prismatic calcium oxalate crystals and milksap tubes (lactifers) are also found in the bark. The wood fibres are (0.1–)0.8–1.2(–1.4) mm long and (17–)22–30(–47) μm wide. Oven-dry wood contains 59% cellulose, 23% lignin, 16% pentosans and 1% ash.

The wood and bark of paper mulberry can be pulped, separately or together, with a number of processes, including the mechanical, kraft and APMP (alkaline peroxide mechanical pulping) processes. Pulping experiments with the whole stem for the production of bleached sulphate and rayon grade pulp have been promising. Bast fibre pulp may be used in blends to increase the tear strength of short-fibred pulps. Interaction of resinous substances with inorganic compounds, especially calcium, may cause ink-repellent spots in paper made from paper mulberry bast fibre.

The flavonoid broussochalcone A (a phenylated chalcone), isolated from the bark, is a powerful antioxidant, primarily because of its free radical-scavenging activity, and also suppresses the production of nitric oxide (NO). As excessive free radicals and NO-production have been associated with various inflammatory diseases, broussochalcone A may have therapeutic potential. It is also a potent inhibitor of platelet aggregation and an inhibitor of respiratory burst in neutrophils. Other compounds with activity against platelet aggregation isolated from the bark of paper mulberry are broussoaurone A, broussoflavan A, broussoflavonols F and G and kazinol A and B. Broussoaurone A, broussoflavan A and broussoflavonol F and G also have antioxidant properties. Broussonin A and B from the bark have shown antifungal and antibacterial activity. Other compounds isolated from the bark are broussochalcone B, broussoflavonol A and B, butyrospermol acetate, erythrinasinate and isoprenylated aurone. Broussoflavonol C, D, E and F, papyriflavonol A, lignoceric acid, marmesin, octocosan-l-ol and squalene have been isolated from the root bark.

Adulterations and substitutes As many representatives of the order *Urticales*, for instance *Artocarpus* spp. and *Ficus* spp., have fibres suitable for barkcloth and papermaking, they may be substituted for paper mulberry fibre. Hemp (*Cannabis sativa* L.) and flax (*Linum usitatissimum* L.) may be used as substitutes for reinforcing short-fibred pulps.

Description A deciduous, dioecious, suckering tree, up to 12(–35) m tall (in cultivation often a multi-stemmed shrub about 3 m tall), containing milksap, with small, axillary, scaled resting buds and shoot apices that are shed. Trunk gnarled, outer bark smooth, inner bark consisting of tough interlacing fibres that can be extracted in broad layers; leafy twigs 1.5–3 mm thick, subtomentose to hirtellous to puberulous. Leaves alternate and spirally arranged or subopposite; stipules free, semi-amplexicaul, ovate, 0.5–1.5 cm long, puberulous, slightly ribbed, caducous; petiole (1–)2–9(–15) cm long, subtomentose; blade ovate to cordiform or elliptic, 5–20 cm × 4–12 cm, entire or up to 5-lobed, slightly asymmetrical, chartaceous, base cordate to rounded or subcuneate, margin crenate-serrate-dentate, apex acuminate to subacute; upper surface hispidulous, scabrous, lower surface usually densely puberulous to subtomentose on the veins; lateral veins 5–9 pairs, tertiary venation scalariform. Male inflorescences solitary or usually clustered on short shoots, spicate, pendulous; peduncle 1–2.5 cm long, puberulous to tomentellous; spike 3–10 cm long; perianth 4-lobed, 1.5–2 mm long, puberulous; stamens 4, inflexed in the bud and bending outwards elastically, 3–3.5 mm long, anthers about 0.8 mm long; bracts subulate, 1.5–2.5 mm long, puberulous. Female inflorescences capitate, solitary in the leaf axils or below the leaves; peduncle 0.3–1.5 cm long, puberulous to tomentellous; head globose, 1–1.2 cm in diameter; perianth tubular, about 1 mm long, 4-dentate; ovary about 0.5 mm long, stigma 1, filiform, 7–10 mm long; interfloral bracts clavate to subpeltate, 1–1.5 mm long, densely puberulous to tomentellous, the apices cohering, but leaving narrow openings to let the stigmas through. Infructescence a subglobose syncarp, 2–2.5 cm in diameter, its fleshy part consists of the interfloral bracts, which usually turn orange, the perianth remains membranaceous; fruit drupaceous, with a narrow base and white exocarp, the endocarp body ovoid, 2–2.5 mm long. Seed small with curved embryo, flat cotyledons and long radicle.

Broussonetia papyrifera (L.) L'Hér. ex Vent. – 1, leafy twig; 2, staminate inflorescence; 3, staminate flower; 4, pistillate flowers and interfloral bracts; 5, infructescence.

Growth and development Paper mulberry is a fast-growing tree, with often abundant sucker formation. Various leaf forms may occur on the same twig: from ovate with entire margins to lobed on one or both sides. In Java (Indonesia) flowering and fruiting is year-round, but trees exploited for their fibres are mostly cut before they reach the flowering stage. Natural reproduction is by seed and root suckers. Paper mulberry trees can regenerate new bark after complete girdling.

Other botanical information *Broussonetia* L'Hér. ex Vent. comprises 8 species, of which 7 occur in tropical, subtropical and warm temperate regions of Asia, and one in Madagascar. Most *Broussonetia* spp. are trees and some are or can be climbers. The abscission of the terminal meristem, the elongation of branches by the terminal axillary bud, and the presence of scaled resting buds are features which suggest temperate origins. The same features are found in the genus *Morus* L. from which *Broussonetia* differs in the features of the pistillate flowers and inflorescences. Cultivars of paper mulberry include those with laciniate leaf blades, white infructescences, yellow or white variegated leaves, or relatively large leaves.

The closest relative of *B. papyrifera* is *B. kazinoki* Sieb., mainly from Japan and Korea, whose bark fibre is also used for paper making. In the Philippines it is experimentally grown as a fibre plant. *B. kazinoki* also occurs wild in secondary forest in Vietnam, where its roots and leaves are used medicinally against snake bites, pimples, stomachache and liver inflammation. Hybrids of *B. papyrifera* and *B. kazinoki* exist, e.g. in Korea.

Ecology Paper mulberry is an element of warm temperate to subtemperate deciduous forest, but it also thrives in tropical lowlands and highlands, in particular in areas with a seasonal climate. It is a vigorous pioneer which can rapidly spread following canopy disturbance or farming and it is sometimes considered a weed, for example in the Philippines. It has been suggested, e.g. in the Philippines, as a potential crop for reforestation and eradication of cogon grass (*Imperata cylindrica* (L.) Raeuschel).

Propagation and planting Paper mulberry is easily propagated by seed or vegetatively by wood or root cuttings, suckers, layering or grafting. Seeds are not very sensitive to light for germination and can germinate in the dark. In Thailand transplanting of suckers 30 cm tall gave better survival than propagation with root cuttings, stem cuttings or seed. In vitro micropropagation of paper mulberry is possible with axillary buds cultured in Murashige and Skoog medium (MS) supplemented with 1.0 mg/l 6-benzylamino purine (BAP) and 0.01 mg/l alpha-naphthaleneacetic acid (NAA).

Paper mulberry is mostly grown in or near villages.

Husbandry Paper mulberry is easy to cultivate, needing no special care. In Indonesia, lateral branches are sometimes pruned and the stem may be supported. It coppices well, and in Japan it is often cultivated in a coppice cycle of 3–5 years.

Diseases and pests No information is available on diseases and pests affecting paper mulberry in South-East Asia. Bacterial blight caused by *Pseudomonas syringae* pv. *broussonetiae* is a disease of paper mulberry in Japan. It also affects *B. kazinoki*, but not mulberry (*Morus* spp.). In China the fungi *Phytophthora boehmeriae* and *Dendryphiella broussonetiae* attack paper mulberry. Paper mulberry is a host of *Agrobacterium tumefaciens*, which causes tumorous growth. A pest of paper mulberry in China is *Apriona germari* (*Coleoptera, Cerambycidae*).

Harvesting In the Moluccas, paper mulberry stems are cut when they have a diameter of 2.5–5 cm, because older trees have a harder and more brittle bark. In Java, trees not older than 2 years are generally harvested for traditional papermaking. In Japan, stems from coppiced paper mulberry are usually harvested every 3–5 years.

Yield In Thailand paper mulberry, spaced 1 m × 1 m apart and harvested 6 and 12 months after planting yielded 2400 and 2800 kg bark per ha, respectively. In Indonesian plantations at 800 m altitude, 2-year-old trees, 2–3 m tall, with a stem diameter of 2 cm, yielded about 300 g fresh bark per tree, equivalent to 90 g dry bark fibre.

Handling after harvest For the traditional production of 'deluwang' paper from paper mulberry in Java and Madura, bark removed from stem pieces about 1.5 m long is cut in strips 5–6 cm wide, the outer bark is removed, and the strips are laid on a beam 20 cm wide and pounded until they are about double in width. The pounded strips are put in water, rinsed, and wrung out. Subsequently, they are folded lengthwise and then in four. They are pounded again until double sheets 50 cm wide have formed. These double sheets are first dried, then soaked, pressed out, folded, and rolled up in banana leaf. By heating for 5–6 days, the two sheets adhere. The resulting sheet is spread out, rubbed, stretched over a stem of the banana tree and dried in the sun. When dry, the side attached to the stem is smooth, the other side rough. The rough side is smoothened by rubbing with a smooth shell. The piece of paper finally obtained is about 50 cm × 37 cm. Cloth is made in a similar way. In the Moluccas the harvested stems are scorched carefully over a fire and the outer bark is pulled off, then the inner bark is peeled and dried. When needed for new clothes, the dried bark is soaked and prepared in a way similar to 'deluwang' paper in Java.

In the production of handmade paper in Japan, the stems are steamed to loosen the bark. The outer bark is scraped off to be used for inferior papers, whereas the inner bark is washed, kneaded in water, rinsed, and laid in the sun for drying and bleaching. Fibres are separated by boiling in a strong alkaline solution and beating with a mallet. The resulting pulp is mixed with water and gums. The pulp solution is scooped up with paper moulds, consisting of fine mesh sieves, with excess water draining away. When the fibre sheets are solid enough, they are removed from the mould and laid in a pile of alternating layers of wet paper and felt. The pile is pressed to remove water, and the sheets are removed from the felt and dried. In Burma (Myanmar), pulp is obtained by pounding the bast with water and boiling it with lime. The pulp is spread thinly over coarse cloth and allowed to dry to form paper.

The general procedure in the manufacture of tapa cloth is to peel bark strips off the stem and to remove the outer bark. After being soaked in water and cleaned, the strips are placed on a log and beaten. Individual strips are united by overlapping the edges and beating them together. Depending on the thickness, the appearance varies from muslin-like to leathery. Tapa cloth is often dyed or otherwise ornamented.

Genetic resources and breeding No germplasm collections or breeding programmes of paper mulberry are known to exist.

Prospects The exploitation of paper mulberry, especially as a source of raw material for speciality papers, e.g. for decoration and currency notes, could have some future and economic potential in South-East Asia. Production could be increased by using adapted cropping methods, the selection of appropriate cultivars and improved processing methods. Compounds from the bark may have some therapeutic potential in inflammatory diseases.

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C.C. Berg

Carludovica palmata Ruiz & Pav.

Syst. veget. fl. peruv. chil.: 291 (1798).
CYCLANTHACEAE
$2n = 18$

Synonyms *Ludovia palmata* (Ruiz & Pav.) Pers. (1807), *Carludovica gigantea* Kuntze (1891), *C. jamaicensis* Lodd. ex Fawcett & Harris (1902).

Vernacular names Panama hat palm, Panama hat plant, jippi-jappa (En). Thailand: paam tham muak paanaamaa (Trang).

Origin and geographic distribution The natural distribution of *C. palmata* is probably from Guatemala through Central America and northwestern South America to central Bolivia; in this area it is also cultivated. In other parts of South America, the West Indies and southern Mexico it has probably been introduced. *C. palmata* has also been introduced into Asia, from India and Sri Lanka through South-East Asia (e.g. Malaysia, Indonesia and the Philippines) to Taiwan, and more recently Africa. It has sometimes escaped from cultivation.

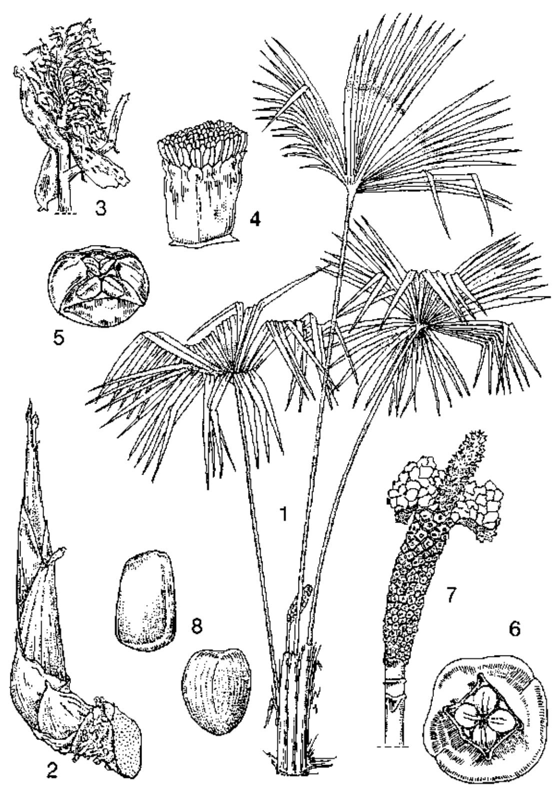
Uses The young leaves of *C. palmata* are made into the famous Panama hats, which are still widely used today. The true Panama hats are made not in Panama, but mainly in Ecuador and to a lesser extent in Colombia and Peru. They probably derived their name from their transshipment through Panama. *C. palmata* is, however, used in Central America for making lesser-quality hats for local use. In South-East Asia hats are made of *C. palmata* in Indonesia and the Philippines, mainly for the tourist industry. In pre-Columbian times, South American Indians used *C. palmata* leaves to weave mats. Older and coarser leaf material still widely serves for making mats, baskets, cigar cases, small bags and similar objects, whereas mature leaves and the stiff outer leaf segments are made into brooms. *C. palmata* leaves are also utilized for thatching, and the petiole fibres for cordage, lashing materials and traps. The fruits and the basal portion of the unopened leaf buds are edible. *C. palmata* is grown pantropically as an ornamental.

Production and international trade The main centres of Panama hat production are the Ecuadorian Provinces of Azuay, Cañar and Manabi, whereas the best weaving material of *C. palmata* is obtained in Manglar Alto in Guayas Province, where the plant is cultivated. In the 1940s more than 4 million hats were exported annually from Ecuador, but exports decreased in the early 1950s due to competition from Japan and the Philippines. The value of Panama hat exports from Ecuador in 1992 was about US$ 4.6 million. More recent production and trade statistics are not available.

Properties Good Panama hats of *C. palmata* have a uniform and fine texture, and are strong, durable, elastic and resistant to water. The best hats, which may take several weeks to make, are so soft and finely woven that they can be rolled up easily. For one Panama hat 6–15 leaves are required. It has been said that a superior quality is made from a single leaf without any joinings, but it is unlikely that one leaf can provide enough material for a hat. The quality of the hat depends as much on skill in treating the leaves and suitable weather conditions as on the material employed. Good hats cannot be made during dry summer weather nor during very wet weather. Roofs thatched with *C. palmata* leaves are very durable.

Adulterations and substitutes In South-East Asia hats are made of a range of other plants, especially *Cyperaceae*, *Palmae* and *Pandanaceae*.

Description An erect, palm-like, monoecious, rhizomatous, perennial herb, 1.5–4(–5) m tall, usually growing in dense clumps. Stem absent or short and underground. Leaves dispersed; petiole subterete, 1–3.5(–4) m long, sheathing at base; blade usually lobed nearly to the base, tricostate, (30–)50–80(–90) cm long and wide, the (3–)4(–5) lobes wedge-shaped, their apical parts again divided into long segments. Inflorescence a spadix, borne in the axil of leaves near ground level; peduncle during anthesis 20–50 cm long, in fruiting stage 1 m or longer, considerably thicker than the petiole; spadix at first enclosed by 3–4 spathes which fall and leave the spadix naked; spathes lanceolate to ovate, 10–35 cm × 3–5.5 cm, acuminate to subcuspidate, the 2 lower ones green and coarse, the 2 upper ones creamy-white to greenish-white; spadix cylindrical, at anthesis 9–22 cm × 1–4 cm; surface of spadix covered with groups of 5 flowers, each group consisting of one central female flower sunken in the spadix surrounded by 4 male flowers; male flowers fleshy, massive, without distinct pedicel, rounded to angular, 3–5 mm long, receptacle flat or shallowly concave, 2–3 mm in diameter, surrounded by a cup-like perianth which bears 15–20, rotundate, apiculate, glanduliferous lobes 1–1.5 mm × 0.4–0.8 mm; stamens 30–55, densely crowded, filaments 0.1–0.2 mm long, slightly thickened at base, anthers 1–1.7 mm × 0.4–0.5 mm; female flowers suborbicular to quadrangular, during anthesis 3–5 mm broad, in fruiting stage up to 10 mm broad; tepals 4, connate at base, obtusely triangular, during anthesis 1.5–3 mm × 2.5–4.5 mm, closely pressed against the style and stigmas and partly connate with the style, in fruiting stage becoming truncate and connate to about half their length, up to 3 mm × 6 mm; staminodes 4, filiform, 3–6 mm long, yellowish-white to silken-white, forming a disordered mass on the flowering spadix; pistil with ovary one-loculed bearing 4 placentas, style one, short at first, later prolonged, together with stigmas 2.5–3.5 mm long, stigmas 4, alternating with the tepals, generally rather broad, ovate to suborbicular when seen from above, entirely encircled by the tepals. Fruit a berry but all berries of the spadix fused to a single, fleshy, yellow-green, cylindrical syncarp up to 30 cm × 5.5 cm; the fruiting layer begins to open in the apical part, being cleft in usually 2 flaps which are successively detached from the rachis and from each other and more or less rolled, showing the bright orange-red



Carludovica palmata Ruiz & Pav. – 1, habit of flowering plant; 2, rhizome part with young shoot; 3, spadix with staminodes; 4, male flower; 5, female flower, one tepal removed; 6, young fruit; 7, dehiscing syncarp; 8, seeds.

to scarlet interior tissue containing small berries with minute slimy seeds. Seed irregularly cylindrical to suborbicular, usually angular, 1.5–3 mm × 1–1.5 mm, dull yellow-white.

Growth and development Under hot and moist conditions *C. palmata* seeds normally germinate within 2 weeks. During germination the cotyledon is enclosed in the seed. The first leaves are undivided and lack a petiole. During subsequent growth the shape and size of newly formed leaves gradually change until the characteristic lobate leaves appear. The leaves grow to their full length while they are still folded. The inflorescence of *C. palmata* is protogynous, with the female flowers being ripe when the spathes open, which is usually at night. Beetles are attracted by the fragrant odour of the staminodes. They stay in the spadix during the day. During the following night, when the female flowers are no longer functional, the anthers of the male flowers open, the beetles eat pollen and become covered with it, leave the inflorescence and fly to an inflorescence in the female flowering stage, where they carry out pollination. After shedding pollen, the male flowers wither and drop off and a syncarp is formed from the female flowers as they enlarge and fuse, forming a thin outer woody layer on the syncarp, with shrivelled remains of the perianth and styles. At maturity, this layer dries up, splits and carries away the red inner tissue containing the small berries filled with slimy seeds. Dispersal is perhaps by ants and rain.

Other botanical information Though the vernacular name 'Panama hat palm' suggests otherwise, *C. palmata* is not a palm. The *Cyclanthaceae* are, however, closely related to the *Palmae*, *Pandanaceae* and *Araceae*, and can be regarded as advanced derivatives of the palms. *Carludovica* Ruiz & Pav. contains 3 species and is distributed from south-eastern Mexico to central Bolivia. *C. palmata* is a polymorphous species, with great variation in both vegetative and floral characters, but the lack of good herbarium material makes an adequate intraspecific classification difficult. The other 2 species are *C. drudei* Mast., grown as an ornamental in Java, and *C. rotundifolia* H. Wendl. ex Hook.f. Both may have been used in hat manufacture as well and in any case seem suitable, because their leaves are very similar to those of *C. palmata*.

Ecology *C. palmata* mainly grows in humid tropical forests up to 1400–1500 m altitude, though it is occasionally found in drier and more open locations, such as roadsides, pastures and scrubland. For optimal growth it requires a hot tropical climate with plenty of rain, but it will not withstand waterlogging, and it is best grown in the shade. Although *C. palmata* can grow under various climatic conditions, high quality hats can only be made in weather that is neither too dry nor too wet.

Propagation and planting *C. palmata* can be propagated by seed, suckers and rhizomes. Suckers are often preferred because plants grown from them require less time before the leaves can be harvested. In Campeche (south-eastern Mexico) rhizomes collected from local populations are planted 1 m apart, resulting in a density of 10 000 plants/ha.

Husbandry No information is available on the husbandry of *C. palmata* in South-East Asia. In Campeche the fields are weeded every few weeks during the first year after planting, until the crop provides enough shade to prevent weed growth. Later on, the fields are regularly thinned to prevent overcrowding. Thinned out plants may be sold as planting material. Fertilizers are rarely applied, but the plots may be irrigated.

Diseases and pests There are no records of serious diseases and pests of *C. palmata* in South-East Asia. In Mexico a serious leaf yellowing disease has been observed since 1994. The causal agent is a phytoplasma closely related to the one that causes lethal yellowing disease in coconut (*Cocos nucifera* L.).

Harvesting *C. palmata* grown from seed requires about 7 years before the leaves can be harvested, whereas leaves can be cut from plants raised from suckers at 18 months after planting, when they have about 20–30 leaves. The leaves are collected while they are still folded or just beginning to fan out. They are cut with a sharp knife, with about 2.5 cm of the petiole left attached to the blade to facilitate handling. In Indonesia the leaves are cut off with about 5–8 cm of the petiole remaining attached. As the lower leaves are cut, new ones develop quickly and leaves can be harvested from the plant throughout its life.

Yield No statistics on the yield of *C. palmata* per plant or per ha are available. In south-eastern Mexico *C. palmata* produces a usable leaf every 15 days.

Handling after harvest The harvested leaves of *C. palmata*, sometimes with the outer segments removed, are usually boiled in water for a few minutes or repeatedly dipped into boiling water. Lemon juice may be added to the water to facilitate bleaching. Subsequently, the leaves are dried and bleached, sometimes in the sun but more often in the shade. Sufficiently bleached leaves are split into uniform strips, which are still connected at the leaf base. Splitting may be done with thumb- and fingernails, with a needle or with a comb of needle points set in a wooden handle. The resulting strips are washed and dried. They may also be immersed in boiling water again or bleached in sulphur fumes while they are still moist. As they dry, the strips, which may be 1 m long, shrivel into a cylindrical form, and they are sold this way to the weavers. Sometimes the harvested leaves are retted in water, after which the pulp and extraneous matter are scraped off, leaving the fibre, which is subsequently bleached. In Indonesia the outer 2–3 leaf segments are removed from the harvested leaves, as well as some inner parts too stiff for handling. The nerves are removed with a needle and the remaining strips are divided into 2–3 ribbons, depending on the required fineness of the product. The bundle of ribbons, held together by the petiole, is dipped into boiling water for one to several minutes and dried. Hats are plaited by hand from leaf strips of uniform thickness. Where the climate is hot and dry, the weavers moisten the strips repeatedly to keep them pliable. For this reason weaving in some places is done mainly in the early morning when the weather is wet. In Java *C. palmata* can be woven throughout the day, if care is taken not to expose the material too much to the sun. First, the top of the crown is woven, for which several strips are used, still joined at the base, and new strips are added when necessary. When half the crown is completed, it is placed on a wooden block of the required size and weaving is continued down to the brim, which is carefully edged. The hats are sold in this form at fairs, where they are bought by exporters. The hats are washed in water and soap, dried in the sun and further bleached with sulphur, after which they are placed on wooden blocks of the required size, dampened with water, ironed into the proper shape and dried in the sun. Then they are removed from the blocks and trimmed with a sharp knife, after which a mixture of sulphur, water and gum is brushed on the inner and outer side of the hats. The hats are dried again and beaten with a wooden mallet on a post or block, after which they are cleaned, examined and trimmed. The finished hats are graded and classified according to the thickness of the weave. The production of Panama hats is a traditional part-time cottage industry in Ecuador, with a specific design woven into the centre of the hat crown signifying the locality or the maker.

Genetic resources and breeding The genetic variation in *C. palmata* has not been recorded or studied so its genetic status is unknown. No germplasm collections or breeding programmes of *C. palmata* are known to exist.

Prospects Though there is an international market for hats made of *C. palmata*, it will be difficult for South-East Asian countries to compete in this market, in view of the long tradition of hatmaking in South America. There is also little prospect for *C. palmata* becoming more important for local use, as there are many other plant resources in South-East Asia with a longer tradition of being used for similar purposes. Moreover, the market in South-East Asia is limited as the habit of wearing woven hats is not widely practised here, except for working in the sun or for open-air leisure purposes. Therefore the main prospects for *C. palmata* in South-East Asia are in the tourist industry.

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H.C. Ong

Ceiba pentandra (L.) Gaertn.

Fruct. sem. pl. 2: 244 (1791).
BOMBACACEAE
$2n = 72–88$

Synonyms *Bombax pentandrum* L. (1753), *Eriodendron anfractuosum* DC. (1824).

Vernacular names Kapok, (white) silk-cotton tree (En). Arbre kapok, kapokier, fromager (Fr). Indonesia: kapuk (general), kau-kau (Bugis). Malaysia: kabukabu, kekabu, kapok. Philippines: kapok (Bisaya, Sulu, Tagalog), buboi, balios (Tagalog). Cambodia: koo, kor. Laos: ngiuz baanz, kok niou, ngiou. Thailand: nun (general), ngiu noi, ngiu sai (northern). Vietnam: (c[aa]y) g[of]n.

Origin and geographic distribution Kapok originated in the American tropics. From there it spread to Africa, where it occurs in the wild along the west coast from Senegal to Angola. It was taken from Africa to Asia to be cultivated; here the cultivated form was developed. Kapok is depicted in reliefs in Java dating from before 1000 AD. It is now cultivated all over the tropics, but mainly in South-East Asia, especially in Indonesia and Thailand.

Uses The fruits of *C. pentandra* are the source of the kapok fibre used for stuffing (e.g. mattresses, pillows, upholstery, protective clothing), and for thermal and acoustic insulation. Lifebelts and life-jackets used to be made from kapok fibre, but were only effective in the days of sail and steam, when there was no danger of oil in the water. During the Second World War many people drowned because their kapok life-jackets had lost buoyancy; nowadays synthetic material is used. In Java the placenta is crushed to produce a secondary quality kapok fibre for cheaper mattresses and for use as an absorbent for oil-contaminated sea water. Placental material is also used for culturing fungi. The shells of the fruits serve as a substitute for pulp material for paper making in Java.
The shells are rich in potash and the ash can be used as fertilizer. They are also used to make baking soda and soap. Dry shells are used as fuel. The seeds contain an oil which is used for soap manufacture, as a lubricant and as lamp oil. The oil has also been used for culinary purposes, but this is not advisable for health reasons. The residual presscake is used as animal feed. In Indonesia and Malaysia the seeds are eaten, but only in small quantities as they upset the digestion.
Young leaves are eaten as a leaf vegetable in the Philippines, young flowers and fruits are eaten in Thailand, and very young pods are eaten in Java. The leaves are used as fodder for cattle and as a soil improver. The wood is used for paper making and for making canoes, carvings, doors, furniture, boxes and toys. The flowers are a good source of nectar for honeybees. In various locations kapok is planted for reforestation, watershed conservation and for supplying fuelwood and fence posts.
In traditional medicine throughout South-East Asia preparations of the leaves are taken against fever, cough, hoarseness and venereal diseases. The bark is considered diuretic and astringent and also serves to treat fever, asthma, gonorrhoea and diarrhoea. The root is considered a diuretic and febrifuge as well. In India root decoctions are used against chronic dysentery and ascites. The Mayan and Aztec people in Central and South America regarded the kapok tree as sacred: its size and stature led them to regard it as a link between the earth and the universe. The kapok tree still has sacred significance for local peoples in many parts of the world.

Production and international trade The kapok tree was an important commercial fibre crop before the Second World War. Indonesia was the most important producer, exporting about 20 000 t per year of very good quality kapok. After the Second World War Indonesian production decreased and Thailand became the main supplier of the world market. Thailand also surpassed Indonesia in the quality of the kapok produced. However, Indonesian kapok production increased again from less than 30 000 t per year in the 1960s to about 80 000 t in 1996–2000, whereas the annual kapok production in Thailand remained stable at about 40 000–45 000 t. Most of the kapok produced was for home consumption. Indonesia, for instance, exported only about 800 t per year, mainly to India, Singapore and the United States.
In 1996–2000 Indonesia produced 206 000 t kapok seed in shell, 20 000 t kapok oil and 109 000 t kapok seed cake per year. The annual production in Thailand was 112 000 t kapok seed in shell, 13 000 t kapok oil and 59 000 t kapok seed cake. There is little international trade in these by-products. In 1996–2000 Indonesia exported on average 250 t kapok oil per year, with the importing countries including Japan and Singapore.

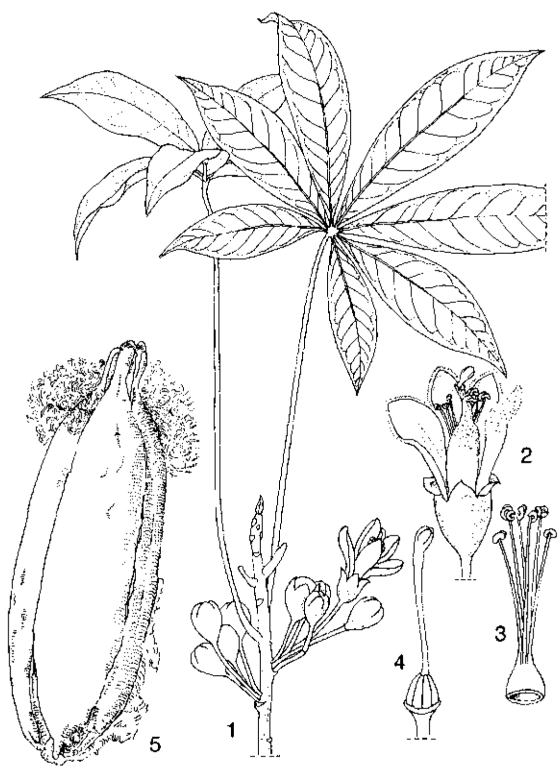
Properties Kapok is the floss derived from the inner fruit wall in which the seeds lie loose when ripe. The total dry matter of ripe fruits, by weight, is composed of 21% fibre, 48% shell, 25% seed and 6% placenta. The fibre cells are (8–)19–22(–35) mm long and (10–)19–20(–30) μm wide, smooth, transparent, cylindrical, with a wide lumen and thin walls. They appear as structureless bent tubes. At one end they taper to a point, whereas the other end has a slightly bulbous base with annulate or reticulate markings. Kapok fibre contains about 43% α-cellulose, 32% hemicelluloses, 13–15% lignin and 1% ash. It is resilient, elastic, light (8 times lighter than cotton), water-repellent and buoyant (5 times more than cork). In an uncompressed state, it can support 20–30 times its own weight in water. This is because when the fibre is immersed in water, the lumen only partly fills with water and contains many air bubbles. Kapok fibre has a low thermal conductivity and very good sound-absorbing properties. A disadvantage of kapok fibre is its high inflammability, but techniques have been developed to make it non-flammable. In its natural form, kapok cannot be spun, because of the smoothness of the outer surface. However, specific techniques have been developed to make spinning of kapok possible. The fibre is long-lasting and is not attacked by fungi and pests.

The seeds yield 11–28% oil. The oil, which greatly resembles cotton-seed oil, contains cyclopropenoid fatty acids such as malvalic acid (7–8%) and sterculic acid (3–4%), which cause abnormal physiological reactions in animals. For this reason the consumption of kapok seeds or seed oil should be discouraged, unless the cyclopropenoid acids have been chemically removed. Per 100 g the press cake contains approximately: moisture 14 g, protein 26 g, fat 8 g, carbohydrates 23 g, fibre 23 g and ash 6 g. The K content of the shell is about 3%, and that of the ash 20–23%.

Bark extracts of *C. pentandra* have shown anti-inflammatory activity in vivo and in vitro. Workers exposed to kapok dust for long periods may develop chronic bronchitis, and people involved in processing of kapok fibres are advised to wear protective masks.

Adulterations and substitutes Floss obtained from the red silk-cotton tree (*Bombax ceiba* L., synonyms: *B. malabaricum* DC., *Salmalia malabarica* (DC.) Schott & Endl.) has many of the qualities of *C. pentandra*, but is less resilient, has a more brown or yellow colour, and can support only 10–15 times its own weight in water. *Bombax anceps* Pierre is also used for stuffing, for instance in Thailand. Other fibres used as a lower quality substitute for kapok include those of *Asclepias curassavica* L., *A. incarnata* L., *A. syriaca* L., *Calotropis gigantea* (L.) Aiton f., *C. procera* (Aiton) Aiton f., *Ceiba aesculifolia* (Kunth) Britten & E.G. Baker, *C. trischistandra* (A. Gray) Bakh., *Chorisia insignis* Kunth, *C. speciosa* St. Hil., *Cochlospermum religiosum* (L.) Alston and *Typha* spp. Kapok has been adulterated with low-grade cotton (*Gossypium* spp.) and cotton waste. For industrial purposes kapok has largely been replaced by synthetic products, for instance for the production of life-jackets.

Description A deciduous tree, 18–70 m tall, in cultivation usually 18–30 m tall. Roots spreading quite horizontally, 10 m or longer, in the upper 40–80 cm of the soil. Trunk with or without buttresses, forked or unforked, spiny or spineless. Branches whorled, dimorphic, whorls usually of 3 branches, horizontally or ascending. Leaves alternate, digitately compound; petiole 7–25 cm long; leaflets 5–11, oblong-lanceolate, 5–16 cm × 2–4 cm, glabrous. Flowers 2–15 together in axillary fascicles, 5-merous, hanging, actinomorphic, bisexual; pedicel 2.5–5 cm long; calyx campanulate, 1–1.5 cm long, 5-lobed, glabrous outside; petals oblong-obovate, 2.5–4 cm long, united at base, usually dirty white with foetid milky smell, glabrous inside and densely silky outside; stamens united at base in a staminal column, dividing into 5(–6)



Ceiba pentandra (L.) Gaertn. – 1, flowering branch; 2, flower; 3, stamens; 4, pistil; 5, fruit.

branches of 3–5 cm length, anthers coiled or reniform; style 2.5–3.5 cm long, constricted at base, obscurely 5-lobed at top. Fruit an ellipsoidal, leathery, pendulous capsule, 7.5–30 cm × 3–7.5 cm, turning brown when ripe, dehiscing with 5 valves ('shells') or indehiscent, many-seeded. Seed obovoid, 4–6 mm in diameter, dark brown, embedded in copious, white, pale yellow or grey silky wool (floss). Seedling with epigeal germination.

Growth and development Seeds germinate within 3 days after sowing. In 6 months the young plants reach a height of 1 m. Two forms are recognized among the cultivated types: the 'pagoda' form with whorls of 3 horizontal branches spaced evenly along the main stem, and the 'lanang' form with irregularly spaced branches.

In Java flowers are initiated before leaf-fall, and flowering occurs on leafless branches at the beginning of the dry season, which starts between March and May. The flowers do not all appear at once, but over a period of 4–6 weeks. Flower buds open 15–20 minutes after sunset. The next morning and during the following day, the petals show the first signs of wilting. The same holds for the filaments and style. At the end of the day, wilting is complete and the flower, with stamens and style, drops off. Self-pollination is predominant in kapok plantations. During the night, the wind moving the flowers causes pollen to be shed on the stigmata of the same flower or neighbouring flowers. Where present, nectarivorous bats are pollinators. Insect pollination occurs in the morning. In Java beehives are placed in plantations to encourage pollination. Natural pollination results in about 8% of fruits ripening. The undeveloped fruits are shed after flowering, during the first and late fruit falls at 4 and 16 days after flowering, respectively. The fruits reach their full size 30 days after flowering. The kapok is formed between the 30th and 70th days and the fruit is ripe on about the 80th day. The size of the fruit and the amount of kapok fibre is proportional to the number of seeds set.

The trees start to bear after 3–4 years, but do not reach full bearing until 7–10 years old. Trees may continue bearing for 60 years or more.

Other botanical information *Ceiba* Miller contains about 10 species, mostly occurring in tropical America. *C. pentandra* is distributed pantropically and is highly variable. Sometimes three varieties are distinguished:

- var. *caribaea* (DC.) Bakh. Occurring wild in the forests of the American tropics and in West Africa; a gigantic tree, up to 70 m tall, with unforked, buttressed and spiny trunk, and horizontal branches; leaf-shedding irregular, leaves narrow; flowering starting in the 11th year and irregular, flowers rose or cream-coloured; fruits rather short and broad, dehiscent; fibre grey to white; $2n = 80, 88$.
- var. *guineensis* (Schum. & Thonn.) H.G. Baker. Occurring wild in savanna woodlands of West Africa; up to 18 m tall; trunk spineless without buttresses, often forked; branches strongly ascending; leaves broad; flowering annually; fruits elongated and narrow at both ends, dehiscent; fibre grey; $2n = 72$.
- var. *pentandra* (syn. var. *indica* (DC.) Bakh.). The cultivated kapok of West Africa and Asia; up to 30 m tall; trunk unbranched, usually spineless, buttresses small or absent; branches horizontal or ascending; leaves intermediate in width; flowering annually, starting in the 4th year after sowing, after leaf-shedding; fruits short or long, narrowed at both ends or banana-shaped, usually indehiscent; fibre usually white; $2n = 72–84$. Because this variety is the cultivated kapok it is more appropriate to classify it as cultivar group Kapok.

Alternatively, var. *caribaea* and var. *guineensis* are grouped into one variety (var. *caribaea*) as 'forest type' and 'savanna type', respectively.

Ecology Kapok thrives best at elevations below 500 m. Night temperatures below 17°C retard germination of the pollen grains. This limits the area in which good crops can be grown to latitudes within about 20°N and 20°S. Kapok requires abundant rainfall during the vegetative period and a drier period for flowering and fruiting. Rainfall should be about 1500 mm per year. The dry period should not contain more than 4 months with less than 100 mm rain per month, and in this period a well-distributed total rainfall of 150–300 mm is required. In drier areas, some of the water demand may be met by groundwater. In the Mekong Delta (Vietnam), where rainfall is inadequate, kapok is grown successfully on river banks. For best results it should be planted on good, deep, permeable soils (in Indonesia volcanic loams) without waterlogging. The tree is easily damaged by strong winds. In Indonesia, flat areas alongside roads and rivers are selected for planting the tree, as these locations have sufficient sunlight and proper drainage. In Java and Sulawesi kapok is also planted on mountain slopes.

Propagation and planting Kapok is propagated by seed or cuttings. Seeds are sown in nursery rows 25–30 cm apart. If the soil is poor, manure should be applied 10 days before sowing. When the young plants are 12–15 cm tall, they can be exposed to full sunlight. Plants not receiving much sunshine grow tall and thin. Young plants are transplanted to the field when 8–10 months old, after the crown has been removed to leave about 1 m of stem. Another method is to sow directly on land which has been properly cleared for planting. Three seeds are sown per hole, and about 2–3 months later, the seedlings are thinned to one per hole. Kapok is easily propagated from cuttings, 5–8 cm in diameter and 1.2–1.8 m long, of 2–3-year-old wood. Cuttings should be taken from orthotropic branches. Trees raised from seeds root deeper than those raised from cuttings, but develop slower, yield less and do not breed true. Therefore in Indonesia it is now recommended that seedlings be grafted with material from high-yielding clones and trees. Grafting is done at the beginning of the rainy season and the grafted seedlings are planted out in the field when the buds have grown into shoots 1 m long. In commercial plantations in Java kapok is planted 8–12 m apart.

In South-East Asia kapok trees are planted around villages, on farmers' plots or on commercial plantations. It is also often planted along roads and on field boundaries. In Java kapok is very seldom planted as a sole crop. It is intercropped with various crops, including cassava (*Manihot esculenta* Crantz), groundnut (*Arachis hypogaea* L.) and turmeric (*Curcuma longa* L.). In Cambodia intercropping with annual crops such as maize, cotton and beans is practised during the first 2–3 years after planting the trees. On some plantations in East Java labourers are allowed to grow maize and beans under the trees in the rainy season.

Husbandry Kapok requires little attention, but the soil must be kept weed-free by occasional hoeing and loosening. Fertilizers are not usually applied and no fertilizer experiments are known of. Pruning is not required.

Diseases and pests Kapok is relatively free of diseases and pests. Stem-boring beetles (*Plocordenes obesus*) are a principal pest of the crop. The kapok pod-borer (*Mudaria variabilis*) can cause severe losses. Natural enemies reducing the damage are *Anastasia* sp. and *Dorylus laevigatus*. The young bud is sometimes bored by the larvae of *Alcides leeuwenii*.

Kapok can be severely damaged by parasites from the *Loranthaceae*. The only cure is to keep the soil bare around the tree.

Harvesting In Java kapok is harvested from August to October. This period falls within the dry season, which is good for the quality of the kapok and also advantageous because very little labour is required for other crops at this time. The fruits are harvested when fully ripe and, in dehiscent types, before they open. Ripeness is indicated by the fruit colour changing from green to brown and the surface possibly becoming wrinkled. In plantations in Java the fruits are sometimes harvested before they are fully ripe to prevent theft. They are usually harvested by climbing the tree and using a knife or a bamboo pole with small hooks attached at the upper end to cut off the fruit. It is not economic to harvest the whole crop at once, as this will result in a mixture of ripe and unripe fruits. In Indonesia harvesting is usually done by the trader and seldom by the farmer.

Yield Under optimum conditions a full-grown kapok plantation tree may yield 330–400 fruits per year, giving 15–18 kg fibre and about 30 kg seed. A satisfactory average annual fibre yield is about 450 kg/ha, whereas about 700 kg/ha is considered very good.

Handling after harvest Inevitably, some immature kapok fruits will be harvested, but these are segregated and spread out on a drying floor and exposed to the sun, eventually turning brown and wrinkled. The fruits are hulled as soon as possible after harvesting. Drying is carried out in the wind or with fans in airy cage-like structures open to sunlight and covered with wire netting to keep the kapok from being blown away. The air movement caused by wind or fans also helps to separate the fibres from the seeds. Sometimes the kapok is spread on the ground in layers of 15–20 cm and prodded with long bamboo forks to loosen the clumps of fibre and expose the fibre to sunlight ('Jepara method').

The seeds lie loose in the floss, and therefore de-seeding is easier than it is for cotton. If de-seeding is done by hand, the floss is beaten with a stick and then screened, the operation being repeated several times. There are various types of de-seeding machines.

The quality of kapok is judged by fibre length, freedom from seeds and foreign matter, moisture content, colour, smell and lustre. In Indonesia the product is classified into 7 grades. 'Prima estate', 'Prima jepara', 'Average Java I', 'Average Java II' and 'C. min' are white-coloured and contain 1%, 1.5%, 2%, 3% and 5% dirt, respectively. 'C off I' is yellowish-white with 6% dirt and 'C off II' is yellowish.

When baling the kapok fibre for export, it should be borne in mind that excessive pressure will destroy the elasticity and diminish the quality of the fibre. The size of the bales exported from Indonesia depends on their destination: Singapore requires bales of 80 cm × 80 cm × 80 cm with a weight of 30–32 kg, Japan and Europe bales of 60 cm × 80 cm × 100 cm with a maximum weight of 100 kg, and the United States and Africa bales up to 130 kg.

Genetic resources In view of its pantropical distribution, kapok does not seem to be threatened with extinction. The small genetic variation of kapok in Asia indicates that the population was derived from only a few trees.
The largest kapok germplasm collection is kept at the Indonesian Tobacco and Fibre Crops Research Institute in Malang (Indonesia) and contains 180 accessions. Of these, 59 are the result of crosses in the colonial period, 88 are local clones and 33 are from explorations in several kapok areas in the 1990s. Some accessions are held at CNSF (Centre National de Semences Forestières) in Ouagadougou (Burkina Faso).

Breeding There is little breeding of kapok. The breeding carried out aims at high production of high quality kapok fibre. Since the fibre has to compete with synthetic substitutes, it could be argued that a type should be produced which is either cheaper or better than its synthetic counterparts. The substitutes are produced in countries which used to import kapok, thus freeing these countries from reliance on kapok. It would be better to gear breeding programmes to the home demands of kapok-growing regions or countries. Selection or crossing could result in higher-yielding types and types producing a better kapok, for instance with longer fibre cells. To this end, indigenous and foreign material should be screened to obtain the desired characteristics. Artificial pollination can be done by hand. Emasculation should be done in the afternoon and pollination at night or early in the morning. Kapok pollen can be stored at room temperature for several days only. The success rate for crosses is usually 15%. Some selection work has recently been carried out in Thailand. Superior trees obtained by selection or crossing can be multiplied by means of vegetative clonal propagation.

Prospects Kapok's importance in international trade will remain very limited. The kapok tree will continue to have some importance in South-East Asia as a multipurpose tree for local use, grown for its fibre and seed, as a reforestation tree, for fuel and for shade. If breeding activities are resumed, they should be directed towards local requirements.

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M. Sahid & A.C. Zeven

Colona Cav.

Icon. 4(2): 47, t. 370 (1798).
TILIACEAE
x = unknown; $2n$ = unknown

Major species and synonyms

- *Colona javanica* (Blume) Burret, Notizbl. Bot. Gart. Berlin 9: 810 (1926), synonyms: *Columbia javanica* Blume (1825), *Grewia involucrata* Blume (1825), *Colona integrifolia* (Ridley) Burret (1926).

- *Colona serratifolia* Cav., Icon. 4(2): 47 (1798), synonym: *Columbia serratifolia* (Cav.) A. DC. (1824).

Vernacular names

- *C. javanica*: Indonesia: sampora, jalupang (Sundanese), kayu ules (Lampung). Thailand: po nguang, po (peninsular).
- *C. serratifolia*: Malaysia: jelunut. Philippines: anilau (Tagalog, Bikol, Bisaya), mamaued (Tagalog), salag (Bikol).

Origin and geographic distribution *Colona* comprises 18–30 species distributed from India and Bangladesh eastward through South-East Asia to the Solomon and Caroline Islands and northward to southern China. *C. javanica* is found in Thailand, Laos, Peninsular Malaysia, the Nicobar Islands (Camorta), Indonesia and the Philippines. *C. serratifolia* is distributed from Peninsular Malaysia (eastern coast) through Borneo and throughout the Philippines.

Uses In Java the bast of *C. javanica* is made into fishing nets and rope used for all domestic purposes requiring strong rope, for instance in the tethering of buffaloes. In South Sumatra, strips from the inner bast of stems or branches up to 15 cm wide are woven into mats on which rice is dried, whereas bast from older trees is used to make walls for houses and barns. *C. serratifolia* bast strips have been made into cords in the Philippines, where, despite the weakness of its fibre, it has been popular in Los Baños and surrounding towns.

Timber from *C. javanica* sometimes serves for house construction in Indonesia, but it is not valued very highly. In Thailand it is used for cabinet work.

Production and international trade No production statistics are available for *C. javanica* or *C. serratifolia*. Their products do not enter international trade.

Properties Coarse but very strong ropes are made by simply twisting the bark of *C. javanica*. With better processing finer, rather strong ropes can be made. The fibre obtained from the bark of *C. serratifolia*, however, is weak, especially when dry. The fibres of *C. serratifolia* are arranged in pyramidal to narrow-rectangular groups, each subdivided into 1–10 strips, which can be separated easily. The ultimate fibre cells are (3–)5(–7)-sided (polygonal), (1.0–)1.6(–2.5) mm long and (5–)14(–27) μm wide, with a lumen width of (1–)4(–8) μm. Freshly isolated fibre strips are yellowish, but upon drying they turn pale brown.

A red dye is obtained from the bark of *C. serratifolia*. Hydrocyanic acid is present in the leaves, roots and stems (traces). The wood density of *C. serratifolia* is 0.33 kg/dm^3.

Adulterations and substitutes Many natural and artificial substitutes are available for *Colona* as a source of cordage, natural ones including other *Tiliaceae*, such as *Grewia* and *Triumfetta* spp.

Description Usually small trees. Leaves alternate-distichous, simple, base often unequal-sided, palmately 3–7-veined, margin finely dentate to serrate. Inflorescence a lax terminal or axillary panicle of small, 3-flowered cymes; flowers bisexual; sepals 5, free, hairy outside, glabrous inside; petals 5, free, glabrous, glandular at base; receptacle raised, slightly lobed; stamens numerous, borne on apex of receptacle, filaments free and filiform, anthers dorsifixed; ovary 3(–5)-locular, each locule with 2–4 ovules; style narrow, tapering to the pointed stigma. Fruit subglobose schizocarp with 3(–5) longitudinal wings, breaking up into 3(–5), persistently connate, 2-alate, 1–4-seeded, indehiscent mericarps.

Colona javanica (Blume) Burret – 1, flowering branch; 2, flower; 3, section through flower showing pistil and part of stamens; 4, fruits.

- *C. javanica*. A tree, up to 15(–25) m tall, stem diameter up to 45 cm. Leaves with petiole 0.2–5 cm long; blade ovate to oblong, 5–30 cm × 2–18 cm, base oblique-cordate and 4–6-veined, margin serrate to serrulate, apex acutely acuminate to caudate, secondary veins 3–5 pairs, scalariform and reticulate veins distinct and always depressed on upper surface, petiole and lower blade surface densely brown stellately tomentose; leaves along the inflorescence stipule-like, those of suckers large with petiole 10–13 cm long, blade subcircular, 25–35 cm in diameter. Inflorescence 10–20 cm long, most parts densely brown stellately tomentose; pedicel articulate, 5–7 mm long; flowers odourless, brownish, diameter about 1 cm; sepals oblong, 5–7 mm long, inside yellow, red-dotted, appressed hairy; petals oblong-spatulate, 4.5–6 mm × 1.5–2 mm, inside yellow, red-dotted, glabrous; stamens glabrous; ovary subglobose, diameter 1–2 mm, hairy; style 3–4 mm long. Fruit ovoid or obovoid, 3-winged, 7.5–10 mm × 20–30 mm (wings included). Seed embedded in mucus.
- *C. serratifolia*. A tree up to 15 m tall, with densely hairy twigs. Leaves with petiole 6 mm long; blade lanceolate, 9.5–24 cm × 3.5–7.5 cm, base oblique, margins with widely spaced, prominent teeth, apex with a long tip, upper surface glabrous, lower surface velvety white-hairy, secondary veins 5–7 pairs and prominently raised below. Flowers 6–7 mm long, petals pink and yellowish or reddish. Fruit about 1 cm long, 3–4 winged.

Growth and development In West Java *C. javanica* is evergreen and flowers from March to December. In Thailand flowering is from June to August and fruiting from December to February. *C. javanica* produces suckers.

Other botanical information Several other *Colona* species are known to yield fibre (see Minor fibre plants). The Philippine vernacular name 'anilau' for *C. serratifolia* has also been recorded for *C. lanceolata* (Warb.) Burret and *C. blancoi* (Rolfe) Merrill, the name 'mamaued' for *C. blancoi*, and the Malaysian vernacular name 'jelunut' for *Commersonia bartramia* (L.) Merrill.

Ecology *Colona* is confined to open habitats, particularly secondary forest, rocky seashores and limestone hills. In West Java *C. javanica* grows up to 300 m altitude, in not very dense, evergreen, heterogenous forest, especially on rather rocky, unfertile soils. It usually occurs scattered and is seldom found in groups. In Thailand it is found up to 800 m altitude in evergreen forest. *C. serratifolia* needs sun and grows in secondary forest.

Husbandry *Colona* is collected from the wild and is not cultivated.

Handling after harvest In Java coarse, strong ropes are made from *C. javanica* by removing the green peel from the bast, which is subsequently twisted manually several times. The division of *C. serratifolia* strips into narrower strips, for the production of finer cords, must be done when they are still fresh, because they become stiff and brittle upon drying. To preserve freshness cord-making is better done in the morning or in cool weather. Wetting of dried fibres can restore them to the fresh condition.

Genetic resources and breeding In the Nicobar Islands *C. javanica* is considered a rare and endangered species. No germplasm collections or breeding programmes of *Colona* are known to exist.

Prospects *C. javanica* will at most remain a local source of cordage, as many natural and artificial substitutes are available. The prospects for *C. serratifolia* are even bleaker, in view of its lower fibre quality.

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Corchorus L.

Sp. pl.: 529 (1753), Gen. pl. ed. 5: 234 (1754).
TILIACEAE
$x = 7$; *C. capsularis*, *C. olitorius*: $2n = 14$

Major species and synonyms

- *Corchorus capsularis* L., Sp. pl.: 529 (1753), synonyms: *C. cordifolius* Salisb. (1796), *C. marua* Buch.-Ham. (1828).
- *Corchorus olitorius* L., Sp. pl.: 529 (1753), synonyms: *C. quinquelocularis* Moench (1794), *C. decemangularis* Roxb. (1814), *C. catharticus* Blanco (1837).

Vernacular names General: jute (En, Fr). India, Bangladesh: pata, jhot. Philippines: saluyot, saluyut (Ilokano), pasau (Tagalog).

- *C. capsularis*: white jute, deshi jute (En). Chanvre de Calcutta (Fr). Indonesia: serani (Aceh), silangkang (Padang Sidempuan), ganja cina (Moluccas). Malaysia: jelita, kanching baju, senerong betina. Philippines: pasau-na-bilog (Tagalog), tagabang (Bisaya). Cambodia: dok kah pha, krachav. Thailand: seng, po seng (northern), pak kom. Vietnam: day qu[ar] tr[of]n.
- *C. olitorius*: tossa jute, Jew's mallow (En). Corète potagère (Fr). Indonesia: gedangan, pisangan (Javanese). Philippines: pasau-na-haba (Tagalog), lumhay (Bisaya). Thailand: krachao, po krachao (central), po krachao fak yao. Vietnam: day, day qu[ar] d[af]i.

Origin and geographic distribution *Corchorus* is a pantropical genus comprising an uncertain number of species, with estimates ranging from 40–100. Most species are of African origin. The centre of origin of *C. capsularis* is the Indo-Burman region, including southern China. The primary centre of origin of C. *olitorius* is probably Africa, with India or the Indo-Burman region as a secondary centre. Both species are cultivated and have naturalized in many parts of the tropics, including South-East Asia.

'Korkhoros' is an old Greek name for *C. olitorius* long in use as a leaf vegetable in the Middle East and North Africa. In Asia and Africa jute has probably also provided fibre for cordage and woven cloth since ancient times. However, there is uncertainty about the time of its first domestication as a fibre crop, because historical references to cloth from plant fibres are not specific. The Sanskrit word 'patta', for instance, may have originally included jute and other fibres as well. There is, however, evidence of trade in jute cloth in 16th Century Bengal. The cultivation of jute in India expanded considerably during the first half of the 19th Century, as a result of growing European interest in jute fibre as a suitable and cheaper substitute for hemp (*Cannabis sativa* L.) and flax (*Linum usitatissimum* L.) in the manufacture of cordage and packaging cloth. Exports of raw jute from Calcutta to England increased from 100 t in 1793 to 28 000 t by 1850. The introduction of jute spinning and weaving machinery, developed for the Scottish flax and jute industry during the 1830s, resulted in a rapid establishment of large numbers of power-driven jute mills and further expansion of jute cultivation in India. Ever since, world jute production and processing has been concentrated largely in the Ganges-Brahmaputra delta of India and Bangladesh, with minor areas of cultivation elsewhere in Asia. Jute was introduced into the states of Para and Amazonas in Brazil around 1930 by Japanese immigrants. India and Bangladesh produce jute from both species. *C. olitorius* is potentially higher yielding and produces a fibre of finer quality but *C. capsularis* is preferred for cultivation in lowland areas because of its tolerance to temporary inundation. *C. capsularis* is most commonly cultivated in all other jute producing countries. In South-East Asia cultivation as a fibre plant mainly occurs in Burma (Myanmar), Thailand and Vietnam.

Uses Jute has been the most widely used packaging fibre for more than 100 years because of its strength and durability, low production costs, ease of manufacturing and availability in large and uniform quantities. About 50% of raw jute is processed into gunny bags and sacks for transportation and storage of agricultural and industrial commodities. Other traditional products include hessian cloth, carpet backing, yarn, twine, cordage, felt and jute carpets. Jute is a versatile natural fibre finding a wide range of new applications in fabrics for furniture, upholstery, soft luggage, wall coverings, laminated sheets for packaging boxes and panelling (as a substitute for plywood), as well as in geotextiles for erosion control on slopes and for agricultural mulching. Whole jute stems are suitable as raw material for paper pulp. However, when jute is used for pulping, it is usually in the form of cuttings from burlap manufacture, old sugar bags and wrappings. The resulting pulp is made into hard, thick paper, suitable for cards and labels. The woody central core or 'stick' remaining after removal of the bast serves as rural building material, thatch, fences, fuel and for charcoal-making. It can also be processed into paper, board and cellulose.

The leaves and tops of *C. olitorius* are eaten as a vegetable, for instance in Malaysia, Indonesia and the Philippines. In Africa and the Middle East *C. olitorius* is mainly grown and used for this purpose, and not for its fibre. The leaves of *C. capsularis* are applied medicinally in Peninsular Malaysia to poultice sores, and in decoction they serve against dysentery, phthisis and cough, and as a tonic for children. In the Philippines the leaves of *C. capsularis* are used against headache. Though the seeds of both *C. capsularis* and *C. olitorius* are toxic, those of the former are recorded as being used, in the form of powder or in decoction, as a tonic, carminative and febrifuge in the Philippines, and those of the latter as a purgative.

Production and international trade The world jute production in the period 1997–2001 averaged 2.76 million t raw fibre per year from 1.46 million ha. India (1.68 million t per year from 862 000 ha) and Bangladesh (852 000 t per year from 474 000 ha) together produced more than 90%. Jute cultivation is very labour intensive and for that reason it is typically a smallholder crop. The flood plains in the lower delta of the Ganges and Brahmaputra rivers combine optimum conditions for jute cultivation (with respect to climate, soil, and adequate surface water for retting) with the availability of inexpensive farm labour. Other countries with noticeable jute production in 1997–2001 were China (125 000 t per year), Burma (Myanmar) (36 000 t), Uzbekistan (20 000 t), Nepal (15 000 t), Vietnam (14 000 t) and Thailand (4900 t). The average annual jute production in Cambodia was only about 800 t in this period.

Most jute fibre is processed within the producing countries. In 1997–2001 world raw jute fibre exports amounted to about 350 000 t per year, and were almost entirely from Bangladesh. Thailand imported on average 17 000 t annually and Indonesia 5000 t. The annual export of manufactured jute products is about 630 000 t per year, 70% from Bangladesh and 25% from India. Exported products include new gunny bags (50%), yarn (20%), hessian cloth (15%), carpet backing (10%) and smaller quantities of twine, cordage, felt, carpets and other products.

Properties Jute fibres are obtained from the bast of *C. capsularis* and *C. olitorius*, where they occur in the form of wedge-shaped bundles. Dry matter partitioning in a fully-grown jute plant is on average: bark 26% (16% fibre and 10% retting waste), wood 47%, leaves 19% and roots 8%. The spinnable units in jute fibre strands are, like those in most other bast fibre crops, filaments composed of a string of cells cemented together by pectin and hemicelluloses. Individual fibre cells are (0.5–)2–2.5(–6.5) mm long, with a diameter of (9–)15–20(–33) μm. The length of the fibre cells decreases from the top to the bottom of the stem, whereas the width increases. The lumen width varies greatly throughout the length of the fibre cell, with the lumen sometimes closing up. Dislocations and cross-markings are faint. The fibre ends show great variation, with spoon-shaped ends being characteristic for jute. The filaments in yarns ready for spinning can vary in length from 1–250 mm. The use of jute is limited to coarse fabrics, because the length:diameter ratio of jute filaments is only 100–120, much below the minimum of 1000 required for fine spinning quality. Jute fibre is hygroscopic and wetted filaments may swell up to 23% in diameter. Typical values of the tensile strength, elongation at break, and Young's modulus of jute fibre are 395–775 N/mm^2, 1.5–1.8% and 26.5 GPa, respectively. The rather low ignition temperature (193°C) of jute fibre poses a considerable fire hazard in warehouses. Jute fibre contains 45–64% α-cellulose, 12–26% hemicelluloses, 11–26% lignin, 0.2% pectin and 1–8% ash. The fibre *of C. olitorius* is finer, softer and more lustrous than that of *C. capsularis*. The former is yellowish to reddish and the latter usually whitish. Jute fibre may be treated with a strong alkali ('woollenization'), resulting in a reduced fibre length, a softer feel and a crimp or waviness, giving the fibre a wool-like appearance. Woollenised jute is used for cheaper rugs and, blended with cotton, for decorative cloths, curtains and upholstery.

The woody central core is of medium durability under exposed conditions. The fibres in the central core are 0.5–0.8 mm long and 29–42 μm wide.

The seeds of *C. capsularis* and *C. olitorius* are poisonous to mammals and insects. They contain cardiac glycosides (often based on strophanthidin (corchorin) and digitoxigenin), which have digitalis-like effects on the heart. In an experiment, a methanolic extract of *C. olitorius* seed and its glycoside fraction were toxic when administered intraperitoneally, but showed little acute toxicity when administered orally. The leaves of *C. capsularis* have a bitter taste due to the presence of glycosides, though non-bitter cultivars exist. The leaves of *C. olitorius* contain only very small amounts of glycosides and are not bitter. The leaves of *C. olitorius* have shown antioxidative properties, and various antioxidative phenolic compounds have been isolated from them. Jute seeds contain 14–18% oil, with the major compo-

nents being linolenic acid (41–43% for *C. capsularis* and 62–66% for *C. olitorius*), oleic acid (29–37% and 9–13%) and palmitic acid (12% and 16–24%).
The 1000-seed weight (6–8% moisture content) is 3.3 g for *C. capsularis* and 2 g for *C. olitorius*.

Adulterations and substitutes The fibres of kenaf (*Hibiscus cannabinus* L.) and roselle (*H. sabdarrifa* L.) are coarser and cheaper than jute. They are acceptable substitutes for jute in the manufacture of coarse packaging fabrics, but a mixture of jute with either of these fibres sold as pure jute is considered an adulteration. Other bast fibres which can serve as substitutes for jute include those from *Abroma augusta* (L.) L.f., *Helicteres isora* L., *Malachra capitata* (L.) L. and *Urena lobata* L. Since the second half of the 20th Century jute has faced substitution as sack making material by synthetic fibres such as polypropylene.

Description Annual herbs or perennial shrubs, often with simple or stellate hairs. Taproot up to 60 cm deep with many lateral roots, adventitious roots on lowest stem section. Stem slender, cylindrical, 0.7–3.6 cm diameter at base, light to dark green or dark red, in cultivation unbranched in vegetative stage, branched near the top on flowering plants. Leaves alternate or spirally arranged, herbaceous; stipules small, caducous; blade simple, serrate to dentate, one or two lowest teeth often enlarged. Inflorescence a lateral or leaf-opposed, 1-several-flowered umbellate or racemose cyme; flowers bisexual; sepals 4–5, free, sometimes hooded at apex, often apiculate or caudate at apex; petals 4–5, yellow, usually shortly unguiculate; androgynophore usually present, at apex with a fleshy, annular to cup-like disk; stamens 4 to numerous, free, filaments terete, anthers dorsifixed; ovary 2–10-locular; ovules 2–many per loculus; style terete, stigma minutely lobed or toothed, fimbriate. Fruit a capsule, 2–10-valved, cylindrical to subglobose, with several seeds per loculus. Seedling with epigeal germination.

– *C. capsularis*. An erect herbaceous annual, 1–2.5 m tall (up to 4 m in cultivation), base often becoming woody, branching near the top with glabrous, terete branchlets. Leaves with linear-ovate stipules 0.5–1 cm long; petiole 0.5–3 cm long, pubescent above; blade narrowly ovate to elliptical, 5–14 cm × 1–6 cm, base rounded, margin serrate with 2 lower teeth prolonged into fine pointed auricles up to 1 cm long, apex acuminate, glabrous above, minutely papillose below. Inflorescence lateral, solitary at nodes, 2–3-flowered; peduncle 1–2 mm long; pedicel 0.5–1.5 mm long, erect in fruit; sepals 5, linear-obovate, 3–4 mm × 1–1.5 mm, hooded, apex apiculate; petals 5, obovate, 4–4.5 mm × 2.5 mm, claw 1 mm long; androgynophore 0.1 mm long, annulus 0.5 mm long, crenate; stamens 20–25, filaments 2.5–3 mm long; ovary obovoid, 10-celled with 10 ovules per cell; style 1–1.5 mm long, stigma 5-toothed. Fruit depressed globose, 1–1.5 cm in diameter, longitudinally sulcate, coarsely verrucose, 10-valvate, with 35–50 seeds. Seed rhomboid to obovoid, about 2–3 mm long, dark brown.

Corchorus olitorius L. – 1, flowering and fruiting branch; 2, base of leaf; 3, flower; 4, seeds.

– *C. olitorius*. An erect herbaceous annual, 1–2.5 m tall (when grown as a fibre plant taller than *C. capsularis*, when grown as a vegetable a well-branched herb up to about 30 cm tall), base often becoming woody, branching near the top with glabrous, somewhat angular or sulcate branchlets. Leaves with setaceous stipules 7–12 mm long; petiole 0.5–6 cm long, pubescent above; blade narrowly ovate to obovate, 3–12 cm × 1–5 cm, base rounded, margin serrate with 2 lower teeth prolonged into fine pointed auricles up to

1.5 cm long, apex acuminate, glabrous or with short simple hairs below. Inflorescence leaf-opposed, solitary at the nodes, 1–3-flowered; peduncle up to 1 mm long; pedicel 2 mm long, erect in fruit; sepals 5, linear-obovate, 6–8 mm × 2 mm, apex with 1 mm long point, glabrous outside, pubescent inside near base; petals 5, narrowly obovate, 6–7 mm × 2 mm, claw 1 mm long, finely ciliate at margin; androgynophore up to 0.5 mm long, annulus 0.2 mm long; stamens 30–50, filaments 3–4 mm long; ovary cylindrical, 3–3.5 mm long, 5–6-sulcate, covered with small stiff ascending hairs, 5–6-celled with 36–42 ovules per cell, style 1–2 mm long, stigma lobed. Fruit somewhat appressed to stem, cylindrical, 3–8 cm × 3–6 mm, straight, longitudinally 10–12-ribbed, glabrous, 5–6-valved, apex undivided-acuminate 5–10 mm long, with 130–200 seeds. Seed rhomboid, about 1–2 mm long, somewhat rugose, bluish green to black.

Growth and development Mature jute seeds have no dormancy. In warm and moist soil the radicle emerges from the seed within 24 hours after sowing and a plumule with cotyledons surfaces within 5–7 days. Initial growth is rather slow and 30-day-old seedlings are only 35–45 cm tall (dry weight of 3 g per plant). Subsequent growth accelerates considerably: to an average height of 150 cm at 60 days and, for cultivars with medium-late crop duration, 290–300 cm (dry weight of 75 g per plant) at 120 days, when these cultivars start flowering. *C. olitorius* generally shows higher growth rates than *C. capsularis*. In both species the duration from sowing to flowering may vary from 82–97 days (early cultivars), 102–109 days (medium cultivars), 124–128 days (late cultivars) to 148–154 days (very late cultivars). Most nodes on the main stem carry axillary buds, but close spacing in cultivation promotes straight vertical growth without lateral branching during the vegetative phase. Forking of the apex into 2 or more branches marks the transition to the reproductive phase. Subsequently, a number of axillary buds below and above the point of forking may sprout into laterals. Inflorescences are borne mainly on the terminal part of the main stem and upper laterals. Flushes of flowering usually last 4–6 weeks in *C. capsularis* and may last up to 10 weeks in *C. olitorius*. In *C. capsularis* anthesis starts 1–2 hours after sunrise and natural cross-pollination is usually less than 5%. Anthesis in *C. olitorius* starts 1 hour before sunrise and outcrossing may be 12% or higher due to larger flowers which remain open over a longer period of time. Cross-pollination is mainly by bees and other insects. Seeds mature within 6 weeks after anthesis. During the reproductive phase the leaves on the main stem turn yellow and abscise, leaving only some smaller green leaves on the upper part of the plant. When most seeds are mature the plant dries up and dies, some 200–220 days after sowing for a standard jute crop in India or Bangladesh.

In Java wild plants of both species flower year-round. In Thailand wild *C. olitorius* flowers and fruits from August to December.

Other botanical information Confusion exists about the number and delimitation of species in *Corchorus*, and a worldwide taxonomic revision is needed. It is the only genus with herbaceous representatives in *Tiliaceae*. Numerous cultivars exist of the 2 species treated here, mostly differing in agriculturally important characteristics. In *C. olitorius* 2 major cultivar groups can be distinguished: one group of cultivars is grown particularly for their use as a vegetable, the other group for their use as a fibre plant. Although *C. capsularis* and *C. olitorius* resemble each other closely, they can be distinguished easily by their fruits, which are subglobose in the former and cylindrical in the latter.

So far, 21 *Corchorus* spp. have been confirmed as diploids with $2n = 14$ chromosomes, similar to the two cultivated species. A few tetraploids are known, such as *C. junodii* N.E. Brown from Mozambique. Strong crossing barriers between species prevent introgression from wild to cultivated species. Artificially (colchicine) induced tetraploids in cultivated *Corchorus* species always have lower fibre yields than diploid cultivars.

Anthocyanin pigmentation of the stem and leaves is controlled by 3 major genes: C–c, pigmented versus green; an allelomorphic gene, Ad–Ar–An–A–a, determining the intensity of pigmentation; and a pigment-reducing factor R–r (reducing versus non-reducing). Stem pigmentation is an important characteristic used to distinguish among cultivars. One major gene determines the bitter taste of leaves: Br–br (bitter versus non-bitter). The non-branching characteristic in a *C. capsularis* cultivar of Sudanese origin is controlled by the recessive allele of gene Br–br. Unfortunately, non-branching appears to be linked to disease susceptibility.

Ecology Jute is mainly grown between 16°N and 27°N, during the hot wet summer season. The daily temperature range for optimum growth is 22–34°C. Growth is retarded at temperatures below 17°C and above 42°C. The annual rainfall should be 1000–2000 mm, with 150 mm of pre-monsoon showers at sowing time in March-April, followed by a relatively dry period with a few light showers in May, and subsequently by the main monsoon rains (June-September). Young *C. capsularis* seedlings can withstand drought better, whereas *C. olitorius* is more tolerant of drought in advanced stages of development. All young jute plants are sensitive to waterlogging, but large *C. capsularis* plants are tolerant of temporary inundation. A relative humidity of 65–90% is most beneficial for the crop. Jute is a short-day plant, with a prolonged vegetative phase where photoperiods are longer than 12–12.5 hours, but the degree of photoperiod sensitivity differs between cultivars and photoperiod-insensitive mutants of both *C. capsularis* and *C. olitorius* have been developed. Flowering is induced within 15–20 days in response to short daylengths after the middle of August.

Jute can be grown on a range of soils from clays to sandy loams provided they are deep, free-draining, fertile and with a pH between 5 and 8.6 (optimum pH 6.6–7). Jute, more in particular *C. capsularis*, is tolerant of fairly saline soils (maximum 1% salt content). Sandy soils increase the risk of wilting of young crops in the case of late starting monsoon rains. Most *C. capsularis* is grown on soils of alluvial origin, especially those of river banks that are inundated every year and enriched by deposits of silt, while *C. olitorius* is generally planted on upland soils.

In South-East Asia *C. capsularis* grows wild in open grassland, waste places, arable land and along watercourses up to 300 m altitude. *C. olitorius* is found as a weed in settled areas, for instance on fallow or waste fields, grassland, open spaces and paddy fields, up to 300 m altitude.

Propagation and planting Jute is propagated by seed. Vegetative propagation by terminal cuttings is possible and sometimes applied to obtain seed of selected plants or to produce breeder seed of new cultivars. Jute seed is hygroscopic and germination may be poor after six months of storage under humid conditions. However, seeds properly dried after harvesting (6–8% moisture content) and stored in airtight containers will retain high viability (more than 80% germination) for 2–3 years even at ambient temperatures of 24–30°C.

Jute is sown directly in the field. In the main jute belt of India and Bangladesh this is done during March–April. In Cambodia *C. capsularis* is sown either in May, as a wet season crop, or in February, as an irrigated dry season crop. In the Philippines it is recommended that jute be sown in April–June. The small jute seeds require a fine seed-bed, which is achieved by repeated ploughing and cross-ploughing followed by laddering (harrowing with a log of wood or bamboo ladder weighted down by the cultivator standing on it) to pulverize and level the soil and also to remove weeds. The first round of ploughing should break up the soil to a depth of at least 40 cm, as jute is a rather deep rooter. Organic manure (composted domestic refuse or water hyacinth, cow dung, rapeseed or castor cake) may be ploughed in when available. Manuring is not needed when jute is grown after a potato crop (residual soil fertility of the previous crop) or in fields which are silted annually by floods. Most jute crops are still sown by broadcasting at seed rates of 7–13 kg/ha for *C. capsularis* and 4–9 kg/ha for *C. olitorius*. Seeds are often mixed with sand to ensure a more even distribution. Immediately after sowing, the seed is covered with soil to a depth of 2–3 cm by harrowing and laddering. Broadcast seeded plots require thinning to a final density of 330 000–440 000 plants per ha. Row planting (30 cm between and 7–8 cm within row spacing) has many advantages: 50% lower seed rates, fewer rounds of thinning and weeding, opportunities to reduce costs by utilizing mechanical implements for sowing, thinning and weeding, more convenient harvesting and generally higher fibre yields. However, it is still not widely practised by South Asian jute growers.

Seeds can be produced on plants left in a corner of the field after harvesting the main crop. However, seed yield and quality are generally low and the longer growth duration interferes with subsequent cropping. Therefore, most jute seed is produced in special plots sown in April or in September on uplands to avoid flooding. Late sowing is becoming general practice because the short days of October induce profuse branching and flowering in the young jute plants, resulting in higher seed yields. Seed quality is also better, because harvesting takes place during the cool dry winter season.

In vitro propagation of jute is possible: multiple plants have been regenerated from cotyledons and shoot tips of both *C. capsularis* and *C. olitorius*.

Husbandry The traditional method of broadcast sowing at high seed rates results in a quick coverage of the soil by a thick stand of young jute plants, provided seed viability is adequate. This suppresses weed growth and also avoids the risk of insufficient crop density after high plant mortality due to failing pre-monsoon showers. Jute grown in this way requires 3–5 rounds of thinning and weeding during the first 2.5 months, which is mostly a manual operation involving about 80–100 man days per ha and accounts for about one-third of the total costs of fibre production.

Nutrient requirements depend on initial soil fertility and yield levels. Responses in fibre yield of 30–200% to N fertilizer applications (25–70 kg N/ha) have been found, without substantial responses to other nutrient applications. However, the uptake per ha of a *C. capsularis* crop, based on 34 t/ha green plants and 2 t retted fibre, is considerable for all major nutrients: on average 63 kg N, 14 kg P, 132 kg K, 71 kg Ca and 26 kg Mg. The lack of response to other nutrients than N is explained by the fact that most soils in the jute belt of India and Bangladesh are deficient in N but high in P, K and other major nutrients. Very few smallholders have the financial means to apply inorganic fertilizers to their jute plots. In seed production it is more common to apply N, P and K fertilizers, as increases in seed yield are generally significant for all three nutrients and the economic value of jute seed is high.

Jute is basically a rainfed crop, but supplementary irrigation during the early stages of crop development can improve fibre yield considerably.

Diseases and pests The fungus *Macrophomina phaseolina* is the principal pathogen in both jute species, causing seedling blight, collar rot and stem rot, whereas its sclerotial stage (*Rhizoctonia bataticola*) causes root rot. Hooghly wilt in India may result in crop losses of up to 40% by the combined action of *Rhizoctonia bataticola*, *Fusarium solani*, the bacterium *Ralstonia solanacearum* and the nematode *Meloidogyne incognita*. Methods of control include seed treatment, crop rotation, avoiding acid soils (pH < 6.6) and excessive N applications, and the use of less susceptible cultivars. Other major diseases are anthracnose (*Colletotrichum corchori* on *C. capsularis* and *Colletotrichum gloeosporioides* on *C. olitorius*), soft rot (*Sclerotium rolfsii*, synonym: *Corticium rolfsii*), black band disease (*Botryodiplodia theobromae*). Diseases of minor importance include leaf spot (*Cercospora*, *Helminthosporium* and *Phyllosticta* spp.), tip blight (*Curvularia subulata*), stem gall (*Physoderma corchori*), mildew (*Oidium* sp.) and a virus causing leaf chlorosis or mosaic (seed borne and transmitted by white fly, *Bemisia* sp.).

Root-knot nematodes (*Meloidogyne incognita* and *M. javanica*), sometimes with secondary infection by *Macrophomina phaseolina*, can cause severe damage to jute crops. Methods of control include deep ploughing, removal of plant debris, proper drainage, avoidance of cropping sequences involving alternate hosts of the nematodes and the use of less susceptible cultivars.

About 40 insect species attack jute in India and Bangladesh, causing considerable yield losses and often adversely affecting fibre quality. The main insect pests are the jute apion or jute stem weevil (*Apion corchori*), the jute hairy caterpillar (*Spilosoma obliqua*), the jute semilooper (*Anomis sabulifera*), the indigo caterpillar (*Spodoptera exigua*) and the mole cricket (*Brachytrypus axhanitus*, synonym: *B. portentosus*). The indigo caterpillar is an important pest mainly of young seedlings. Mealybugs (*Pseudococcus virgalatus*) may attack *C. olitorius* particularly late in the growing season. Parasitization can be an important factor in natural control of the above-mentioned insect pests, particularly in the case of the jute apion and semilooper. This calls for judicious application of insecticides. The hairy caterpillar can be effectively controlled by hand picking. An old but effective method of natural control of the semilooper is the erection of perches in the jute field to attract predatory birds. Mites can be a problem during dry weather. *C. olitorius* is more susceptible to yellow mite (*Hemitarsonemus latus*, synonym: *Polyphagotarsonemus latus*), whereas the red mite (*Oligonichus coffeae*) occurs only on *C. capsularis*.

Harvesting Jute is generally harvested between 100 and 120 days after sowing when most plants are flowering. Earlier harvesting will result in lower yields of immature, finer fibres, whereas later harvesting will produce higher yields of coarse low-quality fibre that requires longer retting. Jute is normally harvested by hand with a sickle, being cut at the base of the stem very close to the soil surface. Thick- and thin-stemmed plants are usually sorted into separate groups (for uniform retting) before stacking them vertically for 2–3 days in the field to induce defoliation and desiccation. After shaking off all remaining leaves the stems or 'reeds' are tied with bark strips into bundles 15–20 cm in diameter. The leaf-shedding operation is not possible if the crop is harvested on flooded land. In that case, the leaves are stripped off directly after harvest.

Yield The world average jute yield is about 1.9 t of raw fibre per ha. National averages are 1.8 t/ha for Bangladesh, 2.0 t/ha for India and 2.2 t/ha for China. Yields of 3.0–5.0 t/ha have been obtained in field experiments in Bangladesh with improved cultivars grown under optimal agronomic conditions. The estimated dry fibre yield in Cambodia is 1 t/ha. In Borneo in the 1940s and in Peninsular Malaysia in the 1950s fibre yields of 0.8–1.1 t/ha were obtained with *C. capsularis* cv. Segama. In experiments in Java and Sumatra fibre yields up to 2.3 t/ha have been obtained. Seed yields vary from 100–250 kg/ha in early sown to 400–1200 kg/ha in late sown multiplication blocks. Potential fibre and seed yields are generally higher for *C. olitorius* than for *C. capsularis* cultivars.

Handling after harvest Jute stems are retted in water for a period of (8–)15–20(–30) days to free the fibres from the surrounding bark tissues by enzymatic action associated with microorganisms. The length of the retting period is of critical importance: if it is too short, the fibre is difficult to remove and clean; if it is too long, the fibres are damaged and of lower quality. Retting of both species is most rapid at a water temperature of 34°C, but the resulting fibre is harsher and less bright than when retted at lower temperatures. Rafts (India: 'jak') consisting of 2–3 layers of stem bundles are steeped in the shallow water of canals, ditches or ponds. Slowly moving water helps to remove the acidic and dark-coloured degradation products and produces the best quality fibre. When retting is complete, the fibres are stripped manually from the stems and washed in clean water to remove all remaining gum, decomposed plant tissues and dirt. The clean fibres are then dried in the sun over bamboo racks for 3–5 days. The quality of jute fibre is to a large extent determined by correct retting, cleaning and drying. Ribbon retting, whereby the bark is stripped from freshly harvested stems by manual or machine decorticators and only the ribbons steeped in water, requires less water and reduces the retting time by half. It is a method that has generally been used in China and it is gradually being introduced in India and Bangladesh, particularly in areas with chronic water shortage during the retting season. The dried fibres are transported in crude bales to local centres for initial grading and packing into low compression 'kutcha' bales of 60–150 kg before transportation to the jute spinning mills. Raw jute for export is carefully graded and cleaned (e.g. removal of coarse butt ends) before packing by hydraulic presses into compact 'pucca' bales with standard weight of 180 kg each. Grading systems vary among countries: Indonesia and Thailand have only 3–4 grades, whereas Bangladesh, India and Nepal have 6–8 grades each for *C. capsularis* and *C. olitorius*. The principal characteristics used in grading are length, strength, colour, lustre, cleanliness, uniformity and the percentage of 'roots' (bark fibres from the basal part of the stem).

In almost all jute-producing countries a part of the jute harvest is not retted, but ribboned, scraped with a knife and dried. The resulting ribbons are used as tying twine or as raw material for the production of yarns and rope.

Pulping of waste material such as burlap pieces and old bags is primarily done with chemical processes such as the soda process. Retted fibre can be satisfactorily pulped with the refiner mechanical pulping (RMP) process; treatment with the white rot fungus *Ceriporiopsis subvermispora* prior to refining results in considerable energy savings and increased strength properties. Unretted bast fibre has been experimentally pulped using the neutral sulphite-anthraquinone (NS-AQ) process, but yields were low and the input of chemicals high, compared to the pulping of retted fibre. The central cores can be pulped with various chemical and chemi-mechanical processes. Pulping experiments with whole stems showed that the soda-amine process (soda process with amines as additives) gave higher yields and better physical properties than the soda and kraft processes.

Genetic resources Early efforts to collect, conserve and characterize local and exotic jute germplasm were initiated in Dhaka in 1904. The genebank of the Bangladesh Jute Research Institute (BJRI) in Dhaka was given the mandate of world repository for germplasm of jute and allied fibres by the International Jute Organization (IJO) in 1987. Since that time the total collection has been extended from 2100 to almost 6000 accessions at the present time, through various germplasm collection projects in Asia and East Africa. These include old and new cultivars, landraces, induced mutants, genetic and cytogenetic stock, and wild species. Some 2370 accessions represent *C. capsularis*, 1440 accessions represent *C. olitorius*, and 2190 accessions are of the allied fibre plants kenaf and roselle. A duplicate set of seed samples for all accessions is stored at the Commonwealth Scientific Industrial Research Organization (CSIRO) in Canberra, Australia. Jute research centres in India, China, Nepal, Thailand, Indonesia and other jute-producing countries have unrestricted access to genetic resources present in the genebank of the BJRI. The Central Research Institute for Jute and Allied Fibres (CRIJAF) in Barakpur (India) maintains a collection of more than 2300 jute accessions.

Breeding Selection and breeding methods common to self-pollinated crops have been applied to jute. Most cultivars are the result of line selection within landraces and cultivars, or of intervarietal crossing within the same species. *C. capsularis* and *C. olitorius* are complementary in a number of agronomic characteristics. The first successful interspecific crosses between *C. capsularis* and *C. olitorius* were realized in 1960, but breeding programmes based on hybridization between the two species have not yet produced superior cultivars. Jute selection with the objectives of higher yields and finer fibre quality was started in Dhaka in 1904 by the Department of Agriculture of (British) India. Cultivars developed by this programme include *C. capsularis* cv. D154 (selected from the earlier 'Kakya Bombai') and *C. olitorius* cv. Chinsurah Green, both released around 1919 and the main cultivars grown until 1952. After 1947 jute breeding activities continued at two locations: the BJRI (formerly Jute Agricultural Research Laboratories) at Dhaka and the Jute Agricultural Research Institute (JARI) at Barakpur in India. In addition to yield, fibre quality and disease resistance, early crop maturity and low photosensitivity (i.e. no premature flowering in early sowings) became important objectives of crop improvement, in order to fit jute into more intensive crop rotation schemes. Early sowing of jute in February (day-length less than 12 hours) will allow 3 crops per year, e.g. first jute, then rice and finally pulses or rapeseed. Examples of improved *C. capsularis* cultivars are 'CVE-1' (released in 1977), 'CC-45' (1979), 'BJC-83' and 'BJC-7370' (both 1995) in Bangladesh, and 'JRC-212' (1951), 'JRC-321' (1952) and 'JRC-7447' (1967) in India. Examples of successful *C. olitorius* cultivars are 'O-9897' (released in 1987) and 'OM-1' (1995) in Bangladesh, and 'JRO-632' (1952), 'JRO-7835' (1971) and 'JRO-878' (1980) in India. The cultivars grown in China, Burma (Myanmar), Thailand, Indonesia and other countries are mostly derived from introductions from India.

Prospects Under pressure from food and other crops, jute cultivation is being pushed onto marginal land in almost all jute-producing countries. It is also finding strong competition from synthetic fibres in packaging materials and from the fact that agricultural commodities are increasingly shipped in bulk or in large containers. Nevertheless, jute fibres are a biodegradable and environment-friendly raw material suitable for many applications in various fabrics, semi-rigid and laminated sheets for packaging and panelling, as well as for the manufacturing of geotextiles. The biomass of jute plants can also be processed into pulp for the paper industry. The market for jute fibre could well expand in the future under the influence of growing concerns about environmental pollution and dwindling forest resources. Strategies in jute research and development will require further adjustment to include such targets as improved tolerance to suboptimal growing conditions and suitability of the plant and fibre to product diversification. Even with less photoperiod-sensitive cultivars the prospects for jute in South-East Asia are limited to production for local and national use, e.g. to substitute for imports in Thailand and Indonesia. It seems impossible for South-East Asia to compete in export markets, in view of the excellent ecological conditions for jute cultivation and the availability of inexpensive labour in Bangladesh and India.

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Corypha utan Lamk

Encycl. 2: 131 (1786).

PALMAE

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Synonyms *Corypha gembanga* (Blume) Blume (1825), *C. elata* Roxburgh (1832), *C. gebanga* Blume (1836).

Vernacular names Gebang palm, buri palm, agel palm (En). Indonesia: gebang, gewang, lontar utan (general). Malaysia: gebang, ibus. Philippines: buri (Bikol, Bisaya, Pampango, Tagalog), silag (Ilokano, Pangasinan), buli (Bisaya, Tagalog). Thailand: lan, lan-phru (southern).

Origin and geographic distribution *C. utan* occurs wild and cultivated from India (Assam, Andaman Islands), Sri Lanka and Bangladesh through South-East Asia to tropical Australia.

Uses Adult leaves of *C. utan* are used for thatching and house-walls and for making articles such as raincoats, umbrellas and coarse mats (e.g. 'kajang' mats in Indonesia). In Timor (Indonesia) they are used to make a traditional musical instrument ('sasando'). Midribs of adult leaves are made into hard brooms and fish-traps. The petiole is cut into strips to be used as weaving material or its fibre ('buntal fibre' in the Philippines) is extracted. In the Philippines this fibre is mainly utilized for the manufacture of the fine 'Baliuag' and 'Lucban' hats, which have been exported from the Philippines as 'Bangkok hats'. It is also made into other utility items, such as bags and placemats, cordage and soft brooms, and can be pulped for specialty paper.

Strips from unopened leaves ('buri strips' in the Philippines) are used for weaving: coarser strips are made into sacks, sails and coarse mats for packing, whereas finer strips are made into low grade hats, baskets and fine mats. The upper epidermis of unopened leaves yields an important fibre ('raffia' or 'buri raffia' in the Philippines; 'agel' in Indonesia) which is made into mats, hats, bags, sails, placemats, folders, shoes and slippers, woven on looms into fabrics ('saguran' cloth in the Philippines) and also serves as tying, wrapping and decor material and for fishing nets. Another product, called 'papas' in Sulawesi (Indonesia), is made from still younger unopened leaves, not longer than 0.5 m. It is used for tying and made into strong cordage and fishing nets. Fibres from the midribs of unopened leaves are woven into the durable 'Calasiao' or 'Pototan' hats and into items such as baskets, trays and cigarette cases. Entire ribs are sometimes made into coarse brooms. They are also used, after soaking in water to make them more pliable, to stitch thatch shingles.

In the Philippines the midribs of young leaves are made into 'buri furniture', which is a very important application of *C. utan*. The hard outer portion of the trunk has also been found suitable for furniture making. The trunk is used for roofs, flooring, panelling and stairs. In Indonesia the trunk is made into drums. Juice can be tapped from the palm tops or from the inflorescence. The juice is sweet and may be turned into palm wine ('tuba' in the Philippines), sugar, alcohol or vinegar. Sago is obtained from the trunk as the palm approaches the flowering stage. The reddish starch is easily digestible, but it is only consumed by people in times of food scarcity. It is also used as livestock feed. The terminal bud is eaten as a vegetable ('palm cabbage'). The young fruits are edible, but nearly-ripe fruits are toxic and used as fish poison. Young seeds are made into a sweetmeat by boiling in syrup. Ripe seeds, hard as ivory and black, are used to make buttons, necklaces and rosary beads.

In traditional medicine, a decoction of the roots serves in Indonesia against diarrhoea and the roots are chewed to treat cough. The sago is taken against intestinal complaints. The red-brown gum oozing from the apex of the palm is used against cough, dysentery, and is applied to wounds. In the Philippines a decoction of young plants is taken against feverish colds. *C. utan* is also grown as an ornamental.

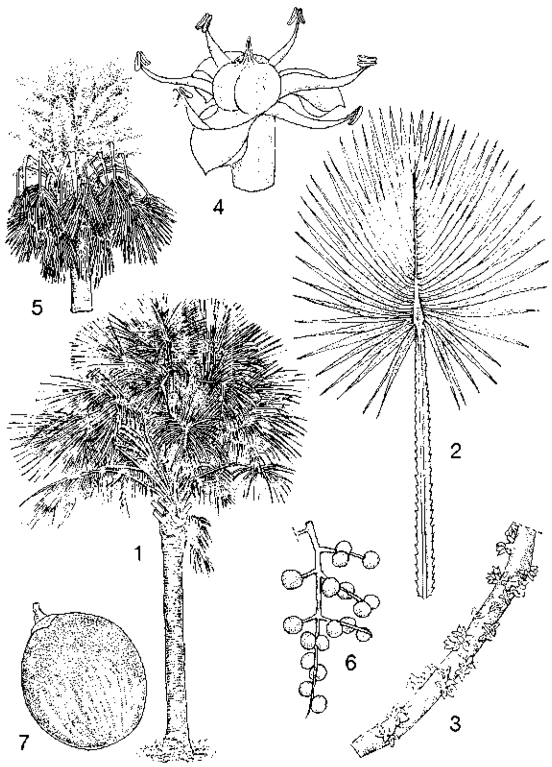
Production and international trade In the Philippines *C. utan* is considered the third most important palm after coconut (*Cocos nucifera* L.) and nipa palm (*Nypa fruticans* Wurmb). The production of raffia fibre from *C. utan* in the Philippines in 1996–2000 averaged 98 t per year, mainly from Aklan (Panay; 69 t/year), Quezon (southern Tagalog; 13 t/year) and Bohol (12 t/year). The average buntal fibre production in the same period was only 8 t per year, mainly from Quezon (5 t/year), Marinduque (2 t/year) and Palawan (1 t/year).

The average annual raw raffia and buntal fibre exports from the Philippines in 1996–2000 were 26 t and 0.4 t, respectively, with an average annual export value of US$ 81 000 and US$ 3200, respectively. Raffia fibre was exported to a number of countries including the United States and Hong Kong and buntal fibre only to Japan and Hong Kong. The export earnings from manufactured products decreased from around US$ 1.5 million per year in the early 1990s to only about US$ 400 000 per year in 1999 and 2000. The average export earnings from manufactured products in 1996–2000 were US$ 820 000 per year, mainly from buri hats (240 000 pieces; value US$ 407 000), raffia hats (69 000; US$ 219 000), buri placemats (211 000; US$ 112 000) and buntal hats (48 000; US$ 79 000). The main export markets for these manufactured products are the United States, Japan, the European Union and Australia. Furniture made from the midribs of the leaflets is also exported from the Philippines. Elsewhere the products of *C. utan* are usually traded only locally and no production or trade statistics are available for countries other than the Philippines.

Properties The ultimate fibre cells of buntal fibre obtained from the petioles of *C. utan* are (1.5–)2.1(–2.7) mm long and (13–)24(–39) μm in diameter, with a lumen width of (3–)12(–24) μm and a cell-wall thickness of (4–)6(–9) μm. The Runkel ratio is (0.46–)1.08(–2.82). The recorded elongation at break ranges from 3–5%. No reliable information is available on the chemical composition of *C. utan* fibre. The fibre cells in the trunk are 1.2–2.3 mm long, with a diameter of 28–35 μm and a lumen width of 13–18 μm. Though adult leaves of *C. utan* are used for thatching, they are not very suitable for this purpose, because they do not last long and rapidly turn brittle.

Adulterations and substitutes In South-East Asia other multipurpose palms such as *Borassus flabellifer* L. and *Nypa fruticans* also yield material for weaving, thatch and palm wine.

Description A robust, solitary, one-stemmed, bisexual tree palm 10–30 m tall. Stem erect, columnar, 35–75 cm in diameter, unarmed, closely ringed with leaf scars. Leaves crowded, forming a large crown, withering early, tending to abscise under their own weight; petiole robust, 2–5(–7) m long, deeply furrowed, margins sharply toothed; blade orbicular, costapalmate, 1.5–3.5 m in diameter, regularly divided to about half its radius into 80–100, single-fold, linear segments. Inflorescence a massive, terminal, much-branched, paniculate structure, 3–6 m long, final branches ending as rachillae bearing spirally arranged adnate cincinni of up to 10 flowers, the whole inflorescence bearing up to 10(–60) million flowers; flowers bisexual, calyx tubular, 3-lobed, about 1.5 mm long;



Corypha utan Lamk – 1, habit; 2, leaf; 3, part of flowering branch; 4, flower; 5, top part of fruiting tree; 6, part of fruiting branch; 7, fruit.

petals 3, boat-shaped, about 3 mm long, white, fragrant; stamens 6, about as long as corolla, with narrowly triangular filaments; pistil with 3-grooved, 3-celled ovary, short style and 3-dentate stigma. Fruit a berry-like drupe, subglobose, 2–3.5 cm in diameter, olive-green, pericarp fleshy, endocarp membranous, on a stalk 3–5 mm long. Seed globose, 1–1.5 cm in diameter, hard, with remote-tubular germination.

Growth and development Fresh seed of *C. utan* germinates in 3–8 months. As with all *Corypha* spp., growth is very slow, particularly in the first 10 years. *C. utan* develops according to Holttum's architectural model, characterized by an unbranched axis and a terminal inflorescence. In contrast to most other palms but in common with *Eugeissona triste* Griff. and *Raphia* P. Beauv., flowering is hapaxanthic: upon flowering vegetative growth of the flowering stem ceases and the stem eventually dies. The vegetative period of *C. utan* lasts 25–30(–100) years, and the flowering and fruiting period is 1–2 years, during which time the stored sago is used up. During fruit development the leaves wither and after fruiting the palm dies. The inflorescence is the largest among seed plants. An individual palm studied in detail in southern Florida flowered after 44 years, during which time it had produced about 350 leaves and a trunk 19 m tall and 86 cm in diameter. The inflorescence was 4.5 m tall and carried an estimated 4–15 million flowers, which after 18 months had yielded 250 000–350 000 fruits.

Other botanical information *Corypha* L. consists of about 8 species, distributed from southern India and Sri Lanka through South-East Asia to southern China and northern Australia. The distribution has probably been greatly influenced by human cultivation activities. *Corypha* needs taxonomic clarification. In the Philippines 2 forms of *C. utan* are distinguished: 'limbahon', with red petioles, and 'lupisan' with whiter petioles.

C. lecomtei Beccari (synonym: *C. laevis* (Loureiro) A. Chev.), occurring in Thailand and Indo-China, and *C. umbraculifera* L. ('talipot palm'), only known from cultivation (mainly in Sri Lanka, India, Burma (Myanmar), Thailand and Indo-China) are or can be used much in the same way as *C. utan*. For centuries strips cut from the leaves of *C. umbraculifera* have been used, after processing and polishing, to write upon with iron styli, for instance in India and Thailand. These leaves usually served for permanent documents, whereas leaves of *Borassus* L. were used for ordinary documents only.

Ecology *Corypha* palms are mostly associated with human settlements. In the wild they are probably a feature of open seral communities such as alluvial plains or coastal forest, and they do not occur in climax tropical rain forest. *C. utan* commonly grows in lowland open locations, rarely above 400 m above sea level. In Java it is found in open locations, especially grasslands, up to 200 m altitude, but not along beaches or in mangroves. In Malaysia it is common in the open country in the north. Flowering seems to be induced by long dry periods.

Propagation and planting *C. utan* is propagated by seed or by seedlings collected from the ground. Seeds lose their viability quickly. The recommended planting distance in the Philippines is 5 m × 5 m, but it is usually planted around the house, not in plantations.

In vitro culture of excised embryos is possible on Murashige & Skoog (MS) medium. Callus production has been induced on MS medium containing 100 mg/l 2,4-dichlorophenoxyacetic acid (2,4-D) and 3 mg/l N6-(δ2-isopentyl)-adenine (2IP).

Husbandry In the Philippines, cultivated *C. utan* is mechanically weeded in early growth stages to avoid competition with weeds and ensure survival. Fertilizing is not usual, but NPK-fertilizers, organic fertilizers and green manure may occasionally be applied. The plants may be watered during early growth. Once established, the palms are left until the first leaves are ready for harvest.

Diseases and pests *C. utan* is a host of cadang-cadang, a devastating disease of coconut in the Philippines, especially in the Bicol region and adjacent provinces. It is caused by the cadang-cadang viroid (CCVD). Symptoms in *C. utan* include reduced frond size, stunting and yellowing of the leaves. Control methods are unknown, but the eradication of diseased palms and the sterilization of tools used on the palms may help to reduce the spread and incidence of the disease.

Harvesting It takes about 6–7 years from planting before the first leaves of *C. utan* can be harvested. To obtain buri material, the palm is climbed and unopened leaves are cut. It is recommended that at least 2 open leaves are left, if not, subsequent leaves open earlier and have shorter petioles and leaflets, and thus are of lower quality. For the production of buntal fibre, petioles of adult leaves are cut at their base and divided into base, middle and tip, to make grading and classification of the fibre easier. Each piece is 1–1.3 m long, the estimated maximum length needed for hat-making.

There are 2 ways of tapping juice. In the first, a deep hole is cut at the base of the emerging inflorescence and the juice which runs from it is collected. In the second, employed on non-flowering palms, the leaves above the prospective tapping point are stripped off the palm, the top is removed, the bare end of the trunk is bound with rattan and arrangements are made for collecting the juice. By repeatedly cutting fresh surfaces the juice is kept running. Sometimes a thatch is made to protect the cut from sun and rain. On average *C. utan* can be tapped for about 2–3 months, after which time the juice stops flowing, and the palm is abandoned to die. In the Philippines, sugar is made from the juice by boiling for 6 hours, after which the kettle is removed from the fire and the contents are stirred until the sugar granulates. To obtain sago, the trunks are cut, split, pounded, and the sago is extracted with the aid of water.

Yield The number of leaves which can be harvested from *C. utan* has been estimated at 8–12 per palm per year. Tapping yields of up to 4000 l juice per palm have been recorded for the Philippines. A single palm contains about 90 kg sago.

Handling after harvest To prepare 'agel' from *C. utan* in South Sulawesi the leaves are torn at the foldings, the ribs are removed and the remaining 2–3 cm wide strips are dried. During drying the shiny upper surface tends to separate from the lower surface. After the hard ends have been cut off, the upper and lower surfaces are separated, and the latter usually discarded. The upper surfaces are bundled and traded. Their value depends largely on the care exercised in preparing them. 'Papas' strips are prepared in a similar way, except that the upper and lower surfaces are separated without prior drying. The upper surface is immediately divided into strips 1–1.5 mm wide, which are soaked in fresh water for a night and placed in boiling water for a quarter of an hour the following day to keep them white. The strips are rolled between the fingers and subsequent drying leads to curling of the edges. In Java and Madura 'agel' is prepared in the same way as 'papas' in Sulawesi: the upper and lower surfaces are immediately separated. In Madura the weaker lower surface is used in weaving as weft. For the production of 'kajang' mats in Indonesia adult leaves are cut into strips in such a way that the ribs are in the middle of the strips. The strips are placed in double layers, with each strip in the upper layer covering halves of 2 different strips in the lower layer, and are sewn together. Two of these double layers are then placed over each other and sewn together.

In the Philippines buntal fibres are extracted from the petioles by hand-pulling or by retting. In the former case the fibrous material is pulled out from the base after the epidermis has been removed. Hand-pulled and retted buntal fibre have 4 grades each. Fibres from the midribs of unopened leaves are made into hats by removing the ribs, grading them to colour, splitting them, removing the soft interior and splitting the halves again once or twice. The resulting strands are smoothed and worked down to the required thickness, after which they are ready for weaving. In the Philippines raffia fibre is commercially traded in bleached and unbleached forms, each with 3 grades.

Genetic resources *C. utan* does not seem to be threatened with extinction. No germplasm collections or breeding programmes of *C. utan* are known to exist.

Prospects In view of the wide range of products obtained from *C. utan*, this palm will undoubtedly remain important as a local source of weaving material and fibres, thatch, palm wine, sago and construction material. Exports of *C. utan* fibre products from the Philippines, however, have declined strongly in the past decade, because the high price of the raw material has made these products uncompetitive. Improved design of existing products and the development of new applications (e.g. specialty papers from buntal fibre) and production technologies are considered necessary to reverse this trend.

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Curculigo Gaertn.

Fruct. sem. pl. 1: 63 (1788).
HYPOXIDACEAE
$x = 9$; *C. capitulata*, *C. latifolia*: $2n = 18$

Major species and synonyms
- *Curculigo capitulata* (Lour.) Kuntze, Rev. gen. pl. 1: 703 (1891), synonyms: *C. recurvata* Dryand. (1811), *Molineria capitulata* (Lour.) Herb. (1837), *Curculigo glabra* Merr. (1907).
- *Curculigo latifolia* Dryand., in Aiton, Hort. Kew., ed.2, 2: 253 (1811), synonyms: *C. sumatrana* Roxb. (1832), *Molineria latifolia* (Dryand.) Herb. ex Kurz (1864), *Curculigo villosa* Wall. ex Kurz (1869).

Vernacular names General: Vietnam: chi s[aa]m cau.
- *C. capitulata*: palm grass (En). Indonesia: bedur (Javanese), congkok (Sundanese), nyeyor-nyeyoran (Madurese). Malaysia: lumbah merah. Philippines: abang-abang (Bikol), atukgan (Igorot), tolábang (Ifugao). Thailand: tong kaai (northern).
- *C. latifolia*: Brunei: lemba. Indonesia: marasi (Sundanese), keliangau (Bangka), doyo (Kalimantan). Malaysia: lumbah, lembah, lumbah rimba. Thailand: chaa laan, ma phraao nok khum (northern), phraa nok (peninsular). Vietnam: s[aa]m cau l[as] r[ooj]ng.

Origin and geographic distribution *Curculigo* comprises about 20 species distributed in the tropics, but most species are also cultivated worldwide as ornamentals. In Malesia 5 species are indigenous. *C. capitulata* occurs from South Asia (India, Sri Lanka, Bangladesh, Nepal) through South-East Asia to Taiwan, Australia and the Pacific Islands (Solomon Islands, Hawaii). In Malesia it occurs in Peninsular Malaysia, Singapore, Indonesia (Sumatra, Java, Sulawesi, the Moluccas), the Philippines (Luzon, Negros, Biliran, Mindanao), New Guinea and Manus Island. *C. latifolia* occurs in India, Burma (Myanmar), Thailand, Malaysia (Perak, Pahang, Sarawak, Sabah), Indonesia (Sumatra, Bangka, Lingga, Java, Kalimantan) and the Philippines (Palawan, Balabac, Samar).

Uses In Borneo and Peninsular Malaysia the leaf fibres of *C. latifolia* are made into fishing nets. In Borneo, they are also used to make ropes, twines, sarongs, rice bags and garments. The cloth made from the fibre is known as 'lemba' cloth. The leaves of *C. latifolia* are rolled into strings. In Indonesia and Malaysia they also serve to wrap fruits, vegetables and other goods for transport. The uses of the leaves of *C. capitulata* in Indonesia are similar to those of *C. latifolia*. The hill people of Camarines in Luzon (the Philippines) make false hair from the leaf fibres of *C. capitulata*. In Ifugao (Luzon) children use *C. capitulata* for warp in toy looms. The Lahu of northern Thailand use the leaves of *C. capitulata* like banana leaves for wrapping.

The fruits of both *C. capitulata* and *C. latifolia* are edible. The fruits of *C. latifolia* taste like sweetened cucumber and increase the appetite. Though the fruits are not extremely sweet themselves, they produce a very sweet aftertaste when a drink is taken after eating the fruit. This also occurs when a sour substance is taken after the fruits, so native people eat the fruits to give a sweet taste to sour foods.

In Peninsular Malaysia infusions of the leaves, stem-tips and roots of *C. latifolia* are all used internally against fever. Decoctions of the flowers and roots are taken as a stomachic and diuretic, whereas rhizome decoctions serve to treat menorrhagia and are applied as a lotion against ophthalmia. The rhizomes are also used against eye diseases in north-eastern India. In Borneo the leaves of *C. latifolia* play a role in magical healing ceremonies. *C. latifolia*, *C. capitulata* and other *Curculigo* spp. are also grown as ornamental plants, e.g. in Indonesia, India, Africa, Europe and the United States.

Production and international trade *C. capitulata* and *C. latifolia* are used locally throughout South-East Asia, but no production or trade statistics are available.

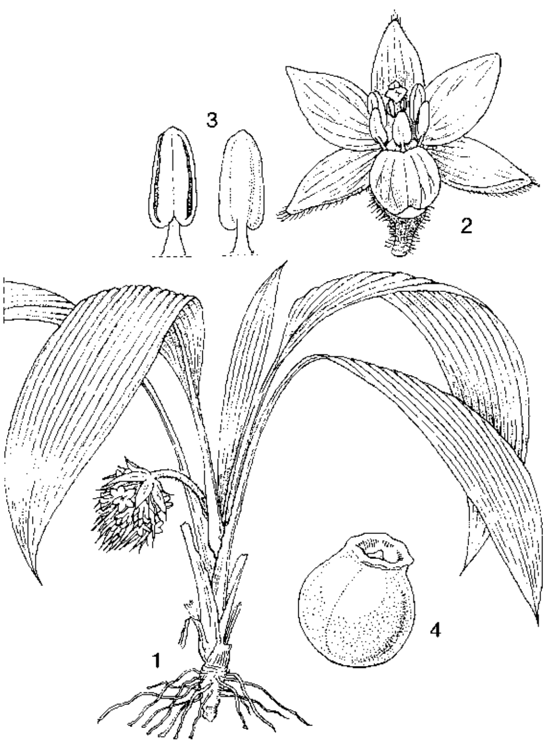
Properties The leaves of *C. latifolia* are tough, thin and broad, which makes them very suitable as wrappings. The fibres obtained from the leaves are relatively hard and, contrary to cotton fibres, very durable in a humid warm climate, which is probably due to their resistance to fungi. Garments made of these fibres by the Benuaq of Borneo cannot be torn and may last a lifetime. No published information is available on fibre dimensions or chemical composition.

The taste-modifying properties of the fruits of *C. latifolia* are due to the presence of the protein curculin. Curculin is a dimer of two identical polypeptides of 114 amino acid residues. It has a sweet taste which disappears rapidly. When taken after curculin, water tastes sweet, and sour substances likewise seem to taste sweet. For instance, a lemon eaten after taking curculin elicits a sweet taste lasting for about 10 minutes. Curculin starts to be synthesized in the fruit a week after pollination and its content increases rapidly (from 0.16 to 1.8%) between 3 and 4 weeks after pollination, shortly before the fruit ripens.

Adulterations and substitutes In Sarawak stronger and more durable strings are made from the bast of *Artocarpus elasticus* Reinw. ex Blume.

Description Perennial herbs, hairy or glabrous, with a thick rhizome. Leaves radical, often petiolate, linear to broadly elliptical. Inflorescence a raceme or spike, sometimes head-like, with few to many flowers; tepals united in a short to elongated tube; stamens 6, free, inserted at the mouth of the tube; pistil with 3-celled ovary, a short, columnar style, ending in 3 oblong stigmas. Fruit fleshy, berry-like, indehiscent or irregularly dehiscent, often with a persistent beak, with few seeds. Seed black, subglobose; testa striate; funicle usually dilated.

- *C. capitulata*. A hairy herb, up to 1.5 m tall. Petiole up to 1 m long; blade elliptical to broadly elliptical, 60–150 cm × 5–15 cm, nearly glabrous. Inflorescence a deflexed and head-like raceme, 2.5–7 cm × 2.5–7 cm; peduncle 7–30 cm long, tomentose to glabrescent at fruiting; bracts 1.5–5 cm long, brownish, villous to glabrescent at fruiting; flowers yellow, villous, subsessile; perianth-tube 1–2 mm long, lobes 6–8 mm long. Fruit globose to ovoid, 10–15 mm long, not beaked, whitish to green; pulp white, not very sweet.
- *C. latifolia*. A hairy herb, up to about 1 m tall. Petiole up to 1 m long; blade elliptical to broadly elliptical, 30–100 cm × 5–10 cm, subglabrous. Inflorescence ovoid to cylindrical, compact, 2–6 cm × 2–6 cm; peduncle 0–4(–10) cm long, glabrescent; bracts 1–6 cm long, green, glabrous or ciliate at margins; flowers subsessile, yellow, villous, subsessile; perianth tube 8–40 mm long, lobes 8–12 mm long. Fruit ovoid, 10–25 mm long, long-beaked, white to green; pulp sweet.



Curculigo capitulata (Lour.) Kuntze – 1, flowering plant; 2, flower; 3, stamen, ventral and dorsal view; 4, fruit.

Growth and development *C. latifolia* flowers throughout the year in South-East Asia. The fruits start to fall about 4 weeks after pollination.

Other botanical information *Curculigo* has been variously included in the *Amaryllidaceae* and the *Liliaceae*, but is nowadays usually considered as belonging to the comparatively small family *Hypoxidaceae*. The *Hypoxidaceae* differ from the *Amaryllidaceae* by their racemose or capitate, bracteate inflorescences; they never have the umbellate inflorescences with spathes found in the *Amaryllidaceae*. Within the *Hypoxidaceae* the genera *Curculigo* Gaertn. and *Molineria* Colla are closely related. Flora Malesiana considers both names as synonyms and maintains the oldest name *Curculigo*, and this view is followed here. Others distinguish the 2 genera as follows: *Molineria* are large plants with capitate inflorescences, anthers dorsifixed with introrse opening, seed with uneven contour and without expanded hilum and strophiole; *Curculigo* are smaller plants with 1-few-flowered inflorescences, anthers basifixed with latrorse opening, seed smooth and glossy with an expanded hilum and strophiole. If *Molineria* is accepted as a separate genus, the two species described here belong to it.

Based on the length of the perianth tube, *C. latifolia* has been subdivided into 2 varieties:

- var. *latifolia*. Perianth tube 8–15 mm long; occurring in forests at high altitudes in India, Burma (Myanmar), Thailand, Malaysia (Pahang, Sarawak, Sabah), Indonesia (Sumatra, Bangka, Lingga, Java, Kalimantan) and the Philippines (Palawan, Balabac, Samar).
- var. *megacarpa* (Ridley) Geerinck (synonym: *C. megacarpa* Ridley). Perianth tube 20–40 mm long; occurring in rain forests at high altitudes in Thailand, Malaysia (Sabah, Perak) and Indonesia (Java).

C. orchioides Gaertner is a well-known medicinal plant also occurring in South-East Asia.

Ecology *Curculigo* spp. are shade-loving plants, thriving under partly shaded or sunless conditions, with abundant water supply. In experiments in the open field, *C. latifolia* grew only very slowly and the leaves remained small. *Curculigo* prefers fertile, well-drained soils, rich in organic matter. In Java *C. capitulata* occurs in primary and secondary forest up to 2000 m altitude and *C. latifolia* in rain forest up to 1100 m altitude.

Propagation and planting *Curculigo* can be propagated by division, suckers or freshly sown ripe seed. *C. latifolia* produces numerous suckers, which can be removed and easily grown into new plants. The Benuaq of Borneo dig up the rhizomes, divide them and wrap the rhizome pieces with some earth in banana leaves held together with rattan. After sprouting, the plants are planted out near the house.

In vitro clonal propagation of *C. latifolia* is possible, with the best results being obtained with rhizome cultures. For this, 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). Survival of the potted-up plants was about 90%.

Husbandry *Curculigo* is easy to cultivate, but requires ample water supply and very good drainage. It responds well to mulching.

Harvesting When harvested for fibres in Borneo, the leaves of *C. latifolia* are simply cut off at ground level. The most suitable time to harvest fruits to obtain curculin is about 4 weeks after pollination, just before the fruits start to fall.

Yield No statistics are available on fibre and fruit yields of *Curculigo*.

Handling after harvest The fibre is extracted by scraping the leaves of *C. latifolia* carefully with a knife. Alternatively, the petiole and leaf tip are cut off and the leaves are soaked in water for some days, then the fibres are removed by scraping with a knife or a piece of bamboo and dried for several days. The Benuaq of Borneo submerge the leaves in water, pull out the veins from the leaves and wash the veins immediately. They are bundled, tied together and hung to dry in the sun. After some time, the bundled individual veins are split manually one by one, starting from the lower end. Each vein yields a large number of fine fibres, which are combed out manually and spun into thread which can be woven. Spinning is done by twisting several individual fibres together with the fingers. The thread is not longer than the original leaf veins, as the spinning of longer threads is unknown to the Benuaq. The bundled threads are coloured with plant dyes obtained from, for example, *Bixa orellana* L. (orange-red) and *Eusideroxylon zwageri* Teijsm. & Binnend. (black). The Ikat technique may be applied. Because of the limited length of the threads, only small pieces of cloth (25–50 cm long and wide) are woven, which are sewn together into garments ('ulap doyo'). The Kenyah in Sarawak plait the freshly picked leaves of *C. latifolia* into strings.

Genetic resources and breeding There are no known germplasm collections or breeding programmes of *C. capitulata* and *C. latifolia*.

Prospects The role of *Curculigo* as a source of fibre will probably remain limited to local uses. *C. latifolia* may gain importance as a source of curculin.

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M. Brink

Cyperus L.

Sp. pl.: 44 (1753); Gen. pl. ed. 5: 26 (1754).

CYPERACEAE

$x = 5, 8, 9, 11, 13, 19, 29$; *C. papyrus*: n = c. 50, $2n$ = c. 102; *C. procerus*: $n = 52$, $2n = 18, 64$

Major species and synonyms

- *Cyperus elatus* L., Cent. pl. 2: 301 (1756), synonyms: *C. racemosus* Retz. (1789), *C. scoparius* Decne (1834), *C. bispicatus* Steud. (1855).
- *Cyperus malaccensis* Lamk, Tabl. encycl. 1(1): 146 (1791), synonyms: *C. monophyllos* Vahl (1806), *C. spaniophyllus* Steud.(1855), *Chlorocyperus malaccensis* (Lamk) Palla (1912).
- *Cyperus papyrus* L., Sp. pl.: 47 (1753), synonyms: *Papyrus antiquorum* Willd. (1812), *P. domesticus* Poir. ex Cuvier (1825), *Chlorocyperus papyrus* (L.) Rikli (1895).
- *Cyperus procerus* Rottb., Descr. icon. rar. pl.: 29, t. 5, f. 3 (1773), synonyms: *C. ornatus* R. Br. (1810), *C. heynii* Boeck. (1868).

Vernacular names General: cyperus, nut grass, nut sedge (En).

- *C. elatus*: Indonesia: wlingi (Javanese), lilisungan (Sundanese), tintilohuangga (northern Sulawesi). Philippines: kobong-kobong (Bisaya). Vietnam: c[os]i m[af]o.
- *C. malaccensis*: Chinese mat grass (En). Indonesia: bundung (southern Kalimantan), darengdeng (Sundanese), pea-pea (Sulawesi). Malaysia: selimbu, menderong darat (Peninsular). Philippines: balangot (general), baga-as (Panay Bisaya), talaid (Bagobo). Thailand: yaa saam liam (Bangkok). Vietnam: c[os]i, c[aa]y c[os]i, l[as]c.
- *C. papyrus*: papyrus, paper reed, Egyptian paper plant (En). Thailand: kok eeyip (Bangkok).
- *C. procerus*: Indonesia: rumput adem (general). Malaysia: rumput mensiang. Thailand: kok ta krap (Bangkok), yaa ta krap (central).

Origin and geographic distribution *Cyperus* comprises about 600 species, of which the majority occur in the tropics and subtropics. Most of the about 80 species found in South-East Asia have a pantropical or palaeotropical distribution. *C. elatus* originated in Asia and is distributed from India to Indo-China, the Philippines and Indonesia. In South-East Asia it is common in Thailand, Cambodia, Vietnam, Peninsular Malaysia, Indonesia (Sumatra and Java), less common in the Lesser Sunda Islands, Borneo, Sulawesi and the Philippines, and absent in the Moluccas and New Guinea. *C. malaccensis*, originating in Asia, is distributed from Iraq through India to southern China, northern Australia and Polynesia and is common throughout South-East Asia. It is cultivated as a matting sedge in northern Sulawesi, the Sangir Islands, and in Brazil. *C. papyrus* originated in Central Africa and has spread over tropical Africa between 13°N and 26°S (including Madagascar). It has been cultivated in Egypt and neighbouring areas since ancient times and is sometimes naturalized in the Mediterranean area (Israel, Sicily). Nowadays it is rarely cultivated as a fibre plant, but it is widely grown as an ornamental, for instance in Java. The origin of *C. procerus* is unknown. It is distributed from India, Sri Lanka and Nepal through South-East Asia to eastern China, Taiwan and Australia (Queensland). In Malesia it occurs in Peninsular Malaysia, Java, Borneo, the lesser Sunda Islands and the Philippines (Luzon), but it is not common.

Uses The stems of *C. elatus* serve in Indonesia for weaving hats (Java) and mats (Sulawesi). The stems of *C. malaccensis* are often and widely used in South-East Asia for tying and for weaving mats, baskets and hats. In some towns on Luzon (the Philippines) slippers are made from them. In Central Java (Indonesia) the stems are plaited into ropes by fishermen to attract young fish, which are caught and placed in fishponds. In India *C. malaccensis* is used for weaving mats, hats and baskets; it is also woven into mats in China and Taiwan. The tough stems of *C. procerus* are split into three to serve as string or binder twine, e.g. in Java.

The pith of the stem of *C. papyrus* was used by early civilizations (Egyptians, Greeks, Romans) to make a primitive form of paper, and the plant was cultivated for this purpose in the Egyptian Nile delta, Palestine and southern Europe. It was already in use by 3500 BC and fragments of papyrus sheets dated at 4600 years old have been found. The fibrous outer parts of the stem were used in ancient Egypt for making ropes, baskets, nets, sails, mats, sandals and furniture coverings. The stems were also made into boats and dried plant material served as fuel. Nowadays it is only cultivated on a small scale and used locally for matmaking and similar purposes. It is considered a potential raw material for the production of paper and board, though pulping experiments carried out in the 1920s and 1950s gave unsatisfactory results. Around 1920, a papyrus-based pulping mill operated for a short time in South Africa.

The rhizomes of *C. malaccensis* are used medicinally in Vietnam for post-partum treatment and against oedemas; they are considered to be diuretic. The stems and rhizomes of *C. papyrus* are edible. *C. elatus* and *C. papyrus* are eaten by cattle. Experiments indicate that the high biomass production of *C. papyrus* makes it effective in removing N and P from wastewater and eutrophic pond water. Many *Cyperus* are considered weeds in rice fields, though they also provide green manure.

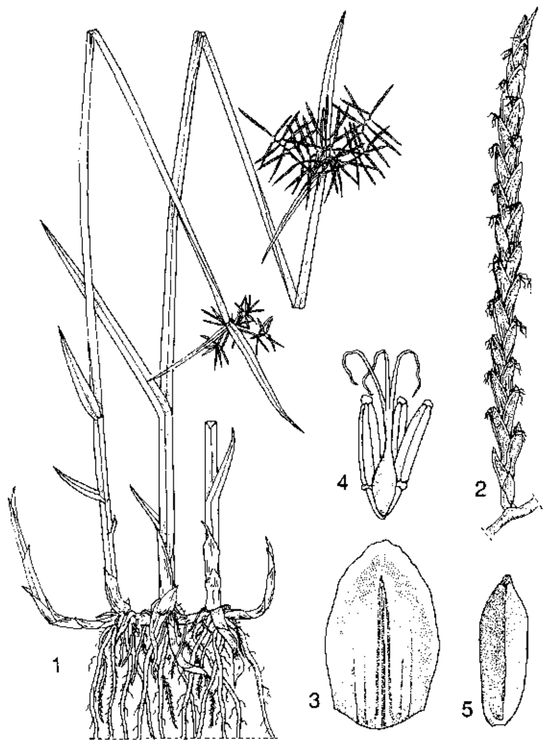
Production and international trade No production or trade statistics for *Cyperus* are available. In the past (1200 AD), mats made from *C. elatus* were traded from Java to China. At the present time mats and other products from *C. malaccensis* are made in Vietnam for export, but quantities are unknown.

Properties *C. malaccensis* has been said to provide very good matting material, but mats made from it have also been described as less durable than those made from *Fimbristylis umbellaris* (Lamk) Vahl and as much more brittle than those of *Lepironia articulata* (Retz.) Domin. The character of weaving material from *C. malaccensis* largely depends on the preparation method. The 3-sided stems may be split and the sides pulled apart, or just one side may be removed. If only a little pulp is removed, the straw is thick and soft, but if much is removed and the straw is finely split, the straw is thin and fine.

Papyrus fibre cells are (1–)1.8(–4) mm long and (8–)12(–25) μm wide. They are narrow, thick-walled and have pointed ends. Investigations in the early 20th Century showed that papyrus stems from Egypt provided a moderate pulp yield of fair quality, but the pulp was difficult to bleach. Experiments with *C. papyrus* in South Africa gave pulp yields of 45–48%. Because the stems have no nodes, the pulp does not contain hard particles, and even rayon-grade pulp has been produced from papyrus. However, the pith must be removed; it does not add strength to the paper but uses pulping chemicals and makes washing and forming of the paper difficult. The pith is not a problem for the production of hardboard. More recently it has been found that the major pulping chemicals successfully pulp papyrus and the pulp can be bleached under conditions similar to those required for rice straw. The resulting pulp can be used as the main constituent of writing and printing papers, but not for wrapping paper.

Vietnamese *C. malaccensis* rhizomes were found to contain approximately 3.1% tannin, 0.7% flavonoids, 0.5% essential oil and 0.5% alkaloids. In a Kenyan study the crude protein content of papyrus umbels decreased from 11% (juvenile) to 4% (dead) and that of culms from 4% to 2%. The ruminal dry matter digestibility of the umbels decreased from 38% to 13% and that of the culms from 46% to 3%.

Description Perennial or annual herbs, tufted or with creeping rhizome or stolons, sometimes with tubers; stem (culm) usually erect, solid, triangular (sometimes terete) in cross-section, usually leafy at the base only. Leaves in 3 vertical ranks, narrowly linear, grass-like, rarely lanceolate or elliptic, the lower ones often scale-like, covering the base of the stem and the rhizome, rarely all reduced to sheaths only. Inflorescence terminal, often anthelate, simple to decompound, umbel-like or umbellate, not rarely capitate by suppression of the rays; rays subtended by a leaf-like bract similar to the leaves, the base enclosed in a tubular, two-keeled prophyll, the bracts usually approximate as though forming an involucre; spikelets subcompressed, quadrangular to subterete, 1–many-flowered; axis (rachilla) often winged by the decurrent base of the glumes, persistent or caducous (in the latter case spikelet falling as a whole); glumes distichous, usually 2 basal ones empty; flowers usually bisexual, the uppermost in a spikelet often male or sterile; sta-



Cyperus malaccensis Lamk – 1, habit; 2, spikelet; 3, dorsal view opened glume; 4, flower; 5, fruit.

mens 1–3; style continuous with the ovary and ending in 2–3 stigmas. Fruit a sessile or short-stalked nut, trigonous or lenticular.

- *C. elatus*. A perennial herb with very short rhizome; stems tufted, tall, 0.5–1(–2) m × 3–10 mm, smooth. Leaves flat or somewhat plicate with midrib prominent beneath and 2 lateral veins strongly marked above; lower sheaths black-purplish; blade 4–10(–15) mm wide, bright green above. Inflorescence up to 30 cm in diameter, compound; involucral bracts 4–8, up to 75 cm long, overtopping the inflorescence; primary rays up to 10, unequal, up to 20 cm long; secondary rays 2–5 cm long; spikes digitately arranged, 2–7 cm × 3–5 mm; spikelets 6–16-flowered, 3–6 mm × 1 mm; glumes ovate, 1.2–1.8 mm × 1 mm, 3–5-veined, mucronulate; stamens 3; stigmas 3. Nut trigonous-ellipsoid, up to 0.9 mm × 0.4 mm, yellow-grey-brown.
- *C. malaccensis*. A perennial herb with stout stolons and woody rhizome; stems approximate, robust, 60–175 cm × 12–15 mm, spongious, triangular with concave sides, smooth. Lower leaves reduced to spongious sheaths up to 20 cm long, upper ones much shorter than the stem but with small blade 5–10(–18) mm wide and abruptly acuminate. Inflorescence broader than long, about 15 cm in diameter; involucral bracts 3–4, flat, erect to reflexed, up to 30 cm × 8–15 mm, overtopping the inflorescence; primary rays 3–6(–10), spreading, unequal, 3–10 cm long; secondary rays slender, about 2 cm long; spikes broadly ovoid in outline with 6–12, spicately arranged spikelets; spikelet subcylindrical, 1–3 cm × 1.2–1.7 cm, with 16–20(–40) flowers; glumes chartaceous, ovate to elliptic, up to 2.2 mm × 1.5 mm, indistinctly 5–7-veined; stamens 3; stigmas 3. Nut trigonous-cylindrical, about 2 mm × 0.5 mm, brown-black.
- *C. papyrus*. A perennial herb with coarse, short rhizome; stems up to 5 m tall, trigonous, pithy, clothed at base with brown bladeless sheaths. Leaves only with small blade up to 1 cm wide in sterile shoots. Inflorescence umbelliform, 20–35 cm in diameter; involucral bracts up to 12, lanceolate, much shorter than the inflorescence; primary rays numerous, slender, suberect, subequal, 10–30 cm long; secondary rays up to 5 cm long; spikes 1–3 cm × 6–10 mm, bearing distichously many spikelets; spikelet cylindrical, 6–12 mm × 1 mm, 5–17-flowered; glumes ovate-elliptic, 2 mm long, 3-veined green keel, light brown; stamens 3; stigmas 3. Nut trigonous-cylindrical, about 1 mm long.
- *C. procerus*. A perennial herb with stoloniferous rhizome; stems stout, 70–125(–175) cm × 0.5–1 cm, smooth, at base clothed with brown to purplish sheaths. Leaves firm, spongious or coriaceous, oblong-canaliculate, 9–15 mm wide, gradually acuminate at apex. Inflorescence subcompound, loose, 10–15 cm long; involucral bracts 3–4, erect to spreading, up to 70 cm long, the larger ones far overtopping the inflorescence; primary rays 3–7, unequal, 6–20 cm long, spreading; secondary rays absent to very short; spikes broadly ovoid, 2–4 cm long and wide, loose; spikelets up to 10–18 in the terminal spike, 3–4 in the lateral ones, spicately arranged, lower ones at right angles to the rachis, 10–35 mm × 2–3 mm, up to 40-flowered; glumes ovate to elliptic, 2.5–3 mm × 2 mm, hardly keeled, 7-veined, red-brown; stamens 3; stigmas 3. Nut obovoid to ellipsoid, triangular, 1.5 mm × 0.8 mm, black-brown.

Growth and development In Java *C. elatus*, *C. malaccensis* and *C. papyrus* flower year-round. Natural propagation of *C. elatus* is by the nuts, which are dispersed by water and birds. The nuts of *C. malaccensis* and *C. procerus* are dispersed. Some *Cyperus* species are known to have C_4-photosynthesis, whereas others have C_3-photosynthesis. *C. papyrus* has C_4-photosynthesis, which contributes to its exceptionally high productivity. The culms have numerous large intercellulair air cavities and 'Krantz' chlorenchyma, which are involved in CO_2-recycling. Under natural conditions average annual growth rates up to about 40 g/m^2 dry weight per day have been recorded, and in hydroponic culture short-term growth rates up to 125 g/m^2 dry weight per day are possible. In Lake Naivasha, Kenya, the total standing biomass was found to be 7.8 kg/m^2 dry weight. Of this total biomass 57% was located in the rhizome, 29% in the culms, 13% in the umbels, and 1% in the roots. The majority of *C. papyrus* umbels do not produce flowers, but the umbels are the principal photosynthetic tissue in mature plants. In a closed canopy the leaves senesce during early extension of the culms, but the leaves can be important for photosynthesis in plants that develop from seed or during regrowth after cutting or burning.

Other botanical information Within the *Cyperaceae*, *Cyperus* is placed in the subfamily *Cyperoideae* and the tribe *Cypereae*, but there is no general agreement on the circumscription and subclassification of the genus. Some subdivide it into 3 subgenera (*Cyperus*, *Pycreus* and *Kyllingia*), others into 2 subgenera (*Cyperus* and *Ano-*

sporum) with *Pycreus* P. Beauv. and *Kyllingia* Rottb. as separate genera. The species treated here and most other Malesian *Cyperus* species are classified in the subgenus *Cyperus*, characterized by the Kranz syndrome and often spicately arranged spikelets.

In *C. procerus* the rachis of the spikes is normally smooth, but in all Malesian specimens it is more or less scabrous hispid. The Malesian plants may therefore be referred to var. *lasiorrhachis* Clarke.

In *C. malaccensis* 2 subspecies have been distinguished:

- subsp. *malaccensis*: found from the Mediterranean to South-East Asia; lower leaf sheaths surpassing the inflorescence rays; uppermost leaf with an elongated blade; spikelets densely flowered with glumes not conspicuously incurved.
- subsp. *monophyllus* (Vahl) T. Koyama: occurring in China and the southern Ryukyu Islands; characteristics opposite to those mentioned above for subsp. *malaccensis*.

For several *Cyperus* species occurring in South-East Asia no reports exist on their use as a fibre plant in the Malesian region, whereas they are known to be used for weaving elsewhere. They include: *C. alopecuroides* Rottb., used for mat-making in Egypt since ancient times; *C. cephalotes* Vahl, made into mats in Japan; *C. compactus* Retz. (synonyms: *C. dilutus* Vahl, *Mariscus microcephalus* Presl), made into low-quality mats in Vietnam (Tonkin) and sometimes used for making roofs in Thailand; and *C. exaltatus* Retz., used as a fibre plant and for making fine mats in Korea since ancient times. *C. corymbosus* Rottb. (synonym *C. tegetiformis* Roxb.), probably does not occur in Malesia, but it yields material for matting and strings in, for instance, Thailand, Indo-China, India and China.

Ecology Most *Cyperus* species are hygrophilous, growing in moist localities at low to medium altitudes, with only a few at altitudes higher than 1600 m. *C. procerus*, and especially *C. malaccensis*, prefer muddy habitats within the influence of salt or brackish water. *C. elatus* grows on riverbanks, in swamps, rice fields and meadows, and other open wet locations up to 700(–1000) m altitude. *C. malaccensis* is found, often abundantly, in moist habitats, usually within the influence of salt or brackish water (muddy estuaries, mud flats and sandy foreshores covered by spring tides) and often forming a dense fringe vegetation. *C. procerus* grows in open, wet locations, like swamps and pools, often near the sea in brackish localities, and in wet rice fields, usually up to 50 m altitude, but also near Bogor (West Java) at 250 m altitude. In Indonesia *C. elatus*, *C. malaccensis* and *C. procerus* are considered weeds of minor importance in rice fields. They can be controlled by manual weeding.

C. papyrus is the dominant species in most African permanent swamps. It is adversely affected by seasonal flooding regimes exceeding 3–4 m in amplitude, flash flooding or very low water levels during the dry season. Papyrus is sometimes considered a nuisance, forming floating islands that obstruct navigation and water flow.

Propagation and planting *Cyperus* can generally be propagated by seed, division, and cuttings. The seed of *C. papyrus* needs light to germinate. Tuber-forming *Cyperus* are easily propagated by tubers.

Diseases and pests In Peninsular Malaysia, *Cyperus* is susceptible to attack by smut fungi (*Ustilago* spp.). In southern China (Guangxi) *C. malaccensis* blight, caused by *Phytophthora cyperi*, occurs widely.

The stem borer *Schoenobius ochraceellus* has been recorded on *C. elatus* and *C. procerus* in Indonesia, mostly in the subterranean stem parts.

Harvesting The stems of *C. malaccensis* are cut when flowering starts.

Yield No information is available on *Cyperus* yields in South-East Asia. The annual above-ground production of *C. papyrus* in Lake Naivasha swamp in Kenya has been estimated at about 50 t/ha dry matter per year.

Handling after harvest In processing *C. malaccensis* stems in Indonesia, one of the ribs is removed and the remaining stem is dried in the sun for 3 days. Then the stems are spread out indoors for 24 hours to become supple, after which they are smoothed with a piece of bamboo. In the Philippines whole stems are plaited into coarse matting, whereas fine matting is made by splitting the stems before drying. Splitting preferably is done when the stems are fresh and in any case before they are dry. The strips may be placed in the sun for a first quick drying. After this, the straw finishes drying in the shade. The resulting unbleached, light green-coloured straw is ready for use, but it may also be whitened and toughened by keeping it damp in the sun for several days. If it dries completely in the sun, it becomes brittle. For mat-making in Gorontalo (Sulawesi) *C. elatus* stems are split into three and the strips are smoothed with a piece of wood. In Vietnam the stems are split and dried in the sun.

In ancient Egypt *C. papyrus* was probably made into writing material by stripping the fibrous outer parts from the stems and slitting the inner pith into strips. These strips were laid side by side, with a second layer of strips placed crosswise on top, dampened, pressed, dried in the sun, and polished.

Genetic resources and breeding No germplasm collections or breeding programmes of *C. elatus*, *C. malaccensis*, *C. papyrus* and *C. procerus* are known to exist.

Prospects Based on their traditional use by local people, *C. elatus*, *C. malaccensis* and *C. procerus* will remain of local importance as sources of weaving and binding material in South-East Asia. *C. papyrus* has a high productivity and may have some potential as a raw material for papermaking.

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U.A. Dasuki

Donax canniformis (G. Forster) K. Schumann

Bot. Jahrb. Syst. 15: 440 (1893).

MARANTACEAE

$2n$ = unknown

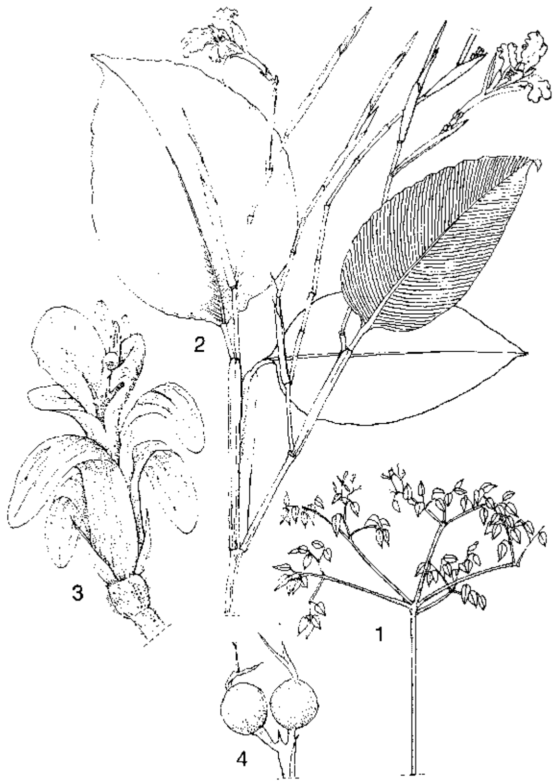
Synonyms *Thalia canniformis* G. Forster (1780), *Donax arundastrum* Loureiro (1790), *D. grandis* (Miq.) Ridley (1899), *D. cannaeformis* (G. Forster) Rolfe (1907), *D. parviflorum* Ridley (1910).

Vernacular names Brunei: bamban, bamban batu. Indonesia: bamban (Malay, Javanese, Sundanese), bangban (Sundanese), moa (Moluccas). Malaysia: bemban, bemban ayer, buluh leck (Kelabit). Philippines: bamban, banban (Tagalog, Ilokano, Bisaya, Manobo, Sulu, Bukidnon). Cambodia: daem run. Thailand: klah, blah, klum (central, Surat Thani, Trat). Vietnam: dong s[aaj]y.

Origin and geographic distribution *D. canniformis* is distributed from India throughout South-East Asia to southern China, Taiwan and Polynesia. Occasionally it is also cultivated.

Uses Stem material of *D. canniformis* is widely used in South-East Asia for the production of baskets, bags, mats and trays. In the Philippines, for instance, it is made into a wide range of articles, including hats, waste baskets, laundry baskets, flowerpot holders, trays, tables, magazine racks and bookshelves. The importance of *D. canniformis* as a source of weaving material in South-East Asia seems to increase as rattans become scarcer, but products from *D. canniformis* are generally of lesser quality than those made of rattans. Because they are usually not durable, baskets from *D. canniformis* are often coarse, with on average wider strips than in rattan baskets. In Sarawak, however, fine patterned baskets such as wedding pouches ('sintong bangin') may occasionally be encountered. Throughout South-East Asia the stems of *D. canniformis* are used for making fish traps, for stitching thatch and for other tying work. In Borneo they have been made into strings for musical instruments. The Semai in West Malaysia make blowpipe darts from the stem. The pith of the stem is used for paper making. The leaves are employed as cigarette paper in New Guinea.

In Indonesia the juice from young, uncurled leaves is used medicinally against eye disease, and that from young stems against snake bites. In the Philippines a decoction of the roots is considered an antidote against snake bites and blood poisoning, the juice from crushed roots is used against



Donax canniformis (G. Forster) K. Schumann – 1, habit; 2, flowering branch; 3, flower; 4, fruits.

fungal infections and an infusion of young shoots is taken to lower fever.

D. canniformis is also made into mats and baskets in the Andaman Islands (India) and into thread in the Solomon Islands. In India and on Martinique it is locally cultivated to obtain starch from the rhizome. The rhizomes are edible and sometimes used for making confectionery.

Production and international trade Baskets and mats made of *D. canniformis* are sold as handicrafts for tourists, but statistics are not available.

Properties The stems of *D. canniformis* yield several grades of strips, the best one being the outer layer ('peel'), which is green if the epidermis is not removed and light to dark brown if the epidermis is scraped off. It is thinner than rattan peel and less robust, breaking more easily when bent and splitting longitudinally when used. Furthermore it does not acquire any aesthetic qualities as it ages. Like rattan, it can be dyed, though it fails to achieve the same depth of colour. The best material comes from the main stem with its longer internodes.

Adulterations and substitutes As a source of weaving material, *D. canniformis* may be replaced by rattans and various *Cyperaceae*, *Palmae* and *Pandanaceae*.

Description A perennial, stout, tufted-rhizomatous, erect, shrub-like herb, 2–5 m tall, with true, slender, sympodially branching stems. Leaves all cauline, sheathed, thin-coriaceous; sheath up to 20 cm long; ligule very short; petiole 1–2.5 cm long, thickened into a cylindrical, pilose pulvinus; blade broadly ovate to elliptical, 10–45 cm × 4–25 cm, base rounded, apex acuminate, underside appressed-pilose along the midrib, lateral veins numerous, running parallel. Inflorescence terminal on a leafy branch, slenderly paniculate, up to 20 cm long, branched at base, partial inflorescences condensed cymose (spiciform) in the axils of primary bracts; bracts 9–11, distichous, obovate to lanceolate, 2.5–3.5 cm long, caducous; pedicel up to 5 mm long, thickened in fruit; flowers in pairs; bracteoles 2 per flower pair, glandular; sepals 3, free, triangular-ovate, 3–5 mm long, white, glabrous; corolla tubular and 3-lobed, tube 8–10 mm long, lobes linear, 1–1.5 cm × 2–3 mm; staminodes and stamen forming a tube 3–4 mm long; outer staminodes 2, petaloid, subequal, obovate, 12–14 mm × 5–6 mm, white; inner staminodes 2, unequal, yellowish; one is the fleshy (callose) staminode, petaloid, about 1.5 cm long, inside at base with a hairy thickened part, apex emarginate; the other one is the hooded (cucullate) staminode, about 1 cm long, enclosing the style and stigma in the hood and bearing a broad lateral lobe; fertile stamen 1, about 8 mm long with a narrowly triangular appendage; pistil with sericeous, 3-celled ovary; style and stigma held erect first by the hooded staminode, when released the upper part springing downwards to form an inverted U, the stigma resting on the callus of the fleshy staminode. Fruit globose to ellipsoid, 1–1.5 cm in diameter, dry, indehiscent, subglabrescent, whitish-cream, crowned by the withered flower, 1–2-seeded. Seed globose to ellipsoid, 7–8 mm in diameter, grooved, warty, brown.

Growth and development The stem of *D. canniformis* rises in a single, cane-like internode from the ground to 2 m long or longer and then in a much shorter internode to the next leaf. Branching is sympodial throughout, with each axillary shoot bearing first a short 2-keeled sheath backing on to the main axis, then close to it an unkeeled bladeless sheath and a foliage leaf, then 1 or 2 more leaves separated by longer or shorter internodes and a terminal inflorescence. *D. canniformis* flowers and fruits throughout the year in Java. In Indo-China it flowers from May to September and fruits in February.

Other botanical information There is no general agreement on the number of species in *Donax* Lour., which, according to different opinions, ranges from 1 to 4. A revision of this genus, along with a group of closely related genera, is needed. There is general agreement that the *Donax* taxa are all closely related. Because information in the literature cannot be assigned with certainty to individual taxa (which are all similarly used), here a single wide species concept is followed. Taxa have been characterized as follows:

- *D. arundastrum* Loureiro. Stem up to 3 m tall; leaf blade small, elliptical, 10–22 cm × 4–10 cm; fruit often trigonous and 3-seeded.
- *D. canniformis* (G. Forster) K. Schumann (synonym: *D. cannaeformis* (G. Forster) Rolfe). Stem up to 5 m tall; leaf blade ovate to elliptical, 10–45 cm × 10–25 cm; flowers large, rich in nectar; fruit globose, 1-seeded.
- *D. grandis* (Miquel) Ridley. Stem up to 5 m tall; leaf blade up to 30 cm × 20 cm, widest near the base; flowers large and corolla tube much longer than the sepals; fruit globose, 1- but usually 2-seeded.
- *D. parviflorum* Ridley. Stem short; leaf blade up to 20 cm × 9 cm, nearly elliptical; flowers small, poor in nectar, corolla tube shorter than the sepals; fruit 2-seeded and bilobed or globose and 1-seeded.

Ecology In general *D. canniformis* grows in wet locations, such as swamps and periodically flooded areas. In South-East Asia it occurs up to about 1000 m altitude in secondary forest, teak forest and bamboo forest, but also in coconut plantations and near paddy fields.

Propagation and planting Though *D. canniformis* is usually gathered from the wild, it is occasionally planted, for instance in Peninsular Malaysia, Sarawak and northern Sumatra. Information on planting and cultivation practices is, however, lacking.

Harvesting The stems of *D. canniformis* are usually gathered from the wild and sold. Quality is determined by dryness, colour and length. Harvested stems are usually several metres long, with a diameter of 1–3 cm.

Handling after harvest In Malaysia the outer layer of *D. canniformis* is separated from the stem and split into long fibres, which are dried in the sun, after which they are ready for use. In Indonesia the green epidermis is scraped from the cut stems, which are dried and split, after which the soft inner layer is removed, leaving hard, shiny, thin strips. In the Philippines gathered stems are dried in the sun, after which they are split and the inner part of the stems is removed until the desired thickness is obtained.

Genetic resources and breeding *D. canniformis* does not seem threatened with extinction, though supply of stem material is decreasing and more uncertain locally in the Philippines. No germplasm collections or breeding activities of *D. canniformis* are known to exist.

Prospects *D. canniformis* seems to be gradually replacing rattan in the handicraft or cottage industry, largely due to the destruction and decline of the primary jungle favoured by many of the rattan species. Because handicrafts made of *D. canniformis* are less durable than those made from rattans, they are generally newer, which may also contribute to the impression that its use is increasing. An advantage of *D. canniformis* is that it is easy to collect and prepare. *D. canniformis* will probably not fully replace rattan, because some rattan species can be (and are) cultivated as well.

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S.P. Teo

Enhalus acoroides (L.f.) Royle

Illustr. bot. Himal. 1: 453 (1840).
HYDROCHARITACEAE
$2n = 14$

Synonyms *Stratiotes acoroides* L.f. (1781), *Enhalus koenigi* Rich. (1814), *E. marinus* Griff. (1851).

Vernacular names Eel grass, tropical eel grass (En). Indonesia: deringu laut (Indonesian), jelamun (Javanese), lamun (Sundanese, Balinese). Malaysia: setul, jerangau laut. Philippines: lamon (Tagalog, Bikol), mariu-bariu (Bikol), pallaipatbaibai (Ilokano).

Origin and geographic distribution *E. acoroides* is a marine plant distributed from East Africa, Madagascar and the Seychelles through the tropical parts of the Indian Ocean, the southern part of the Red Sea, and throughout South-East Asian coastal waters to China, northern Australia, Micronesia and Melanesia. It is rare in the Indian Ocean area, but very common in South-East Asia, where it occurs around Thailand, Cambodia, Vietnam, Malaysia, Indonesia, Papua New Guinea and the Philippines.

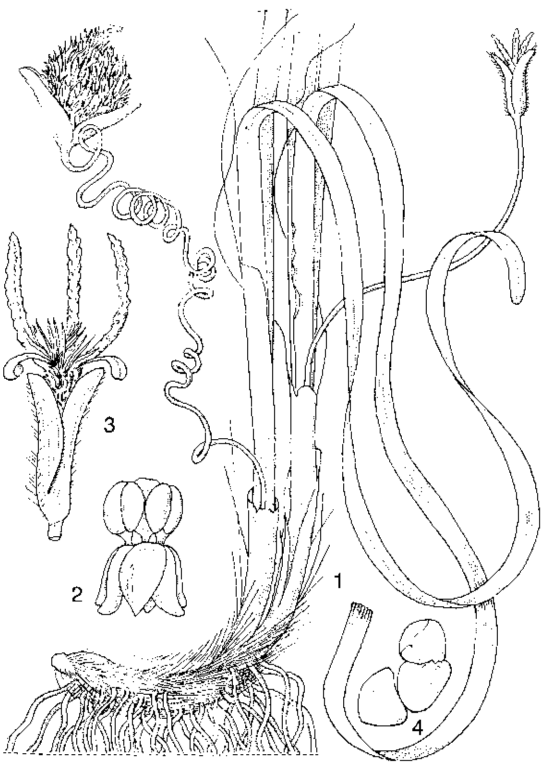
Uses The black fibre strands of the leaf margins of *E. acoroides* persist after the leaves decay and are used for making fishing nets (the Moluccas, New Guinea and Micronesia). They have also been used for mats, ropes and paper making. The raw, boiled or roasted seeds are edible and are sometimes eaten in the Philippines, Indonesia (Java, the Moluccas) and India. In the Philippines the fruits and leaves are chewed or macerated and the mixture is applied to wounds to staunch bleeding, whereas the seeds are credited with aphrodisiac and contraceptive properties. *E. acoroides* is grazed by turtles and dugongs (*Dugong dugon*).

Production and international trade In some regions of the Philippines seeds of *E. acoroides* are sold in local markets, but no statistics are available on production or trade.

Properties Fishing nets made of *E. acoroides* are very durable in sea water and tanning is not needed. On Yap (Caroline Islands, Micronesia) the traditional nets used to be used throughout a person's life and were passed on to the next generation. Nets that were not used for some time were protected by being periodically dipped in sea water, dried, and wrapped to protect them against rats and geckos. No information is available on the physical and chemical properties of the fibre.
The raw seed is described as crunchy and sweet, whereas the boiled seed tastes like boiled sweet potato or chestnut. The testa is bitter and should not be eaten. Flour prepared by grinding dried *E. acoroides* seed from the Philippines contains per 100 g approximately: moisture 10 g, protein 9 g, fat 0.2 g, carbohydrates 72 g, crude fibre 2 g, ash 6 g, Ca 90 mg, P 240 mg and Fe 280 mg. The energy value is about 1370 kJ per 100 g.

Adulterations and substitutes Substitutes for *E. acoroides* as a source of fishing nets include *Anodendron* spp. and ramie (*Boehmeria nivea* (L.) Gaudich.).

Description A perennial, marine, submerged, dioecious, rhizomatous, coarse, glabrous herb. Rhizome creeping, up to 1.5 cm in diameter, inside with wide, septate air channels, outside bearing numerous simple, cord-like roots 10–20 cm × 0.3–0.5 cm and densely clothed with persistent fibrous strands of decayed leaves. Leaves sessile, usually 2–6, distichously arranged at the end of the rhizome, together enclosed by a flattened, transparent sheath about 15 cm long, often twisted and damaged, bright to dark green; blade ribbon-like, 30–150 cm × 1–1.8 cm, base sheathed, margin thickened by coarse, very tough vascular bundles which become black after the blade decays and remain attached to the rhizome, apex rounded or obtuse, veins 13–19, running longitudinally parallel, air channels 30–40, parallel to the veins, visible outside as a fine striping with irregularly spaced septations. Male inflorescence an axillary, peduncled spathe consisting of 2 connate bracts, the margin of the outer one embracing the inner one; peduncle terete, 5–10 cm long; bracts ovate-lanceolate, 5 cm × 3 cm, faintly keeled, rough long-haired on the keel; flowers small, numerous, pedicelled, on a central stipe, caducous just before anthesis and the mature buds rising to the level of the water; pedicel 3–12 mm long, unequal, very thin; sepals 3, oblong, 2 mm long, reflexed, white; petals 3, ovate, wider but slightly shorter than sepals, white; stamens 3, erect, 1.5–1.8 mm long, anthers subsessile, 2-locular, dehiscing latrorsely, pollen grains spherical, about 175 μm in diameter. Female inflorescence a stalked spathe consisting of 2 nearly free bracts, one embracing the other with both margins, persistent in fruit, enclosing 1 flower; stalk (pedicel) 40–50 cm long, spirally contracted after fertilization, in fruit unrolled again; bracts oblong-lanceolate, 4–6 cm × 1–2 cm, strongly keeled, keel and veins rough long-haired; sepals 3, oblong, reddish; petals 3, oblong-linear, 4–5 cm × 0.3–0.4 cm, white, surface waxy and papillose; ovary rostrate, 5 cm × 0.5 cm, densely set with long fringe-like



Enhalus acoroides (L.f.) Royle – 1, habit of female flowering and fruiting plant; 2, male flower; 3, female flower; 4, seeds.

hairs, composed of 6 carpels, 1-locular, ovules numerous; styles 6, very short; stigmas 6, each forked from the base, 10–12 mm long, densely covered with linear papillae. Fruit berry-like, ovoid to subglobose, 5–7 cm in diameter, ribbed lengthwise, densely hairy, green, brown or black, opening irregularly at the apex at maturity, 8–14 seeded. Seed angular-obconoidal, 1–1.5 cm × 1.2 cm, brown.

Growth and development Both leaf growth and leaf initiation rate of *E. acoroides* increase with water temperature. Observed leaf growth rates in South-East Asia range from 0.7–3.1 cm per day, with a new leaf being initiated every 27–35 days. The largest part of the plant biomass is located in the subterranean rhizome and roots.

Flowering appears to be year-round. Pollination is effected by the male flowers detaching from the parent plant, floating on the water, and coming into contact with the stigmas of the female flowers ('*Hydrocharitaceae* epihydrophily'). The male flowers open in the closed spathe and are liberated when the spathe opens, but only when the low spring tide occurs during the day. Pollination requires the female inflorescence to reach the water surface, which only occurs during sufficiently low tides, when the water level is no more than 0.4 m above the seagrass bed. The female flowers on the water surface 'attract' the male flowers by the hydrophobic properties of the petals. When the tide rises again the female flowers are submerged, the petals close together, 'capturing' the male flowers, and pollination occurs. Fruiting seems to occur year-round as well, though in Papua New Guinea successful fruit formation occurs mainly between April and August. The time from pollination to opening of the fruits varies from 3–5 months in Papua New Guinea. There are indications that fruits open predominantly during spring-ebb tides. When the fruits open, the seeds are already in an early stage of germination. Seeds with the testa loosely attached float on the water, those without testa sink. The seeds are distributed not only by sea water, but also by dugongs.

Algal epiphytes are usually present on the leaves of *E. acoroides*. In Papua New Guinea they were found to contribute 3–17% to the total aboveground plant biomass and 2–9% to the mean annual aboveground plant production.

Other botanical information *E. acoroides* is the only species in *Enhalus* Richard (1814). The *Hydrocharitaceae* family comprises species with both freshwater and marine habitats, a rather rare occurrence in angiosperm families. The family comprises about 15 genera, but its delimitation is constantly changing and its floral biology is not fully understood.

Ecology *E. acoroides* is found along sheltered or exposed shallow sea-coasts, from around the low-water mark to about 5 m depth. It occurs in a wide range of habitats and thrives in small depressions on tidal flats between the levels of mean low water and low water at spring tide. *E. acoroides* may occur patchily or form a closed monospecific stand, the latter particularly on sandy and muddy bottoms, often mixed with coarser material. It may grow abundantly in fish ponds, waterways and coastal resorts, and can form an obstruction.

Propagation and planting *E. acoroides* can be propagated by seed, but is not planted deliberately. Fibres and seeds are obtained from wild stands.

Husbandry Experiments in the north-western Philippines have shown that shoot size and leaf growth of *E. acoroides* are sometimes limited by the availability of nutrients, especially nitrogen.

Harvesting In Yap, fibres of *E. acoroides* were traditionally collected at low tide from special, protected marine meadows. First the leaves were pulled up, and debris and epiphytes were stripped off. Then a thumb was inserted in the axil of the chosen leaf which was subsequently separated from the plant. The outermost leaf was usually not picked, because its fibres are generally broken and too stiff to be used. The basal portion of the harvested leaf was grasped in one hand and the central portion of the leaf blade stripped away with the thumb of the other hand, leaving a short section of the leaf blade with long strips of the leaf margin extending on either side.

Yield In the north-western Philippines *E. acoroides* produces about 150 seeds/m^2 per year. No statistics or estimates of the fibre yield are available.

Handling after harvest In Irian Jaya (Indonesia) the longest fibres are scraped off, dried in the sun, separated and twisted into rope. In Yap, the traditional processing method was to tie the harvested strips in bundles and hang them on poles to dry, after which the fibres were carefully extracted from the surrounding tissue. To extract the fibres, the double strands were held firmly in one hand and the connecting leaf blade was grasped firmly between thumb and forefinger and stripped off, exposing the fibres, from which the remaining leaf tissue was subsequently stripped off. If the leaf tissue became too dry, it was rewetted and dried to the appropriate dryness for fibre extraction. Once extracted, the fibres are stable and can be stored.

In Yap about 4–5 fibres were made into a strand by twisting them with the finger and rolling them on the thigh. Then 2 strands were rolled together to make a twine, to which new strands were added to make the twine longer. The twines were made into nets.

Genetic resources Because of its wide distribution and range of habitats, *E. acoroides* seems not to be threatened with extinction, though South-East Asian seagrass ecosystems in general are subject to threats such as heavy deposits of mining spoils, destructive fishing methods, conversion in favour of aquaculture and increased sedimentation due to deforestation. There are no known germplasm collections of *E. acoroides*.

Prospects *E. acoroides* will probably continue to be locally used as a source of fibre for fishing nets. Though the nutritional quality of flour made from the seeds is good, mariculture of *E. acoroides* is not feasible because of the low yield per area unit.

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Y. Umi Kalsom

Eugeissona triste Griff.

Calcutta Journ. Nat. Hist. 5: 101 (1845).

PALMAE

$2n$ = unknown

Vernacular names Bertam, bertam palm, mountain nipa (En). Malaysia: bertam, beltop (Sakai), cembag (Semang). Thailand: chaak khao, chaak cham (peninsular).

Origin and geographic distribution Bertam is endemic to Peninsular Malaysia and peninsular Thailand. In Peninsular Malaysia it is very common and considered a forest weed.

Uses The leaves of bertam are widely used in Peninsular Malaysia for making roof thatch ('atap'). The Orang Asli of Malaysia use the leaves not only for making roofs, but also for house partitions, screens and baskets. The petiole and midrib, with the leaflets removed, serve as crossbeams in traditional house-building. Flattened petioles or strips cut from the outer portion may be woven into mats for walls of traditional Malay houses. Strips of the petiole are also used to make sun-blinds and fish traps. Fibres may be beaten out of the petioles and twisted into strips for necklaces.

The petiole and midrib are made into fishing poles and clothes-hangers. Ornamental walking sticks are made from the petioles and the roots. The petioles or strips of their outer layers are used by traditional Chinese communities as a supporting material for the paper models of figures and other items such as lanterns, houses, effigies, horses, cars and television sets used in funerals and memorial ceremonies. A portion of the inflorescence is sometimes used as a ceremonial knife for cutting the umbilical cord at birth. The midrib of the leaflet and the epidermis of rachis and petiole are made into darts for blowpipes. The pith of the petiole provides the base of these darts and root portions serve to close the bamboo tubes holding dart poison. The roots are made into flooring material for houses.

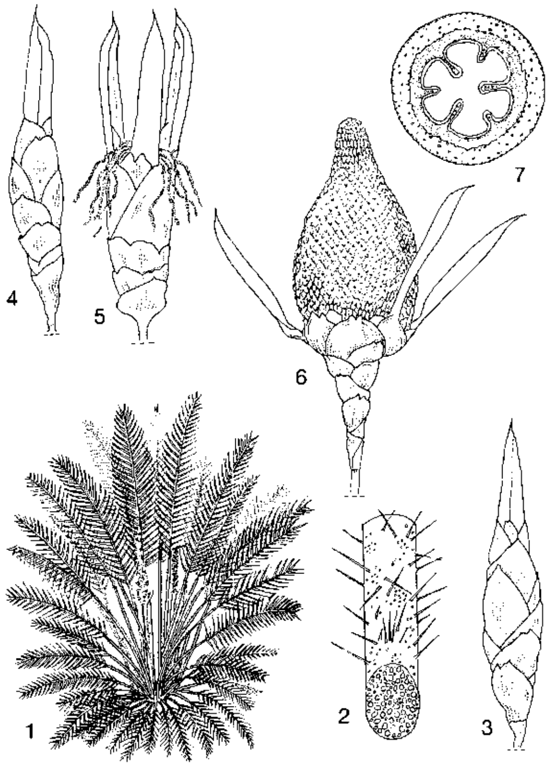
Some sago may be obtained from the stem and inflorescence, and the young fruits are eaten. The flower buds exude drops of sugary nectar when cut. This sugary solution is tapped and drunk, either fresh or fermented into an alcoholic drink. Fruits and unopened inflorescences are cut, dried and lacquered to make ornamental and decorative objects sold to tourists. Bertam is sometimes planted as an ornamental.

Production and international trade No statistics on production and trade of bertam are available. In Perak (Malaysia) petioles are collected and sold to Chinese funeral parlours. Some products used by Chinese communities may be sold in Singapore or Brunei. The demand and utilization of bertam is much lower than the supply available.

Properties To remain waterproof, roofs to be thatched with bertam need to be steeper than those thatched with nipa palm (*Nypa fruticans* Wurmb). At a pitch of 50° and laid closely, bertam roofs have been estimated to last for 4–5 years. No information is available on the morphological, physical and chemical properties of the fibre.

Adulterations and substitutes Substitutes for *E. triste* as a source of thatch are mainly members of the *Palmae* (*Borassus flabellifer* L., *Cocos nucifera* L., *Metroxylon sagu* Rottboell, *Nypa fruticans*), *Pandanaceae* (*Pandanus* spp.) and *Gramineae* (*Imperata* spp., *Miscanthus* spp.).

Description A robust, acaulescent, rhizomatous, spiny, hapaxanthic palm, up to 10 m tall, growing in clumps up to about 3 m in diameter, surrounded by a thick cover of long persisting dead leaves. Rhizome creeping, 1–1.5 m long, 10–20 cm in diameter, extremely woody and hard, branching at short intervals, with a shoot at the end of each branch, covered with slender feeder roots and deeper penetrating, thicker anchorage roots. Leaves numerous, pinnate, erect to ascending; sheath 60–90 cm long, deeply split, densely covered with silver to brown indumentum, armed with black, needle-like spines 2–5 cm long; petiole 3–5 m long, indumentum and spines like those on sheath; midrib 3–4.5 m long, spines as on petiole; leaflets arranged regularly, up to 55 on each side of midrib, oblong, 45–70 cm × 3–4 cm, with scattered spines on midrib. Inflorescence interfoliar, panicle-like, narrow-elongate, erect, up to 3 m long; peduncle up to 1 m long, rachis up to 2 m long with 15–25 erect, adpressed branches up to 30 cm long, which themselves branch again, and all branches covered by numerous, brown, overlapping bracts which are tubular at base; flowers paired, terminal on short branches 5 cm long (rachillae) which end in a cupule, a symmetrical male flower developing first, later pushed off by a lopsided bisexual flower that is protandrous and longer than the male flower; calyx tubular, with 3 teeth at apex; corolla tubular, 5 cm long, 3-lobed, connate in lower third enclosing the ovary in bi-



Eugeissona triste Griff. – 1, habit; 2, part of petiole; 3, male flower bud; 4, bisexual flower bud; 5, open bisexual flower with hanging anthers; 6, fruit; 7, cross section of the fruit.

sexual flowers, lobes long and narrow, sharply pointed, woody, brown; perianth falling in male, persisting in bisexual flowers; stamens 20–25, inserted in corolla just above the ovary or about in the middle, filaments short, anthers narrow, elongate, pollen brown-purple; ovary (absent in male flowers) 3-chambered but partitions not joined, ovules 3; stigma on top of ovary, pyramidal, hard. Fruit a spindle-like drupe, up to 10 cm × 5 cm, covered with small irregularly arranged dark brown scales with frilled margins; mesocarp somewhat corky and fibrous; endocarp stony, with 3 big and 3 small flanges penetrating into the fruit cavity (and into the endosperm of the seed), forming symmetrical, incomplete partitions. Seed basally attached, single, filling the fruit cavity, closely adhering to the endocarp; seedcoat thin, dry; endosperm homogeneous, hard, embryo basal.

Growth and development At germination of bertam seed a cotyledonary stalk grows about 15–20 cm vertically down into the soil, after which it bends sharply. At the bend a leaf sheath pushes through the apex of the stalk and grows up to the soil surface, where the first leaf emerges from the sheath and rises above the ground. Temporary roots emerge from the stalk where it starts in the seed, whereas the first permanent root emerges at the bend. It has been suggested that this type of germination ('cryptogeal germination') is to get the seedling into the ground through the litter layer.

Germination takes at least 3 months, and the first and second leaves appear on average 5 and 9.5 months after sowing, respectively. The time between leaf appearance and complete unfurling of the leaflets is 9–14 weeks. At 3.5 years after germination, bertam planted in Kepong (Malaysia) was only about 1.5 m tall with 10 leaves, and clump formation had not yet begun.

Bertam grows according to Tomlinson's architectural model, characterized by the repeated development of equivalent orthotropic modules in the form of basic branches; growth of the modules is usually continuous, sometimes rhythmic. Bertam produces horizontally growing, sympodially branched, hard and woody rhizomes, with short vertical branches carrying the leaves and inflorescences. Dead leaves do not abscise neatly, but tend to flop down and rot while still attached to the stem.

In contrast to most other palms but in common with *Corypha utan* Lamk and *Raphia* P. Beauv. flowering is hapaxanthic: upon flowering the stem ceases to grow vegetatively and eventually dies. The plant continues to grow through the rhizome, which develops new shoots. Bertam has both male and bisexual flowers, with the male ones developing first and reaching maturity at 4–5(–7) months after bud initiation. Within 2 weeks after male flowering the hermaphrodite flowers protrude, reaching maturity 3 months later. The pollination system is not well known, but in view of the flower morphology and the wind-still rainforest habitat, self-pollination is unlikely and insects probably play a more important role in pollination than wind. Fruits take about 6–7 months to mature. Wild pigs, squirrels and rats eat from the fruits and probably play a role in the dissemination of the seed.

Other botanical information *E. triste* is the type species of *Eugeissona* Griff. The genus name is based on the suitability of *E. triste* for thatching, from the Greek words 'eu', meaning 'good', and 'geisson', meaning 'a tile, cornice of a roof'. In many literature sources *E. triste* can also be found as *E. tristis*, but Griffith published this taxon as *E. triste*. Bertam shows considerable morphological variation, e.g. in the size of its leaves and inflorescences; this may be due to ecological variations as well as to some genetic variation. In Johor (Malaysia), for instance, a form with more slender petioles, narrower leaflets, and smaller inflorescences is found in seasonally swampy forests and on some mountain slopes.

Ecology Bertam is found in a wide range of forest types, from swamp margins to hilltops. It is most abundant on hill ridges up to 1000 m altitude, where it dominates the undergrowth after logging and prevents regeneration of commercially important timber trees such as *Shorea curtisii* Dyer ex King. Bertam is found on almost all hill-forest soils, from clays to coarse sandy loams, but thrives in well-drained habitats. Bertam is most common on the western coast of Peninsular Malaysia, including the western flanks of the main range. In the eastern part it is much more scattered; nevertheless it is locally just as abundant as in the western part. The Malaysian Forest Department is trying to find a way of preventing forests from becoming bertam groves after logging instead of regenerated forest. Although considered a forest weed, bertam may serve an important auxiliary function on slopes, controlling soil erosion and increasing soil stability. Cut leaves rot slowly and blanket the soil for a long time.

Propagation and planting Bertam can be propagated by seed, but is not planted deliberately. Material for thatching and other purposes is obtained from wild stands.

Husbandry Bertam grows well without much care or attention. In fact, more research has been carried out on the control of bertam as a weed than on its cultivation. To permanently eradicate a bertam clump the rhizome needs to be killed, for instance using systemic herbicides such as hexazinone. However, no effective and economic control method has been found that does not have side-effects on neighbouring trees.

Diseases and pests Bertam is not known to be seriously affected by any disease or pest.

Harvesting As many long spines are present on the leaf stalks as well as on both sides of the leaf blades, great care must be taken when harvesting bertam leaves. If the whole leaf is required, spines are removed from a small portion of the leaf base, to make handling easier. If only the leaf stalks are required, all the spines and leaflets are removed by scraping with a sharp knife. The clean leaf stalks are then tied in bundles and carried out of the forest.

Yield No statistics are available on yield of bertam leaves, fruits or other products.

Handling after harvest Bertam leaves are processed while still fresh, because dried leaves are too brittle to work. Similarly, bertam petioles and strips of petioles are best used while moisture is still present in the tissues. Dried strips of petioles are soaked in water for some time before being used, so they are not too brittle.

Genetic resources and breeding Bertam does not seem to be threatened with extinction. There are no known germplasm collections or breeding programmes or experiments.

Prospects It is very unlikely that bertam will become economically important in Malaysia or Thailand. For people living in the forest or forest fringes, however, bertam will remain a useful forest resource with multiple uses. Though usually considered a weed by foresters, it may play a role in the prevention of erosion.

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H.C. Ong

Fimbristylis umbellaris (Lamk) Vahl

Enum. pl. 2: 291 (1806).

CYPERACEAE

2n = 6

Synonyms *Scirpus umbellaris* Lamk (March 1791), *S. globulosus* Retzius (July-Nov. 1791), *Fimbristylis globulosa* (Retzius) Kunth (1837).

Vernacular names Globular fimbristylis (En). Indonesia: mendong (Javanese), jukut bubu-ut (Sundanese), werot (North Sulawesi). Malaysia: rumput sandang (Peninsular). Philippines: tikog (Bisaya, Cebuano), badang-badang (Ilokano), anahiunan (Manobo, Cebuano). Thailand: phrong klom noi (Trang). Vietnam: c[or] qu[aw]m b[oo]ng tr[of]n.

Origin and geographic distribution *F. umbellaris* originates from South-East Asia and is distributed from India and Sri Lanka through South-East Asia to China, Japan (Ryukyu Islands), Micronesia and Polynesia. In South-East Asia it occurs in Indo-China, Peninsular Malaysia, Indonesia (throughout), Brunei Darussalam, the Philippines (throughout) and New Guinea. It is cultivated in Peninsular Malaysia, Indonesia (West Sumatra, Java, North Sulawesi) and the Philippines.

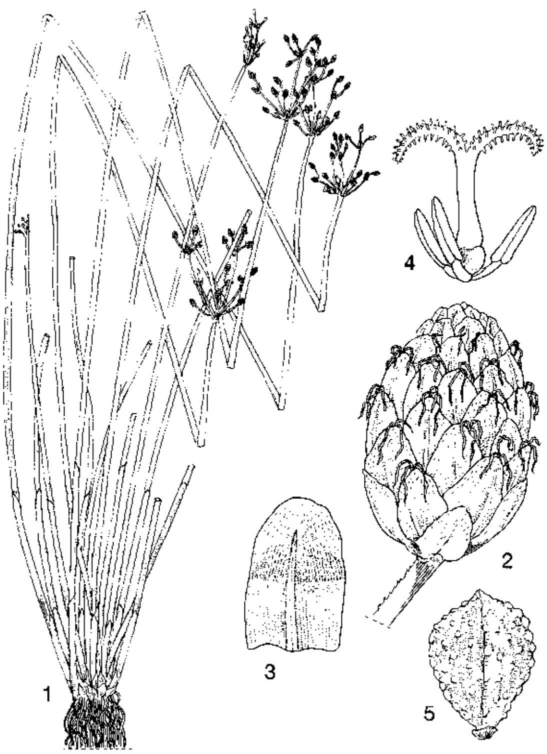
Uses The stems of *F. umbellaris* are widely used in South-East Asia for weaving, especially for the production of fine mats, hats and baskets. It is probably the most important matting sedge of the Philippines, where it is extensively used for making sleeping mats, floor mats, and to a lesser extent, hats, slippers, handbags, tobacco cases and cushions. In Leyte and Samar *F. umbellaris* weaving is an important alternative income source for farmers. In Indonesia the principal use is for sleeping mats, but it is also utilized for small wickerwork. The stems also serve as string for tying.

In the Philippines *F. umbellaris* is administered as a medicine to treat enlarged spleen. A weed in rice fields, it is ploughed in as green manure.

Production and international trade In Tasikmalaya Regency, the centre of plaited handicraft industry in West Java, the total area under *F. umbellaris* cultivation in 1989 was 55 ha, with a total production of about 800 t. Local production supplied about 50% of the *F. umbellaris* material used, the rest was brought in from Central and East Java. Indonesia exports mats made from *F. umbellaris*, but trade statistics are not available. In the Philippines the production and local trade is concentrated in eastern Visayas and northern Mindanao, but production statistics are not available. In the Philippines *F. umbellaris* products are considered to have great export potential, but due to current limitations in the supply of raw materials, even local demand cannot be met.

Properties Processed *F. umbellaris* stems are up to 4 mm wide, flat and supple, with an elastic feel and a light-grey to white colour. They are strong and durable and have good dye-absorbing characteristics, when properly harvested and processed. Stems of inferior quality lose their suppleness during processing, develop a red-brown coloured surface and are not suitable for weaving.

Description An erect, glabrous, perennial herb, up to 120 cm tall, with a short horizontal rhizome clothed with brown scales, growing densely tufted in a clump. Stem rigid, obtusely trigonous to subterete, 20–120(–200) cm × 1–5 mm (in cultivation reaching 2 m or taller), usually flattened below the inflorescence, striate, smooth, light green. Leaves on the stem reduced to bladeless, cylindrical, obliquely truncate sheaths with brown margins, lower ones scale-like, 2–4 cm long, the upper ones up to 20 cm long; leaves of sterile shoots narrow and short, flat or canaliculate, about 1.5 mm wide, without ligule. Inflorescence usually a much reduced simple or compound umbel or open corymb, up to 10 cm long, with up to 40 spikelets; basal involucral bracts 2–3, erect, lanceolate, up to 1 cm long; primary rays up to 10, unequal, up to 5 cm long, smooth; spikelets solitary, globose, ovoid or ellipsoid, 4–8(–12) mm × 3–4 mm, densely many-flowered, red-brown; rachilla persistent, narrowly winged; glumes spirally arranged and tightly imbricated, membranous, ovate, up to 2.5 mm × 1.5 mm, base obtuse, margins broadly white-membranous, apex rounded and often torn, obscurely 2–3-veined on both sides of the ridged midrib which ends below the apex; flowers bisexual; stamens 2–3, about 1 mm long, anthers oblong-linear; style 1–2 mm long, widened at the base, glabrous, usually trigonous with 3 stigmas, sometimes flat with only 2 stigmas, articulated with the ovary (falling off as a whole). Fruit nut-like, a



Fimbristylis umbellaris (Lamk) Vahl – 1, habit; 2, spikelet; 3, glume, dorsal view; 4, flower with 2 stigmas; 5, fruit.

compressed-trigonous or biconvex achene, 0.8–1 mm × 0.6–0.8 mm, finely warty, pale yellow when mature.

Growth and development In Java *F. umbellaris* is established and starts tillering at 1–2 weeks after planting of a clump division. Tillering continues until the plants are 4–5 months old and have about 100–120 stems. The plants are normally harvestable at 3–6 months after planting, before flowering has started and may be harvested repeatedly. With good care, a crop may last up to 9 years. In Java *F. umbellaris* flowers year-round. Natural propagation is by the fruits, which are dispersed by water, birds and soil tillage. *Fimbristylis* Vahl has C_4 photosynthesis.

Other botanical information *F. umbellaris* is often referred to as *F. globulosa*. However, the epithet *umbellaris* is correct because *Scirpus umbellaris* was described a few months earlier than *S. globulosus*. Plants with two stigmas have been considered as a different species (described as *F. torresiana* Gaudich. or *F. utilis* Elmer). However, they cannot be segregated satisfactorily from plants with three stigmas. The cultivated form is a stout cultivar with two stigmas. In Indonesia two forms have been distinguished, a fast-growing ('genjah') and a slow-growing ('dalam'). The stems of the former are shorter and narrower and said to be less durable. In Tasikmalaya Regency (West Java) the slow-growing form is mostly cultivated.

Ecology *F. umbellaris* grows well at an average temperature of 25–27°C with ample sunshine. It generally needs fertile soils with regular irrigation and grows well on soils rich in organic matter and on clay loams or sandy loams, with a pH of (4.5–)6–7(–8). It is sometimes grown in a 'sawah' (irrigated rice field) which is less suitable for rice cultivation, but more often it is planted in naturally wet locations, which are terraced like sawahs. In Tasikmalaya Regency it is usually grown at 300–700 m altitude. *F. umbellaris* grows wild, frequently abundantly, in open, wet locations, such as swamps and grassland, usually at low altitudes, rarely up to 1000 m. In Indonesia *F. umbellaris* is considered a weed of minor importance in rice fields, where it can be controlled by chemical means.

Propagation and planting *F. umbellaris* can be propagated by seed or vegetatively by clump division. Where it is cultivated, planting material is normally obtained by division. The plant spacing is 15–30 cm, depending on soil conditions. Dead or missing plants are replaced 1–3 weeks after planting. The field is prepared by hoeing or ploughing and harrowing and sometimes enriched with manure, after which it is levelled and divided into compartments to facilitate water management. Because it is grown in wet locations, *F. umbellaris* can be planted throughout the year. In the Philippines the onset of the rainy season is considered the ideal time for planting. Because of the rather intensive husbandry, planted *F. umbellaris* fields in Java are always close to the home. In West Java cultivation of *F. umbellaris* is sometimes combined with aquaculture, with the fish (carp and tilapia) usually fed rice bran. Here, the crop is planted at a spacing of 40 cm × 40 cm, and fish are released 3 days after planting. In natural stands in the Philippines the average density is about 150 000 clumps per ha, with each clump having up to 160 stems.

Husbandry Regular weeding is necessary in young *F. umbellaris* plantings, but profusely tillering plants compete effectively with weeds.

In West Java, chemical fertilizers are applied: per ha 60–90 kg N, 30–40 kg P and 10–13 kg K, with the N application repeated after each harvest. In the crop-fish system in West Java, the fields receive about 100 kg/ha N in the first 2 months of each cropping cycle.

Old plantings must be thinned when the clumps become too big. In the Philippines overmature stems are removed to enhance sucker production.

Diseases and pests In the Philippines the major pests of *F. umbellaris* are stem-borers, which feed inside the stems and cause yellowing of the plants, and the golden snail ('kuhol'). The stem-borers are checked by picking the larvae, whereas snails are controlled by draining the field and collecting the exposed snails and eggs. Insects found in a production and storage room in Tasikmalaya Regency (West Java) were *Ahasverus advena* (grain beetle) and *Ectopsocus pumilis* (both fungivorous), *Cardiocondyla* sp. and *Xylocoris flavipes* (predators), *Lepisma saccharina* (silverfish; xylophagous), and *Minthea rugicollis* (phytosaprophagous).

Harvesting The first harvest of *F. umbellaris* takes place 3–6 months after planting, when the stems are still green. Overmature stems become hard and brittle when dry and are not suitable for weaving. Subsequent harvests are at 2–4 month intervals. For natural stands in the Philippines the recommended harvest level is 50% of the stems every 2–4 months.

In Indonesia the water is drained from the fields just before harvesting. The stems are cut with a knife or sickle. Only as many stems are harvested as can be processed in a day, since unprocessed stems become brittle when kept overnight. After the fields have been harvested, fertilizer is applied and 1–2 days later they are inundated again. After the final harvest the clumps are pulled out and those with thick stems and a well-developed root system are used for propagation. In the Philippines harvesting is done by pulling out the stems.

Yield On fertile soils and with adequate husbandry the first harvest of *F. umbellaris* can yield 18 t/ha of fresh material or 6 t/ha of dry clean material. The average yield of fresh material in Tasikmalaya Regency in 1989 was 15 t/ha. From natural stands in the Philippines 20–25 million stems may be harvested per ha per year, whereas plantings with a spacing of 25 cm × 25 cm may yield 10 million stems per ha per year.

Handling after harvest In Indonesia, the damaged, short and too old stems are removed from the harvested *F. umbellaris* material. The selected green stems are dried and bleached by spreading them in the sun and covering them with a thin layer of ash or sand. Good material turns light grey and remains shiny and supple. The dried material is washed and the stems are tied in bundles of about 450 stems, cut to an equal length of about 75 cm. In Blitar (East Java) the wet stems are rubbed with sand to remove the green colour and they are flattened with a pestle.

In the Philippines the harvested stems are bundled and dried in the sun for 3–5 days, until they become pliant and unbreakable. Stems not dried immediately after harvesting deteriorate in quality and colour. After drying, the stems are sorted and graded according to length (primary, longer than 2 m; secondary, 1–2 m long; and tertiary, less than 1 m) and diameter (small, less than 2 mm; medium, 2–3 mm; and large, over 3 mm). Stalks of similar length and diameter are tied into bundles of about 0.45 kg. Secondary stems are normally used for the larger 'double-sized' mats and tertiary stems for the smaller 'single-sized' or 'baby' mats. Before weaving, the stems are usually dyed and flattened by pressing them against an instrument called 'lag-ot'. Weaving may be done manually or on a wooden handloom. Weaving should be done in the early morning or late afternoon, or on rainy days, because the stems become brittle and difficult to weave at low relative humidity. Woven mats may be embroidered, for instance with coloured leaves of *Corypha utan* Lamk.

Genetic resources and breeding No germplasm collections or breeding programmes of *F. umbellaris* are known to exist.

Prospects The prospects for the production of *F. umbellaris* handicrafts for the tourist industry and for export are promising. However, local demand for *F. umbellaris* products may decrease as a result of the import of synthetic products. From an environmental point of view this substitution is undesirable.

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U.A. Dasuki

Furcraea foetida (L.) Haw.

Syn. pl. succ.: 73 (1812).

AGAVACEAE

$2n = 18, 34, 60$

Synonyms *Agave foetida* L. (1753), *Furcraea gigantea* Vent. (1793), *F. tuberosa* Hassk. (1856).

Vernacular names Mauritius hemp, green aloe (En). Chanvre de Maurice, aloès vert, fourcroya (Fr). Vietnam: giwa dai hai.

Origin and geographic distribution *F. foetida* is native to tropical South America and it is distributed from southern Mexico (Yucatán) to the northern and eastern coast of South America and the south-eastern Antilles. It has been introduced into many tropical and subtropical countries as an ornamental, hedge plant or fibre plant and is often naturalized. In some areas it has become a noxious weed. Experimental plantings for fibre production have been established in many regions including South-East Asia, e.g. in Java and the Riau Archipelago (Indonesia), in Peninsular Malaysia and Singapore, and in Vietnam. It has been grown on a commercial scale in Mauritius, Madagascar and St Helena and in India, South Africa, Venezuela and Brazil. Nowadays it is mainly planted as an ornamental and in hedges, e.g. in

Java, where it is often grown in gardens and parks.

Uses Fibre from the leaf of *F. foetida* can be used for making twine, ropes, cloth and sacks. It can be woven into tapestries and mats. It has been used in admixture with other fibres such as those from abaca (*Musa textilis* Née) and sisal (*Agave sisalana* Perrine) for the production of medium grade cordage. *F. foetida* hedges form an effective barrier against humans and animals and are, for instance, planted along railway tracks in India and Sri Lanka.

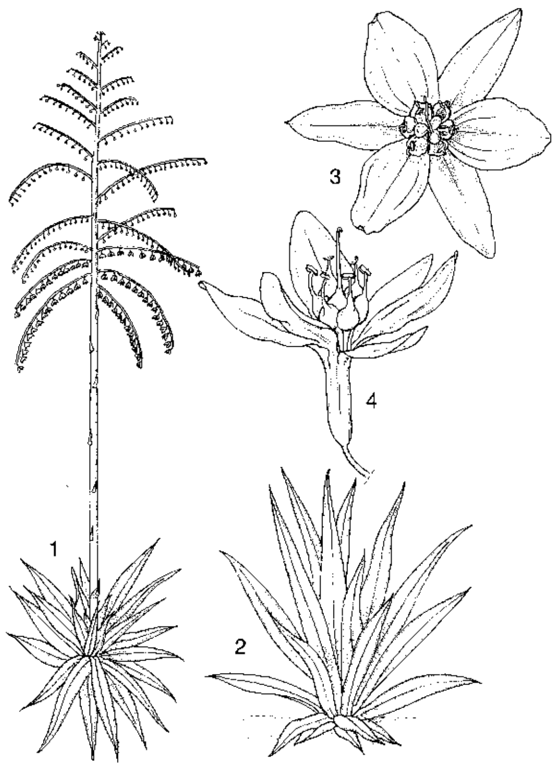
Production and international trade No recent production or trade statistics for *F. foetida* are available. In the 1950s the area under *F. foetida* in Mauritius, the main producing country, was about 7000 ha (of which about 5600 ha were wild), giving an annual production of about 1000 t fibre, mainly used locally for the production of sugar bags. Since then production has declined.

Properties The fibre content of fresh *F. foetida* leaves is (1.0–)2.0–2.5(–3.8)%, which is less than that of sisal and cantala (*Agave cantala* Roxb.). The extracted fibres are 1–2 m long. The ultimate fibre cells are (1.0–)1.3–3.8(–6.1) mm long and (14–)15–24(–42) μm wide, with rather thin walls and wide lumina. The longitudinal cell shape is approximately cylindrical, the cross-sectional shape of cell and lumen is polygonal. *F. foetida* fibre is longer, finer, softer and whiter than sisal fibre, but it is not as strong. It takes dyes fairly well. The deterioration in sea water of rope made of *F. foetida* fibre is similar to that of rope made of sisal or abaca, but because of its low strength, *F. foetida* rope is not considered suitable for marine cordage. In studies in Indo-China in the 1940s, the fibre of *F. foetida*, separated by retting for 13 days, contained 63% cellulose, 18% pentosans, 12% lignin and 2% ash.

The leaves contain an irritant substance in the sap and handling the crop requires protective gloves. The juice is toxic to fish, guinea pigs and rabbits. The leaves of *F. foetida* contain hecogenin (0.3% of the leaf dry weight), a steroid sapogenin which can be used as a precursor in the partial synthesis of corticosteroids. However, the leaves also contain tigogenin (0.2%), a contaminant of hecogenin. Furcreastatin, a steroid saponin consisting of hecogenin as the aglycone and a hexasaccharide, has been isolated from Thai *F. foetida* leaves and has shown cytotoxicity on mutated mouse fibroblasts at lower doses than on the parental cell line. It has also shown cytotoxic activity on various human carcinoma cell lines.

Adulterations and substitutes For rope-making *F. foetida* competes with sisal and abaca, with the latter two possessing clear advantages in terms of fibre strength and the availability of good machines for fibre extraction. For the production of sacks, jute (*Corchorus* spp.) and synthetic products are substitutes.

Description A robust, perennial herb with a short thick stem up to 50 cm tall, bearing about 50 densely crowded leaves. Leaves broadly oblanceolate to lanceolate, larger ones 1–2.5 m × 12–20 cm, margin usually with upcurved, robust spines 4–10 mm long, red-brown, 1.5–6 cm apart, sometimes upper half or total leaf spineless, apex ending in flexible spine 5 mm long, tough-fibrous, glossy green, lower surface manifestly rough in the middle of the upper half, leaves fetid when bruised. Inflorescence a terminal panicle, 6–13 m tall; peduncle 6–10 m long; pedicels bearing bracteoles in the axils of which bulbils are produced; flowers bisexual, about 4 cm long, greenish-white outside, white inside; perianth lobes 6, almost free, ellipsoid, 3 outer ones 11–14 mm wide, 3 inner ones



Furcraea foetida (L.) Haw. – 1, habit of flowering plant; 2, habit non-flowering plant; 3, flower in top view; 4, flower in side view.

14–18 mm; stamens 6, filaments about 1 cm long, thickened in lower half, anthers 4–5 mm long; pistil with inferior, 3-locular ovary bearing many ovules, style about 1 cm long, basally much thickened and trilobed, upper half filiform ending in small stigma. Fruit a capsule, ellipsoid-trigonous, loculicidally 3-valved, with numerous but rarely produced seeds. Seeds flat.

Growth and development *F. foetida* is a monocarpic plant, dying after flowering, and has a life span of 7–10(–16) years, in which about 200 leaves are formed. The leaves continue to elongate for about 5 months after they leave the central spindle, resulting in longer leaves than those found in sisal, whose leaves do not elongate much after leaving the spindle. At flowering, which in Java may occur at any time of the year, long slender poles are produced, with bisexual flowers. Pollination is probably by moths and bees. The plants do not form suckers and they rarely set seed, but bulbils are formed in the inflorescence and they develop roots after they fall to the ground.

Other botanical information *Furcraea* Vent. is a poorly known tropical American genus with about 20 species of arid and semi-arid regions, formerly often classified in the larger family *Amaryllidaceae*. In taxonomic literature, orthographic variants of the name *Furcraea* can be found, including e.g. *Fourcroea*, *Fourcroya*, *Furcroea* and *Furcroya*. *Furcraea* resembles *Agave* L. but can be distinguished by its flowers, which have a rotate white perianth, with stamens shorter than the perianth, and filaments and style thickened below the middle.

In Mauritius, fibre is mainly obtained from *F. foetida* var. *willemettiana* Roem., known locally as 'common aloe' or 'aloe creole', which differs from the species type ('aloe malgache') by its leaves, which are smaller, with short inconspicuous spines at the leaf tip, more sharply upwards curving marginal spines and a higher fibre content. The ornamental cultivar 'Mediopicta' has broad, spineless, variegated leaves and is considered particularly attractive.

F. selloa K. Koch, grown as a fibre plant in Central America, yields a fibre identical to that of *F. foetida*; it is grown as an ornamental in Peninsular Malaysia. Other *Furcraea* species cultivated for their fibres in tropical America and occasionally elsewhere include *F. andina* Trel., *F. cabuya* Trel., *F. cahum* Trel., *F. guatemalensis* Trel., *F. hexapetala* (Jacq.) Urb., *F. humboldtiana* Trel., *F. macrophylla* Baker and *F. quicheensis* Trel.

Ecology High temperatures and semi-humid conditions are essential for optimal growth of *F. foetida*. In Mauritius it occurs in areas with an average annual rainfall of about 1000 mm, with most precipitation from December to March. *F. foetida* seems to prefer shade. It grows well on many soils, but prefers fertile sandy clays.

Propagation and planting *F. foetida* is propagated by bulbils, which may be raised in nurseries and transplanted into the field after about a year. In Mauritius it is planted at a density of 5000–7500 plants/ha in double rows.

Husbandry *F. foetida* plantations in Mauritius are not weeded, but the lanes between the rows are cleared just before harvest.

Diseases and pests *F. foetida* is a host of the Mexican sisal weevil (*Scyphophorys interstitialis*), the most important insect pest of sisal.

Harvesting The first harvest of *F. foetida* usually takes place when the plants are 3–4 years old and subsequent harvests every (8–)18–36 months thereafter. At each harvest 30–40 leaves are cut and 5 leaves are left on the plant. After a leaf is harvested, the terminal spine is cut off and the butt trimmed, after which the leaves are bundled and tied.

Yield Recent yield data are not available, but average fibre yields of cultivated *F. foetida* in Mauritius in the 1950s were about 3.7 t/ha per cutting, from about 150 000–200 000 leaves, whereas yields from wild plants were about one-third of those from cultivated plants. On some estates fibre yields of 5 t/ha per harvest and 2.5 t/ha per year have been obtained. In Java it was estimated, on the basis of experimental plantings, that one hectare with 1270 plants would yield about 250 000 leaves and 5 t fibre over the life cycle of the crop.

Handling after harvest Fibre extraction of *F. foetida* is normally by decortication and retting. The fibres must be extracted as soon as possible after harvest because drying makes decortication more difficult. Decortication is by hand or by machine, but there are no machines with an output and efficiency level for *F. foetida* similar to that of sisal decorticators. After decortication, the fibres, still containing extraneous matter, may be retted for 2 or more days. Soap may be added to the retting tanks to improve the colour. After decortication and retting the extracted fibres are washed and dried in the sun, after which they may be brushed to make them softer and more lustrous. Finally they are graded and baled for the market.

Genetic resources and breeding No germplasm collections or breeding programmes of *F.*

foetida are known to exist. Breeding is difficult because of the general inability of *F. foetida* to produce seed, though seedlings have on occasion been obtained.

Prospects In view of the competition from jute for the manufacture of sacks, from sisal and abaca for rope-making, and from synthetic products for both, there is little prospect for revitalization of commercial *F. foetida* production in Mauritius or elsewhere. Experimental plantings have shown that *F. foetida* can be grown for fibre in South-East Asia. However, it seems not worthwhile re-establishing it as a fibre crop for local use, since superior fibre crops such as sisal and abaca are already available in the region.

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S. Brotonegoro

Gossypium L.

Sp. pl.: 693 (1753), Gen. pl., ed. 5: 309 (1754).

MALVACEAE

x = 13; *G. arboreum*, *G. herbaceum*: $2n$ = 26 (diploids); *G. barbadense*, *G. hirsutum*: 52 (allotetraploids)

Major species and synonyms

- *Gossypium arboreum* L., Sp. pl.: 693 (1753), synonyms: *G. indicum* Medik. (1784), *G. obtusifolium* Roxb. ex G. Don (1831), *G. nanking* Meyen (1834).
- *Gossypium barbadense* L., Sp. pl.: 693 (1753), synonyms: *G. vitifolium* Lamk (1786), *G. acuminatum* Roxb. ex G. Don (1831), *G. brasiliense* Macfad. (1837).
- *Gossypium herbaceum* L., Sp. pl.: 693 (1753), synonym: *G. frutescens* Lasteyrie (1808).
- *Gossypium hirsutum* L., Sp. pl., ed. 2: 975 (1763), synonyms: *G. religiosum* L. (1767), *G. latifolium* Murray (1776), *G. javanicum* Blume (1825).

Vernacular names General: cotton (En). Coton, cotonnier (Fr). Indonesia: kapas. Malaysia: kapas. Philippines: kapas (Ilokano), bulak (Tagalog), indamey (Bontoc). Cambodia: krabas. Laos: fay hua. Vietnam: chi b[oo]ng.

- *G. arboreum*: tree cotton (En). Coton arborescent, cotonnier arborescent (Fr). Indonesia: kapas merah (general), kapas beureum (Sundanese), kapas jawa (Javanese). Cambodia: krabas tes. Thailand: faai daeng (Bangkok). Vietnam: b[oo]ng c[or], bong hang ni[ee]n.
- *G. barbadense*: sea island cotton, Egyptian cotton, Pima cotton (En). Coton des Indes Occidentales, cotonnier d'Egypte (Fr). Indonesia: kapas rampit, kapas kayu. Philippines: pernambuko (Tagalog, Bikol), bulak-kastila (Tagalog). Laos: dok foy. Thailand: faai chan (Lampang), faai dok (Chiang Mai), faai thet (north-eastern). Vietnam: b[oo]ng h[ar]i d[ar]o.
- *G. herbaceum*: Arabian cotton, Levant cotton (En). Cotonnier herbacé, cotonnier d'Asie (Fr). Thailand: faai (general).
- *G. hirsutum*: upland cotton, American upland cotton (En). Coton velu, cotonnier américain (Fr). Indonesia: kapas mori (Java), kapas kejerat (Sumatra). Vietnam: b[oo]ng lu[oof]i.

Origin and geographic distribution *Gossypium* comprises 40–50 species distributed in warm temperate to tropical zones. The origin of the genus is unknown, but 3 primary centres of diversity exist: in Australia, in north-east Africa to Arabia, and in west-central to southern Mexico. The 4 cultivated cottons of the world (the Old World diploid 'desi-cottons' *G. arboreum* and *G. herbaceum* and the New World tetraploids *G. barbadense* and *G. hirsutum*) have been domesticated independently in different parts of the world. The 4 species are probably all grown in South-East Asia although some doubt exists about *G. herbaceum*.

G. arboreum is only known in cultivation. Its origin is uncertain. It may have developed from *G. herbaceum*, though molecular comparisons support the hypothesis that *G. arboreum* and *G.*

herbaceum diverged from a common ancestor. It has been cultivated in South and South-East Asia and southern China for many centuries. It is still found there, but has mostly been replaced by *G. hirsutum*.

G. barbadense probably originated in Peru as a cross between *G. herbaceum* and *G. raimondii* Ulbrich or *G. gossypioides* (Ulbrich) Standley. It grows naturally on the coasts of Peru and Ecuador and perhaps the Galapagos Islands. It was domesticated in north-western South America, is cultivated in South and Central America and has been introduced into Africa, Asia and the Pacific Islands, where it has become established in some regions. It was introduced into the United States in 1785 where it was known as 'sea island cotton', as opposed to 'upland cotton', the name for *G. hirsutum*. Cv. group Braziliense has long been cultivated in South-East Asia for local home industry, whereas representatives of cv. group Barbadense were introduced into South-East Asia in the 20th Century, but usually with little success.

G. herbaceum is possibly native to South Africa and reached Asia and America in early prehistoric times. It is cultivated in Asia and Africa, and sometimes planted in the New World. It has possibly been grown in South-East Asia, e.g. in Indonesia and Cambodia.

G. hirsutum probably originated as a cross between *G. herbaceum* and *G. raimondii* or *G. gossypioides* in southern Mexico and was domesticated in Central America or northern South America. It has become the main cotton of commerce and is widely cultivated throughout the warmer parts of the world, including South-East Asia. It has often naturalized.

Cotton has been gathered and cultivated on different continents for thousands of years. The oldest evidence of the use of cotton, probably *G. arboreum*, as a fibre plant in the Old World was found in Pakistan and is estimated to date from about 2300 BC. In Peru, cotton products from *G. barbadense* such as yarn, cordage and fishing nets date back to about 2500–3500 BC. For a very long period India was the centre of cotton-cloth production, but developments in the second half of the 18th Century altered this situation. The main factors were the invention of the high capacity saw gin in North America in the 1790s, resulting in a strong increase in cotton production in the United States, and the development of the mechanized power-driven factory system in England in the second half of the 18th Century. Following these developments, a rapid expansion of the cultivation and use of cotton occurred in the 19th Century, and the share of cotton in world textile production increased from only 4% at the end of the 18th Century (versus 78% for wool) to about 80% by the end of the 19th Century. In South-East Asia cotton-cloth was already being imported from India some 2000 years ago, and subsequently cotton cultivation and home ginning, spinning and weaving became established in the region. Cotton cloth production in South-East Asia gradually declined in the 19th century due to the vigorous expansion of the European cotton industry.

Uses Cotton is the most important fibre plant in the world. The main fibres of the cotton plant are the longer seed hairs ('lint'), used for making yarn to be woven into textile fabrics, alone or in combination with other plant, animal or synthetic fibres. Cotton lint is also made into other products including sewing thread, cordage and fishing nets. Cotton textile cuttings and rags serve in the paper industry for the production of the best writing, book and drawing paper. Short fibres ('fuzz' or 'linters') are processed into a range of products, including paper, twine, automobile upholstery, explosives, plastics and photographic film. Linter pulp is made into different types of paper, depending on its grade. Linters have also been used for the production of cellulose acetate and viscose. Cotton stalks are processed into paper and paperboard, for instance in China, and into cement-bonded particle board.

Cotton is an important oil plant. The oil serves locally for cooking and frying and industrially in a range of products, including margarine, mayonnaise, salad and cooking oils, salad dressing and shortening. The oil is also made into soap, cosmetics, lubricants, sulphonated oils and protective coatings. The residual seed cake is an important protein concentrate for livestock. Low-grade cake is used as manure. The whole seed can be fed to ruminants, which are less sensitive to the toxic gossypol in the seed than non-ruminants, or is applied as manure. Hulls are a low-grade roughage for livestock or serve as bedding or fuel. Leftover bolls, 'burs', leaves and thin twigs are grazed by ruminants. Dry stalks serve as household fuel.

In the Philippines a decoction of *Gossypium* leaves is applied medicinally against diarrhoea and mild dysentery. In Indo-China entire plants are antifebrile; a decoction is taken against malaria and other fevers; an infusion of flowers and leaves is used as a pectoral; a concentrated maceration is utilized against inflammation; the roots are astringent, antidysenteric, diuretic and emollient, and they are used in fumigations against haemorrhoids.

Production and international trade The estimated annual world cotton production in 1996–2000 was 53.5 million t seed cotton (unginned cotton, containing seed, lint and fuzz) or 18.7 million t lint, from 33.2 million ha. The main producers were China (4.3 million t lint per year), the United States (3.7 million t), India (2.0 million t), Pakistan (1.7 million t) and Uzbekistan (1.1 million t). The main producing country in South-East Asia in this period was Burma (Myanmar), with about 55 000 t per year, whereas smaller amounts were produced in Vietnam (24 000 t), Thailand (15 000 t), Indonesia (9000 t), Laos (6000 t) and the Philippines (1000 t). More than 90% of the world cotton production comes from *G. hirsutum*, which is highly productive and shows strong yield responses to improved growing conditions, fertilizers, crop protection and supplementary irrigation. Most of the remainder comes from *G. barbadense*, which produces longer, finer and more expensive fibre than *G. hirsutum* but yields less and shows limited adaptation to most cotton-growing areas. *G. arboreum* and *G. herbaceum* are grown to some extent in Asia and Africa. In India, for instance, about 10–15% of the cotton area is under *G. arboreum* and 13% under *G. herbaceum*.

In 1996–2000 world cotton lint exports amounted to about 5.4 million t per year, with a value of US$ 7.8 million. The major exporting countries were the United States (1 210 000 t per year), Uzbekistan (820 000 t), Australia (610 000 t), Argentina (250 000 t) and Turkmenistan (180 000 t). There was hardly any export from South-East Asian countries. The main importers in 1996–2000 were China (620 000 t), Indonesia (490 000 t), Brazil (390 000 t), Turkey (350 000 t), Italy (320 000 t) and Thailand (310 000 t). Malaysia imported 75 000 t per year, Vietnam 61 000 t per year, and the Philippines 57 000 t per year. South-East Asia uses about 1 million t of cotton lint per year but produces only 100 000 t and must therefore import 900 000 t. The low cotton production in South-East Asia is mainly due to unattractive pricing by buyers, averaging US$ 0.40 per kg seed cotton, whereas imported cotton lint costs US$ 1.80 per kg (equivalent to a seed cotton price of about US$ 0.60 per kg).

The world cottonseed oil production in 1996–2000 averaged 3.7 million t per year. The major producers were China (960 000 t), the United States (490 000 t), India (400 000 t), Pakistan (340 000 t), Uzbekistan (240 000 t) and Turkey (220 000 t). In South-East Asia, Burma (Myanmar) produced about 16 000 t cottonseed oil per year in 1996–2000, Thailand about 5000 t, Indonesia about 3000 t and Laos about 2000 t.

Cotton production systems range from smallholdings in most developing countries to large-scale farms in developed countries.

Properties Cotton fibres are unicellular extensions of epidermal seed cells. One seed produces 12 000–16 000 fibres. Some hairs remain short and form the 2–7 mm long fuzz covering the ripe seeds, providing the commercial linters. Seeds of some genotypes, particularly modern *G. barbadense* cultivars, do not produce any fuzz. More important are the long hairs ('lint'), which are more than 25 mm long in modern cultivars. The fibre walls contain many layers of cellulose chains, which run spirally and give dry cotton fibres their characteristic twisting appearance. The hairs are covered with a waxy cuticle, giving unprocessed fibre a greasy feel and making it water-repellent. Lint fibres are smooth-looking, ribbon-like and twisted, with the fibre walls showing longitudinal and spiral striations. Linter fibres are similar in appearance, but shorter, more cylindrical and with thicker walls. Cotton fibre contains 88–96% α-cellulose, 3–6% hemicelluloses and 1–2% lignin. Cotton lint fibres are 10–40(–64) mm long, with a diameter of (12–)18–28(–38) μm and a length:width ratio of 1000–4000. *G. barbadense* yields the highest quality lint of all cottons, with a fibre length of 30–40(–64) mm. The lint of *G. hirsutum* is about 20–30 mm long. *G. arboreum* yields short (normally less than 25 mm long), usually rather coarse lint. The lint of *G. herbaceum* is (10–)20–25 mm long and mostly coarse, though very fine fibres also occur and are processed into handmade, decorative traditional textiles (the 'woven winds of India'). In international trade, the fibre length or 'staple length' of cotton is expressed in fractions of inches. Commercial upland cotton (*G. hirsutum*), a medium staple cotton, generally has a range of staple length from 13/16 to 1 1/4 inch. Commercial pima cotton (*G. barbadense*), an extra-long staple cotton, mostly ranges from 1 5/16 to 1 1/2 inch. Apart from fibre length and its uniformity, the most important properties of cotton are strength, elasticity and fineness (diameter). The combined fineness and maturity (the degree to which the secondary cell wall has developed) of cotton fibre is usually determined by resistance to air flow, and expressed in a value called 'micronaire', reflecting the linear density of fibres. Typical values of the tensile strength, elongation at break, and

Young's modulus of cotton fibre are 285–595 N/mm^2, 7.0–8.0% and 5.5–12.6 GPa, respectively. Among the world's major textile fibres cotton has a unique combination of properties, being strong, comfortable, washable, durable and printable. It also blends well with other fibres to give it additional strength, lustre and crease resistance.

Cotton seeds remaining after ginning consist of linters (5–10%), oil (15–33%), oilcake (33–45%) and hulls (24–34%). The semi-drying oil is obtained by mechanical and/or solvent oil extraction from the seed. The principal fatty acids in cottonseed oil are linoleic acid (42–55%), palmitic acid (20–27%) and oleic acid (19–25%). The oil as well as other plant parts of *Gossypium* contain gossypol, a triterpenoid aldehyde, which is toxic to monogastric animals in particular. Gossypol has insecticidal, antimicrobial, antifertility and antitumour properties. Gossypol and related compounds have been implicated in conferring insect tolerance or resistance and antimicrobial properties to cotton plants. Glandless, gossypol-free cultivars exist, but they are more vulnerable to pests. Gossypol can be removed from the oil by solvent extraction, following mechanical and/or solvent oil extraction from the seed. The cake and meal contain over 40% crude protein, but, because of the gossypol present, are not without danger for monogastric animals. The gossypol in the cake can be removed or made harmless by chemical (ferrous salts) or physical (heating) means, but this is more difficult to achieve economically than in case of the oil.

The 1000-seed weight is 100–130 g.

Description Annual herbs, subshrubs, perennial shrubs or rarely small trees, nearly all parts irregularly dotted with black oil glands. Leaves spirally arranged, most often palmately lobed or parted, margin entire, palmately veined, usually with 1–5 nectaries on the central basal veins beneath. Flowers solitary, usually on sympodial branches; pedicel not articulated, below the insertion of the epicalyx segments usually bearing nectaries; epicalyx segments (bracteoles) 3, free or connate at base, usually leaf-like, entire or dentate to deeply gashed into long triangular segments, persistent; calyx cup-shaped, truncate, undulate or 5-dentate or 5-lobed, outside at the base usually bearing 3 nectaries; corolla with 5 imbricate, showy petals, yellow, white, red or purple, often with a purple or purple-spotted centre; stamens numerous, forming a column, lower part of filaments united into a tube, upper part usually free with unicellular anthers; pistil with 3–5-loculed ovary and one short style with clavate, 3–5-sulcate stigma. Fruit (boll in agronomic literature) a capsule, globular to ovoid, rarely fusiform, opening loculicidally. Seed ovoid, with a dense covering of long woolly hairs (lint or floss) and sometimes also with a fine, short tomentum (fuzz). Seedling with epigeal germination.

- *G. arboreum*. An annual or perennial shrub or small tree, 1–2 m tall, extremely variable, most parts densely covered with minute stellate hairs and patent simple hairs. Twigs slender, prostrate, terete. Petiole 1.5–14 cm long; stipules linear to lanceolate, often falcate, 4–15 mm long; leaf-blade ovate to orbicular in outline, 2–12 cm in diameter, palmately lobed or parted with 3–7 segments, frequently with an extra tooth in the sinuses, base cordate and 5–7-veined, 1–3 veins with an oblong nectary. Pedicel 0.5–2 cm long, usually without apical nectaries; epicalyx segments closely embracing the corolla and fruit, rarely spreading, 1.5–3.5 cm × 1.3–3 cm, united for 1 cm or more, base deeply cordate, margin entire or remotely toothed, apex acute, slightly accrescent in fruit; calyx cupular, about 5 mm tall and 7 mm wide, inconspicuously 5-dentate; petals obovate, 3–4 cm long, at opening usually cream to yellow and after 1–2 days turning red or purple, with or without a purplish centre; staminal column 1.5–2 cm long, filaments 1.5–2 mm long. Capsule ovoid to globular, 1.5–2.5 cm in diameter, beak 3–5 mm long, after dehiscing and splitting often reflexed, outside densely pitted and glabrous, 3–4-celled. Seeds 5–8 per cell, ovoid to globular, 5–8 mm in diameter, lint copious, fairly long, white or rusty, firmly attached to the seed; fuzz present.
- *G. barbadense*. An annual subshrub, perennial shrub or small tree. Twigs first angled, becoming terete, often tinged with purple. Petiole as long as or slightly longer than the leaf-blade; stipules large, leaf-like, linear, lanceolate or ovate, in flowering shoots often broadly ovate to orbicular and auricled at base; leaf-blade orbicular to broadly ovate in outline, 3–5-palmately parted with central segment largest, superior leaves sometimes not segmented, base cordate, 3–7-veined, 1–3 central veins with an elliptical nectary slightly above the base beneath. Flowers with pedicel shorter than petiole, sharply trigonous, at apex usually with nectaries; epicalyx segments erect, appressed against corolla or fruit, orbicular to ovate, large, at base cordate and strongly auricled, with 10–15 acuminate teeth; calyx cupular with 5 obtuse short teeth at

truncate apex, densely gland dotted, at base with 3 nectaries, splitting after flowering; corolla usually yellow with a dark red spot at the base, petals obovate, 5–8 cm long, truncate and emarginate at apex; staminal column erect, 3–4 cm long, filaments short. Capsule ovoid to fusiform, beaked, glabrous, densely pitted, black. Seed ovoid with an acute hilum, black to dark brown, lint long, fine, white and easily removed, fuzz only at the hilum.

- *G. herbaceum*. A perennial or annual shrub or subshrub, usually 1–1.5 m tall with few branches. Stem thick and rigid, twigs and young leaves usually sparsely hairy, fruiting branches mainly jointed. Stipules small, linear, caducous; leaf-blade 3–7-lobed, cut less than halfway; lobes ovate to rounded, only slightly constricted at the base, without accessory lobes between the main lobes, glands present on midrib. Pedicel glandless; epicalyx flaring widely from the flower and the fruit, rounded or broadly triangular, usually broader than long, cordate at base, margin with 5–13 triangular teeth; corolla 3.5–5 cm long, yellow or white with a dark centre; staminal column antheriferous throughout, filaments short; style short, stigma entire, rarely cleft at the top. Capsule rounded, 2–3.5 cm long, beaked, surface smooth or very shallowly dented, with few oil glands, 3–4-valved, opening slightly when ripe. Seeds up to 11 per valve, with pure white, long lint and short fuzz, strongly attached to the seed.
- *G. hirsutum*. An annual herb or perennial shrub, 1–3 m tall. Petiole 2–10 cm long; stipules ovate to lanceolate, often falcate, 6–13 mm × 2–5 mm; leaf-blade orbicular in outline, 3–15 cm in diameter, mostly palmately 3-lobed, rarely palmatifid, lower ones sometimes 5-lobed, upper ones occasionally ovate and entire, base cordate, 5–7-veined; segments broadly ovate to triangular, acuminate, sinuses acute to rounded, midrib nectary oblong. Flowers with pedicel 1–2.5 cm long, at apex with 3 nectaries; epicalyx segments free, closely enveloping the flower and fruit, widely ovate to triangular, 2–6.5 cm × 1.5–4 cm, at base deeply cordate and auricled, margin with 7–12 acuminate teeth; calyx campanulate to cupular, 6–7 mm tall and 6 mm in diameter, with 5 rounded (rarely acuminate) segments, outside with 3 inconspicuous nectaries, ruptured after flowering; corolla usually pale yellow to white, rarely with a purplish centre; petals obovate, 4–5.5 cm long; staminal column 1–2 cm long, filaments 3–4 mm long, higher ones longest. Capsule ovoid or globular, 2–5 cm × 1–1.5 cm, rostrate at apex, coarsely pitted, 3–5-celled. Seed ovoid, 3.5–5 mm long, acute at the hilum, black or brown with white or rusty, easy or difficult to remove lint and with fuzz everywhere or only at the hilum.

Gossypium hirsutum L. – 1, flowering branch; 2, flower in longitudinal section; 3, fruit; 4, opened fruit.

Growth and development Cotton is normally a perennial plant with an indeterminate growth habit, but is usually grown as an annual, with the formation of nodes on the main stem stopped by fruit load, temperature, soil moisture, photoperiod, or a combination of these factors. The crop cycle ranges from 120–220 days. Seedlings emerge 5–15(–20) days after sowing and the first true leaf unfolds 7–9 days later, but these processes vary with temperature. The plant remains unbranched for about 1 month. Upon germination, seedlings initiate a long taproot, which can reach a depth of more than 25 cm by the time the cotyledons unfold and may reach a depth of 3 m by mid-season. The shoot system is dimorphic, with the main axis and lower branches (emerging from axillary buds) being monopodial and vegetative, whereas the fruiting branches (emerging from extra-axillary buds) are sympodial. Fruiting branches develop as primary branches higher on the main stem and as secondary branches on vegetative branches. Generally only one sympodial branch develops at each main stem node, with 3–5 fruits per branch. The first sympodial branch appears at node 4–10 of the main stem, between 1 and 2 months after sowing, and visible flower buds appear as small, green, pyramidal structures, known as 'squares'. They need 20–35 days to develop into open flowers. The flowers mostly open near dawn and pollination normally occurs within a few hours. Self-pollination is the predominant mating system, but visiting insects can cause considerable outcrossing (usually 5–30%). The flowers turn pink in the afternoon and red by the following day. They start withering late on the second day and die on the third day. Flowering peaks at 3(–6) weeks after the onset and may continue for about 6 weeks. The fruits grow very quickly after pollination, reaching their final size at about 20–25 days. After a further (20–)25–45(–60) days, depending on genotype and environmental conditions, they are ripe. Usually the dry fruits open at their sutures and the white, fluffy fibre-mass emerges. The seeds remain attached to the placenta and are only separated by picking or by very strong rain or wind. During the first 2–4 weeks after flowering (the elongation phase) the fibres grow rapidly, reaching their full length, and during the next 4–6 weeks (the secondary thickening phase) the secondary cell walls of the fibres thicken through deposition of cellulose in consecutive layers. The fibre cell wall thickness, or the degree to which the fibre has been filled with cellulose, mainly depends on plant vigour during ripening. Upon boll opening the fibre dries and the lumen collapses, resulting in the characteristic twisted, ribbon-like appearance of the fibre that makes it spinnable.

Shedding of squares and young bolls is common in cotton. It is aggravated by adverse conditions such as prolonged overcast weather, extreme temperatures, water stress, water logging, nutrient deficiencies, diseases and insect damage. Commonly 60% of the squares and young bolls are shed, but flowers are rarely shed. Characteristic for cotton is its ability to overcome adverse events by compensatory growth. However, recovery is only partial and insignificant when severe insect damage occurs late in the season.

Other botanical information The taxonomy of *Gossypium* is complicated, partly due to the domestication of 4 distinct species and extensive interspecific hybridization. The literature is confusing and authors disagree on the identity of many species, subspecies, sections, varieties, forms, races and cultivars that have been distinguished. Currently the taxonomic system of P.A. Fryxell, with about 50 species grouped into 4 subgenera and 8 sections, is the most generally accepted one. It is mainly based on morphological and geographical data, but is confirmed by cytogenetic and molecular evidence. Cytological research has led to the recognition of 8 basic diploid 'genomic groups', designated A through G, plus K. In general, species within a genomic group can form fertile interspecific hybrids. *G. arboreum* and *G. herbaceum* are included in the subgenus *Gossypium*: diploid Old World species with A-genome, whereas *G. barbadense* and *G. hirsutum* belong to the subgenus *Karpas*: tetraploid New World species with AD-genome. Most probably the 4 cultivated cottons all occur in South-East Asia, but it is difficult to obtain confirmation about the exact cultivar groups that are grown from the literature alone. A brief survey of the major groups distinguished within the 4 species is given below.

G. arboreum is only known from cultivation. Its large variation has been classified into 6 geographical groups, usually indicated as races, but probably mostly cultivar groups:

- cv. group Bengalense: annual cottons, cultivated in eastern Bengal, western Bangladesh and Assam in regions that are subject to frost. The lint is coarse and short.
- cv. group Burmanicum: perennial cottons, cultivated in north-eastern India and South-East Asia, particularly Burma (Myanmar). The lint is variable.
- cv. group Cernuum: annual, long-bolled cottons, grown in northern India (Assam). Included by some in cv. group Burmanicum.
- cv. group Indicum: mostly perennial shrubs, although in India some annual cultivars ('Rozi' cottons) exist. It is the most primitive cultivated group within *G. arboreum*, and is mostly grown along the eastern coast of Africa and in Madagascar. The lint is scanty, course and frequently coloured.
- cv. group Sinense: annual cottons, early maturing. Cultivated in China, Korea and Japan. It provides the original Asiatic cotton.
- cv. group Soudanense: the 'Senaar' tree cottons, large perennial shrubs or small trees. It is grown in north-western Africa and the Sudan. The lint varies from coarse to moderately fine.

G. herbaceum is primarily known from cultivation but wild forms exist as well. It is usually subdivided into 5 races or cultivar groups:

- cv. group Acerifolium: cultivated perennial cottons, large, rounded, many-branched shrubs with small bolls, in which the seeds are sparsely covered with coarse lint. It is the most primitive cultivated form of *G. herbaceum* and is grown in northern Africa and Arabia. Some authors believe that this group is or has been cultivated in South-East Asia. However, others state that *G. herbaceum* is not grown at all in South-East Asia.

- cv. group Africanum: the group of wild forms in *G. herbaceum*, perennial bushy shrubs, many-branched, with small bolls. They are found in southern Africa, and is classified by some as a subspecies. In cotton production it plays a minor role but is considered the common ancestor of the cultivated diploid cottons.
- cv. group Kuljianum: annual, very small, slender, sparsely branched subshrubs, with small bolls and scanty lint of low quality. It is early maturing, selected for regions with short, hot summers and long, cold winters. Mainly cultivated in Russia and western China.
- cv. group Persicum: annual, small, sparsely branched, stout subshrubs, with large, round bolls and copious lint of moderate quality, adapted to regions with a relatively cool winter season. Initially spread around the Mediterranean, this was the first cotton cultivated in the Nile delta. Later it also spread to Afghanistan and Turkestan.
- cv. group Wightianum: annual, large, stout, moderately branched shrubs, with large bolls and copious lint of high quality. They are cultivated in western Peninsular India.

G. hirsutum is primarily known from cultivation, but wild forms exist as well. Several subdivisions have been proposed, but none is used widely. Some better known races or cultivar groups are:

- cv. group Latifolium: annual subshrubs with medium large to very large bolls, early maturing but with a wide range of day-length sensitivity. They are cultivated throughout Central America, extending pantropically. This is commercially the most important cotton group of the world, collectively also called upland cotton. Modern cultivars are difficult to identify on the basis of vegetative characteristics alone, making reliable seed propagation methods very important.
- cv. group Marie-Galante: perennial, strongly arborescent (dominant stem up to 14 cm in diameter) group, cultivated in northern and northeastern South America and the Caribbean. Cultivars are strongly day-length sensitive.
- cv. group Morrilli: stout, upright, profusely branched shrubs with a rounded appearance, with small, round bolls. Grown in central Mexico.
- cv. group Palmeri: pyramidally shaped, glabrous shrubs with distinctive laciniate leaves, flowering prolifically and bearing numerous small bolls. They are cultivated in western Mexico.
- cv. group Punctatum: perennial, slender stemmed shrubs, characterized by leaves with 3 lobes and shallow sinuses, bearing a large number of small bolls having seed with short fibres. Mainly occurring in Central America. Agronomically it is a very primitive group.
- cv. group Richmondi: large, profusely branched, sprawling shrubs with bolls of moderate size. It is grown on the Pacific side of the Isthmus of Tehuantepec (southern Mexico and Guatemala).
- group Yucatanense: small, highly branched, procumbent or prostrate subshrubs, only known wild in undisturbed beach vegetation on the northern coast of the Yucatan Peninsula. Bolls are small, widely flaring, and the lint of the small seed is sparse, coarse, brown. Agronomically it is the most primitive group, the only one known to grow wild, intergrading morphologically with cv. group Punctatum.

G. barbadense has been subdivided into 3 races, varieties or cultivar groups:

- cv. group Barbadense: annual shrubs, cultivated mainly in the West Indies, Central America and the southern parts of the United States, but also in Egypt and Sudan.
- cv. group Braziliense: the 'kidney cottons' of the Amazon Basin. The seeds in each locule of the capsule are fused into a solid kidney-shaped mass. Under primitive agricultural conditions the kidney seed mass facilitates hand ginning.
- cv. group Darwinii: perennial shrubs with fine brown lint. The group comprises the allotetraploid cottons endemic to the Galapagos Islands. Some consider this group a separate species (*G. darwinii* Watt), which is supported by evidence from molecular data.

Ecology Nowadays cotton is found from 47°N to 32°S. The optimum temperature for germination is 29–30°C and the minimum temperature for germination of most cultivars is about 14–15°C, though some germinate at temperatures as low as 12°C. For optimum growth and development an average growing season temperature of 25–30°C is needed. Cool weather slows growth and development, leading to retarded and sometimes insufficient ripening. Cotton is extremely frost-sensitive. Ample sunshine promotes flowering and fruit set and the highest yields are obtained in dry areas under irrigation, for example in Arizona, United States. Cotton does not tolerate shade. The average rainfall during the growing season should be 500–1500 mm, with dry weather during ripening, because rainfall after fruit opening leads to a decreased fibre quality. When the rainfall during the growing season is less than about 500 mm, irrigation is necessary. Because of its deep rooting system, cotton is drought tolerant, but prolonged drought during flowering and fruiting causes yield reduction. Strong winds can damage the seedlings and the open bolls. Primitive cottons are usually photoperiod-sensitive, becoming reproductive at short to medium photoperiods, but modern cultivars are generally photoperiod-insensitive and can be grown at a wide range of latitudes provided there are about 6 months of hot rainy season.

Cotton is not very demanding with respect to soil quality, but it needs deep soils (permeable to water and roots down to at least 1.2 m), with sufficient drainage and a pH between 5.5–8.5. Very fertile soils stimulate vegetative growth and may cause an excessively long vegetative period. Cotton is relatively salt tolerant, with a salt content of 0.5–0.6% normally not causing damage, but cultivars differ considerably in this respect.

Propagation and planting Cotton is propagated by seed. Organized seed multiplication and distribution is important to guarantee seed quality and purity. Where smallholder cultivation predominates, ginners are usually required to set aside seed for planting. It is usually recommended that seed be delinted by mechanical or chemical means, with the former being preferred for economic and environmental reasons. For mechanical sowing, removal of the fuzz is obligatory. Seeds lose their viability rapidly if their moisture content exceeds 10%, but seeds with a moisture content of 7% can be stored in sealed jars for up to 15 years. It is possible to propagate cotton vegetatively by cuttings, budding or grafting. When grown as a perennial, cotton can be cut back and ratooned, but this is not advisable. The development of rapid, reproducible and genotype-independent systems of in vitro propagation of *Gossypium* has been difficult, though methods have now been developed to produce large numbers of somatic embryos from callus from hypocotyl or cotyledon explants of *G. arboreum*, *G. barbadense*, *G. herbaceum* and *G. hirsutum*.

In many countries sowing is done by hand. The planting density varies widely with cultivar, climate and soil characteristics, and cultivation as well as harvest methods. Spacings are 50–120 cm between rows and 20–60 cm within the row. About 10–20 kg/ha delinted seed is necessary for sowing, for instance at 80 × 30 cm spacing (41 700 hills/ha) with 2–4 seeds per hill. The seed should not be sown deeper than 5 cm. Good soil preparation before sowing is very important, because the seedlings do not penetrate hard or crusted soils easily and do not compete well with weeds until they are 3 weeks old. Dry season weeds can be killed by harrowing or hoeing. This greatly reduces weed competition after planting. Early soil cultivation, allowing early planting, extends the growing season. Ridges are necessary on poorly drained soils. Cotton is usually grown in rotation with other crops to control pests and soil-borne diseases.

Husbandry Within 1–2 weeks after sowing gaps in the stand of cotton are resown, followed by rapid between-row weeding. Two weeks later the hills are thinned to 1 plant by sideways pulling, and within-row weeding is carried out. A month later the third weeding follows. Cotton has a very good nutrient uptake ability, and nutrient requirements are therefore moderate. The uptake of a crop producing 1680 kg/ha seed cotton has been estimated at 105 kg N, 18 kg P and 66 kg K per ha. With the seed cotton 40 kg N, 7 kg P and 14 kg K per ha are removed; with the crop residues (especially the leaves) 65 kg N, 11 kg P and 52 kg K per ha are removed. Half the N and all P and K should be applied before sowing in a fertilizer furrow close to the intended contour furrows for sowing. This application is mainly for rapid and firm development of roots, stem, leaves and branches. The 2nd application of 60 kg/ha N, about 2 months later, is meant for rapid fruiting and filling of the bolls. Too much N stimulates vegetative growth and extends the vegetative period, whereas N-shortage leads to chlorosis, reduced growth and boll-shedding. Sufficient K is important for fibre quality and disease resistance and shortage leads to mottled yellowish leaves with brown concentric spots, with the leaf margins drying and curling inwards, and the leaves eventually drying out and being shed. P-deficiency results in dark green leaves and delayed flowering and fruiting. *G. hirsutum* is mostly grown under rainfed conditions and *G. barbadense* with irrigation. Under rainfed conditions supplemental irrigation may help early planting and alleviate dry spells in mid season. To stop vegetative development, irrigation should cease shortly after boll opening has started.

Diseases and pests Diseases are less important in cotton than pests. The most widespread diseases are bacterial blight, leaf spot, blackarm or boll rot caused by *Xanthomonas campestris* pv. *malvacearum*, anthracnose caused by *Glomerella gossypii*, Fusarium wilt caused by *Fusarium oxysporum*, and Verticillium wilt caused by *Verticillium dahliae*. Bacterial blight is controlled by growing cotton only once every 3 or more years on the same field, removing the harvest remains and seed treatment. *G. hirsutum* cultivars with adequate host resistance are available. Anthracnose can be controlled by the same measures, but resistant cultivars are not available. *G. hirsutum* and *G. arboreum* cultivars with resistance to Fusarium wilt and *G. barbadense* cultivars with adequate resistance against Verticillium wilt are available. Cropping methods to control wilt diseases include crop rotation, sufficient K-fertilization and the control of nematodes.

Cotton suffers from a wide spectrum of pests. Bollworms are among the most serious. They feed inside the bolls, damaging lint and seed and so causing considerable reduction in yield and quality. The main bollworms are American bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*) and spiny bollworm (*Earias* spp.). Spiny bollworm, to which *G. arboreum* and *G. barbadense* seem less susceptible than *G. hirsutum*, has a serious early effect of tipboring in the main stem leading to excessive formation of vegetative branches and delaying the setting of bolls, which makes them vulnerable to mid-season American bollworm and stainers. Resistance to bollworms has not been achieved to the desired extent, and their control has long relied heavily on insecticides. Leaf, stem and bud-sucking bugs can cause considerable damage. Jassids (*Amrasca*, *Empoasca*, *Erythroneura*, *Jacobiella* and *Jacobisca* spp.) are the first pests to appear, but a dense coating of long hairs on leaves and stems provides good protection. Whitefly (*Bemisia tabaci*) and cotton aphid (*Aphis gossypii*) are pests later in the season. Early sowing, weeding and harvesting and the use of short-season cultivars can reduce their damage. Cotton stainers (*Dysdercus* spp.) occur in all cotton-growing countries. About 4 alternating sprays of organophosphates and pyrethroids can overcome this pest. Fairly effective preventive control can be obtained by strict phyto-sanitation, early cropping of maize or sorghum followed by early ploughing and close planting of cotton using an early maturing cultivar. The boll weevil (*Anthonomus grandis*) is economically the most serious cotton pest in the United States, causing estimated annual yield losses of 8%. Close relatives of cotton, such as *Abutilon* spp., growing nearby are alternative hosts of cotton pests, especially stainers.

Insect pests in cotton have been effectively controlled since 1945 with the use of insecticides. The repeated development of resistance of insect pests (especially the American bollworm) to new insecticides has in some countries led to excessive spraying, up to 15 sprays per season, killing all natural enemies. This may also induce outbreaks of previously minor pests, requiring additional spraying. In the early 1990s, it was estimated that cotton used 53% of the pesticides applied in Indian agriculture, while occupying only 5% of the cultivated area. To reduce the use of pesticides, the application of Integrated Pest Management (IPM) or Integrated Weed and Pest Management (IWPM) is advocated. Very early field preparation including repeated weeding, fertilizer application, early planting of jassid-resistant cultivars, gapping, thinning and judicious use of pesticides on the basis of insect monitoring and damage thresholds, form the basis of interacting IWPM farming practices. Preventive weed control by ploughing or hoeing promptly after clearing the preceding crop stores moisture from unexpected storms in the subsoil which makes it possible to plant early. This encourages early fruiting well ahead of the main pest, American bollworm, and provides ample time for compensatory fruiting in case of early fruit damage. As insecticides against jassids are no longer needed they do not kill the natural enemies which control American bollworm in its vulnerable young stage. By the time the later pink bollworms, stainers and whitefly occur, the main crop will be safe. Recommended IPM practices to control American bollworm in the Philippines include the use of specific cultivars, a short planting period, adequate fertilizer application, planting of trap crops, weekly pest monitoring, release of natural enemies (*Trichogramma chilonis*), spraying with *Bacillus thuringiensis* at an early growth stage and the use of synthetic insecticides when the American bollworm population reaches a critical level.

The most widely distributed economically important nematode in cotton is the root-knot nematode (*Meloidogyne* spp.), whereas the reniform nematode (*Rotylenchus* spp.) is more restricted to tropical and subtropical environments. They can be controlled by rotation and chemicals, whereas cotton genotypes have been developed with some tolerance to the reniform nematode.

Harvesting Cotton in South-East Asia is picked by hand 4–6 months after sowing. Handpicking gives the cleanest cotton and the highest recovery. Picking should be done regularly, because leaving open bolls in the field may result in deterioration of lint quality. Usually 3–4 pickings are carried out in a field. Mechanical harvesting is practised in the United States and Australia, where hand-picking is too expensive; here low-growing, weakly-branching cultivars are sown at narrow spacings, and plants are sprayed with defoliants before harvesting. Mechanically harvested fibre needs heating and shaking to remove impurities, and this operation makes the fibre more brittle. Mechanical harvesting is not feasible for the tiny plots of South-East Asia, where the hairy, jassid-resistance cultivars are grown, and hand-picking is much cheaper.

After picking, the seed cotton is cleaned and transported in bags or sheets to the ginnery (privately or co-operatively owned) for checking, weighing, sorting and payment. The seed from the first 1/3 of the crop picked is usually the most viable and may be kept separately in clearly marked bags. The lint from the first 2/3 of the crop is the most mature and strong.

After the cotton has been harvested, the field is often grazed by cattle, sheep or goats. The stalks may be lifted, roots and all, and stacked to dry and provide household fuel. The field can then be hoed or ploughed to stop weeds from seeding or rooting as an early IWPM measure. In many countries the destruction of harvested stalks was prescribed to control pests and soil-borne diseases. At present, the plants are often pulled up with their roots and used as household fuel.

Yield A seed cotton yield of up to 4 t/ha is possible under optimal conditions, but in practice it is seldom over 2.5 t/ha and the average world yield is only about 1.6 t/ha. In most African countries the yield is well below 1 t/ha. Seed cotton of primitive cultivars yields 20–25% fibre after ginning, whereas good upland cultivars have a 'ginning-outturn' of at least 35% and sometimes over 40%. Some modern *G. arboreum* and *G. herbaceum* cultivars grown in India and China also yield up to 40% lint. On average, 1 t seed cotton of *G. hirsutum* yields 350 kg fibre, 120 kg oil, 300 kg cake, 160 kg hulls and 60 kg fuzz.

Handling after harvest Cotton lint is removed from the seeds by ginning, which can be done with a hand gin (capacity of 2–3 kg lint/hour) or mechanically with a saw gin (capacity of 300 kg lint/hour) for the shorter-stapled cottons or with the more gentle roller gin (capacity of 30 kg lint/hour) for the longer-stapled fine types. The ginner is an indispensable link between farmers and the complex textile chain. If he pays low prices, farmers will in response lower inputs, neglect the crop and eventually reduce their area under cotton. They may even decide to opt out completely as witnessed by deserted ginneries in Thailand and the Philippines.

Cotton fibre quality is defined in terms of its length and uniformity, strength, elasticity and maturity, whereas whiteness and trash content also play a role. These properties can all be measured rapidly by the 'High Volume Instrument' (HVI). The lint is baled under pressure and covered with hessian or another material. Modern processing of cotton fibre into fabric consists of the following steps:

- blending: several bales of cotton are thoroughly mixed to ensure a uniform product of the desired quality;
- cleaning: the lint is passed through a series of small-toothed saws that pick the fibres apart and remove the trash;
- picking: continuation of the cleaning process by picking or fluffing the fibres so that they barely hold together in a continuous sheet ('picker lap');
- carding: the picker lap is converted by a card machine into a thin sheet that is slightly twisted to produce a loose rope ('sliver');
- drawing: several slivers together are drawn out or stretched to form a more uniform single sliver with more parallel fibres;
- roving: further drafting and twisting of the sliver to produce roving, which is wound on to a bobbin;
- spinning: further drafting of the roving into small fibre strands that are twisted into yarn;
- warping: thousands of yarns are wound parallel on a giant spool ('warper beam') to form 'warp' yarns, which will later run the length of the fabric;
- slashing: coating of the yarns with starch to temporarily give the extra strength and resistance to abrasion which are needed for weaving;
- weaving: warp yarns are interlaced with 'weft' yarns (filling or cross yarns) on a loom to produce fabric.

Fuzz is removed by additional saw ginning at the oil mill before seeds are crushed. Linters are pulped by caustic solutions and bleached. Cotton textile cuttings and rags are pulped using the soda process. Dyed textiles and the presence of synthetic fibres and elastic materials in rags can cause problems in paper making.

Genetic resources The largest cotton germplasm collection is the Cotton Germplasm Collection of the United States Department of Agriculture, Agricultural Research Service (USDA/ARS) at College Station in Texas, United States, which contains about 9000 accessions of 41 species (including about 4600 of *G. hirsutum*, 2500 of *G. arboreum*, 1200 of *G. barbadense* and 200 of *G. herbaceum*). The Central Institute for Cotton Research at Nagpur, India, also has a large collection (including about 4000 accessions of *G. hirsutum*, 1700 of *G. arboreum* and 400 each of *G. barbadense* and *G. herbaceum*). The genebank of CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) at Montpellier, France, contains about 3600 accessions of 35 species. Cotton germplasm collections are also maintained in China, Vietnam and other cotton-producing countries.

Breeding Until the 1930s cotton breeding was limited to crossing within the diploid and tetraploid groups. After this, polyploidization of the diploids greatly increased breeding opportunities. Crosses between Old World and New World genotypes have become important, especially for resistance breeding and the breeding of better cultivars for regions in Asia where *G. arboreum* and *G. herbaceum* grow well, but *G. hirsutum* does not. F_1 hybrid cultivars with considerable hybrid vigour for yield have been successfully developed. However, the available systems of cytoplasmic male sterility have been inadequate for large-scale production of hybrid seed, mainly due to incomplete expression of fertility restorer genes in the male parents. Current use of cotton hybrids is limited to South Asia and China, where seed production by manual emasculation and pollination is economically feasible because of low labour costs.

The main objectives in cotton breeding, apart from higher yields, are photoperiod-insensitivity, early maturity, adaptation to mechanical harvesting (through low growth, little branching, short flowering time, loosely attached seeds, less hairy leaves), fibre quality (length, fineness, strength and elasticity), seed quality (oil content and low gossypol content by glandless plants, increased suitability of the presscake as a source of protein for humans and animals), resistance to diseases (e.g. bacterial blight and Fusarium wilt) and pests (e.g. bollworms, jassids) and tolerance to drought, cold and salinity. There has been little progress in breeding for pest resistance (except for resistance to jassids), but much success has been obtained in resistance and tolerance to Fusarium and Verticillium wilts, bacterial blight and nematodes.

Molecular breeding has been applied to cotton with considerable success. Bt-cotton, genetically modified (GM) cotton cultivars with resistance to bollworms based on Bt genes derived from *Bacillus thuringiensis*, is already grown on 4.3 million ha, including 1.5 million ha in China alone. Bt-cotton was first released in Indonesia in 2001. Work is in progress to develop wide-spectrum insect resistance based on a combination of several Bt and proteinase-inhibitor genes. Cotton has also been genetically modified to express resistance to the herbicides bromoxynil ('Bromoxynil-resistant cotton') or glyphosate ('Glyphosate-tolerant cotton'). Some GM cotton cultivars have combined insect and herbicide resistance. The impact on reduced insecticide use in Bt-cotton should become manifest in the coming years, as the area of such cultivars is rapidly increasing. So far, there has been little proven evidence of negative effects of GM cotton on the environment.

Prospects Because of its excellent fibre properties and low price, cotton will remain very important on a worldwide scale. In South-East Asia, however, less than 1% of the arable land is used for cotton. The small acreage and low yields are mainly due to the generally low price paid for seed cotton in the region and the high damage caused by pests. So, farmers tend to only grow small fields of cotton for their minimum cash needs, whereas they would probably grow more if they were paid more. Furthermore, a higher price would lead to better crop management and increased input use by farmers, and thus to higher yields. Most of South-East Asian cotton production is of a quality aimed at its own low-cost garment market. As a result, it is not easily exported to important markets such the European Union and Japan. The quality can be much improved as happened in Laos after massive and repeated reselection and progeny testing over a period of 3–4 years.

Ginned seed is an excellent concentrate for young non-lactating ruminants (cattle, buffaloes, goat and sheep). In South-East Asia over 5 million head of cattle are slaughtered per year, with an average live weight of 360 kg. A young animal of 270 kg can be fed with ginnery seed at a daily rate of 1% of its live weight, reaching 360 kg in about 6 months, requiring a total of about 540 kg ginnery seed. To fatten 5 million head of cattle would require 2.7 million t ginnery seed. The present 300 000 t seed cotton harvested yearly in South-

East Asia produces about 200 000 t ginnery seed. With a cotton lint production equal to the internal consumption in the region (about 1 million t), about 2 million t of ginnery seed would be available. The high susceptibility of cotton to pests is another major factor responsible for the low cotton production in South-East Asia. Integrated Pest Management, especially but not exclusively for cotton, should be further developed in close cooperation with cotton farmers. The use of genetically-modified cotton such as Bt-cotton and herbicide-resistant cotton is another promising option, though its use is still meeting public resistance in some countries.

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G.J. Kerkhoven & H.J.W. Mutsaers

Heliconia indica Lamk

Encycl. 1: 426 (1783).
HELICONIACEAE
$2n$ = unknown

Synonyms *Heliconia bihai* auct. mult., non (L.) L., *H. buccinata* Roxb. (1824), *Heliconiopsis amboinensis* Miq. (1859).

Vernacular names Lobster-claw; false bird-of-paradise (En). Indonesia: kokin (Ambon), daun meji (Moluccas), eki (central Sulawesi). Papua New Guinea: pena.

Origin and geographic distribution *H. indica* occurs in South-East Asia and the South Pacific, from the Moluccas through New Guinea and the Solomon Islands to New Caledonia and Vanuatu. It is cultivated throughout South-East Asia for its leaves or as an ornamental. Ornamental cultivars are also grown in Europe and the United States.

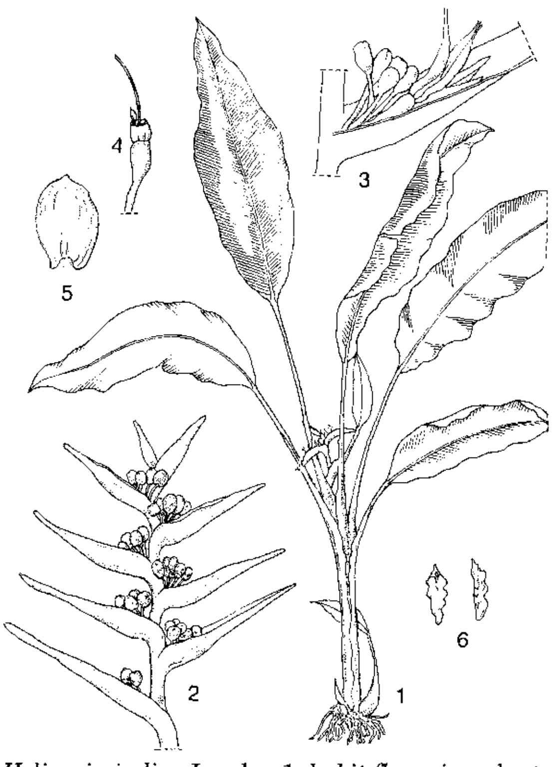
Uses The leaves of *H. indica* are used traditionally as platters for food, tablecloths and napkins, for instance in the Moluccas (Indonesia). They are usually replaced after each meal. In the Moluccas they also serve, after being dried and smoothed, as cigarette paper. In Sulawesi (Indonesia) the leaves are used to cook rice, meat and vegetables in, and to wrap up cooked food. The leaves of *H. indica* are also used for wrapping food in Papua New Guinea, the Solomon Islands, New Caledonia and Vanuatu. The pseudostems can be twisted into rough cordage. *H. indica* is widely planted as an ornamental.

Production and international trade No production statistics for *H. indica* are available. As a source of platters, wrapping material and cordage it is used locally and does not enter international trade. *H. indica* has more commercial importance as an ornamental, but no trade statistics are available.

Adulterations and substitutes Other leaves used for wrapping include those from *Musa* spp., *Curculigo capitulata* (Lour.) Kuntze and *C. latifolia* Dryand.

Description A perennial, rhizomatous herb with banana-like habit, up to 8 m tall, forming a dense clump with up to 50 or more leafy shoots.

Pseudostem (formed by the leaf sheaths) cylindrical, 100–300 cm × 4–10 cm, green to yellow-brown, sometimes red or grey marbled, glabrous or glaucous. Leaves 4–6 per shoot; petiole 50–140 cm × 1.6–2.9 cm, yellow-green, sometimes red, glabrous or glaucous; blade narrowly elliptical, up to 100–240 cm × 27–60 cm, base attenuate to cordate, margins entire, apex acute, upper surface green, sometimes with red margins, glabrous, midrib green or reddish, lower surface green, glabrous, midrib green to maroon marked with a yellow or red stripe. Inflorescence erect, thyrsiform, up to 60 cm long, composed of 4–14, distichously arranged, spathaceous bracts each with an axillary cincinnate flower cluster; peduncle 0–15 cm × 1–2.6 cm; rachis subflexuose with average internode length 1–4 cm; spathaceous bracts boat-shaped, oriented 60–90° to axis of inflorescence, 14–25 cm × 6–9.5 cm, round at base, margins straight to revolute, apex acuminate, outer surface green-yellowish or red at apex and near rachis, inner surface light green (sometimes red), with 10–25 flowers per cincinnus; flowers bisexual, exserted from the spathes with their upper halves only, subtended by acute, keeled, white to yellow-green floral bracts up to 8 cm × 2.5 cm; pedicel 12–35 mm long; perianth white to yellow-green, 5–6.5 cm × 1–1.5 cm, with its 6 segments (calyx and corolla) basally united into a short firm tube 8–10 mm long and the posticous tepal free, reflexed and adhering to the adjacent margins of the 2 other ones; fertile stamens 5, the 6th one reduced to a white staminode 6–12 mm × 5–8 mm and fused to perianth tube 5–10 mm above the base; stamens with anthers connivent inside apex of corolla tube; ovary trigonous, 9–16 mm × 7–12 mm, green, yellow or orange, glabrous. Fruit a red drupe, 1.5–3 cm × 1.3–2 cm. Pyrenes ellipsoid, 10–20 mm × 5–9 mm, rounded to pointed at base and apex, generally without dorsal crest, surface verrucose.



Heliconia indica Lamk – 1, habit flowering plant. Var. rubricarpa – 2, inflorescence; 3, flower at anthesis (cincinnal bract partly cut away, floral bracts removed); 4, pistil with base of corolla tube and staminode; 5, staminode; 6, pyrene, ventral and lateral view.

Growth and development *H. indica* flowers throughout the year. Flowering is after sunset and pollination may be effectuated by bats, as in *H. papuana* W.J. Kress and *H. solomonensis* W.J. Kress. It is not clear whether *H. indica* is self-compatible, like most Central American *Heliconia* spp., or self-incompatible, as is probably the case with *H. solomoniensis*.

Other botanical information *Heliconia* L. is primarily a neotropical genus, containing 200–250 species. *Heliconia* has traditionally been included in a widely circumscribed *Musaceae*, together with *Musa* L., *Ensete* Bruce, *Strelitzia* Dryand., *Ravenala* Adans., *Phenakospermum* Endl. and *Orchidantha* N.E. Br. Now it is most common to distinguish 4 families: *Musaceae* (*Musa*, *Ensete*), *Strelitziaceae* (*Ravenala*, *Phenakospermum* and *Orchidantha*), *Heliconiaceae* (*Heliconia*) and *Lowiaceae* (*Orchidantha*). The paleotropical *Heliconia* plants have sometimes been considered as comprising one single species only, called *Heliconia bihai* (L.) L. or *H. indica*. Here the opinion is followed in which 6 palaeotropical *Heliconia* species are distinguished, all endemic to Asia and the South Pacific. The 6 paleotropical species, including *H. indica*, together comprise the subgenus *Heliconiopsis*, distributed from the Moluccas (and possibly Sulawesi) through New Guinea, the Solomon Islands, Vanuatu and New Caledonia to Samoa and Fiji. They can be distinguished from the neotropical species by their primarily green inflorescences, nocturnal anthesis and large, red to orange fruits.

In *H. indica* 5 geographically distinct varieties have been distinguished, differing in the vestiture on the peduncle and rachis, the colour of the inflorescence, and cincinnal bract size and shape, but the morphological boundaries are not always sharp. In South-East Asia 3 varieties occur:

- var. *indica*: probably endemic to the Moluccas and occurring in dense forest on ridges up to 200 m altitude; now also in cultivation in Sulawesi and other parts of Indonesia; characterized by shoots less than 4 m tall, longest leaf blade less than 2 m long, peduncle and rachis puberulous to tomentose, cincinnal bracts usually less than 7;
- var. *rubricarpa* W.J. Kress: endemic to eastern Papua New Guinea and found in primary and secondary rainforest, often along creeks or rivers, typically below 200 m attitude, but sometimes up to 900 m; characterized by shoots taller than 5 m, longest leaf blade more than 2 m long, peduncle and rachis puberulous to tomentose, cincinnal bracts usually more than 7;
- var. *micholitzii* (Ridley) W.J. Kress: endemic to Papua New Guinea (Bismarck Archipelago), found in rainforest habitats up to 700 m altitude; also in cultivation in Sulawesi, where it is called 'daun nasi' or 'daun laicit' ('rice leaf'), referring to its main use; characterized by shoots 4–8 m tall, longest leaf blade less than 1.7 m long, peduncle and rachis glabrous, cincinnal bracts 4–10.

Of the other varieties, var. *dennisiana* W.J. Kress is endemic to the Solomon Islands and var. *austrocaledonica* (Veill.) W.J. Kress to New Caledonia, Vanuatu and the Santa Cruz Islands. Published cultivar names of *H. indica* are 'Rabaul', 'Sanderi', 'Spectabilis', 'Striata' (synonyms: 'Aureo-striata', *H. aureo-striata* Hort. ex Bull.) and 'Viridis'.

Other *Heliconia* species occurring naturally in South-East Asia are *H. papuana* (endemic to Irian Jaya and Papua New Guinea) and *H. solomonensis* (endemic to the Solomon Islands and Bougainville Island in Papua New Guinea.

Many neotropical *Heliconia* species have been introduced into South-East Asia and can be found in gardens and along streets in Malaysia, Indonesia and Papua New Guinea, e.g. *H. aurantiaca* Ghiesbr., *H. bihai* (L.) L., *H. collinsiana* Griggs, *H. latispatha* Benth., *H. metallica* Planchon & Linden ex Hook., *H. psittacorum* L.f., *H. rostrata* Ruiz & Pavon, *H. stricta* Huber and *H. wagneriana* Petersen. In Thailand *H. psittacorum* and some other species, including *H. collinsiana*, *H. stricta* and *H. wagneriana*, are commercially grown as ornamentals. There are no records of hybridization between paleotropical and neotropical species.

In the Solomon Islands the leaves of *H. solomonensis* are used for temporary shelters and for wrapping and cooking food. The leaves of *H. paka* A.C. Smith serve for making temporary thatch in Fiji. In Samoa the leaves of *H. laufao* W.J. Kress are used for wrapping food, for covering stone ovens and for making temporary covers for dwellings, whereas dried fibres stripped from the petioles and midribs of the leaves are used as strainers for making coconut cream.

Ecology *H. indica* is found in primary and secondary rainforest up to 700 m altitude. In general, *Heliconia* needs ample water and, in the tropics and subtropics, semi-shaded conditions. In forest it is normally only found in open spots where light reaches the soil. Fertile soils with good drainage are preferred.

Propagation and planting *Heliconia* is usually propagated by division, sometimes by seed. Many *H. indica* cultivars rarely produce fertile seed, because flowers contain sterile pollen or fail to open properly, which may be due to artificial selection or inbreeding.

In South-East Asia *H. indica* is planted around the house. In Papua New Guinea attractive *Heliconia* plants are transplanted from the forest to gardens.

Diseases and pests No information is available on pests and diseases affecting *H. indica* in South-East Asia. Fungi reported to attack *H. indica* cv. Spectabilis in Hawaii are *Calonectria spathiphylli* and *Pythium* spp. The most pronounced symptoms caused by *Calonectria spathiphylli* are leaf yellowing, drying of leaf margins, sheath spots and petiole blights. Eventually the leaves die. The primary symptoms of infection with *Pythium* spp. are root rot and slow decline of the plants.

Harvesting *H. indica* leaves are harvested as needed.

Handling and harvest In Sulawesi (Minahassa Peninsula) the leaves are made supple by holding them over a fire for a short time, after which they are very suitable for wrapping food.

Genetic resources and breeding No germplasm collections of *H. indica* are known to exist. Ornamental cultivars have been developed, but no breeding programmes aimed at improving its properties as a fibre plant are known to exist.

Prospects The role of *H. indica* as a source of platters, wrapping material and cordage will remain limited to local use. Worldwide, its importance as an ornamental is greater, and this situation is likely to remain so.

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B.I. Utomo

Helicteres isora L.

Sp. pl.: 963 (1753).
STERCULIACEAE
$2n = 18$

Synonyms *Helicteres grewiaefolia* DC. (1824), *H. roxburghii* G. Don (1831), *H. chrysocalyx* Miq. ex Mast. (1874).

Vernacular names Red isora, Indian screw tree (En). Indonesia: jelumpang, dlumpangan (Javanese), puteran (Sundanese). Malaysia: chabai tali, chabai lintal, kayu ulas. Burma (Myanmar): thoo-gnaichay. Thailand: po pit (central, northern), cho (Karen, Chiang Mai), po thap (Chiang Mai). Vietnam: du[oo]i ch[oo]n.

Origin and geographic distribution *H. isora* is distributed from India, Pakistan, Nepal and Sri Lanka through Burma (Myanmar), Thailand, Indo-China, Malaysia and Indonesia to southern China and northern Australia. It is occasionally grown in Java.

Uses *H. isora* yields a bast fibre used in Java for tying and for making ropes, and formerly in West Java (Indramayu) for making sacks. In India it is known as 'kaivun fibre' and is used for making ropes and sacks and as supplementary raw material for paper making.

In Indonesia, Malaysia, Thailand and India the fruit (known in the Javanese medicine trade as '(buah) kayu ules', 'kayu puter' or 'ulet-ulet') is used internally or externally against intestinal complaints, particularly in children. In Malaysia and southern Thailand the dried fruit is employed in compound tonics, especially those given after childbirth. *H. isora* also has ornamental value. In India *H. isora* is not only used for fibre (stems and twigs) and medicine (fruits) but also for fodder (leaves and tender branches), fuel (wood) and gunpowder (charcoal).

Production and international trade The processing of fibre obtained from *H. isora* bark into bags and canvas was an important cottage industry in certain parts of India at the beginning of the 20th Century, but its importance declined with the advent of jute (*Corchorus* spp.). Recent information on production is not available.

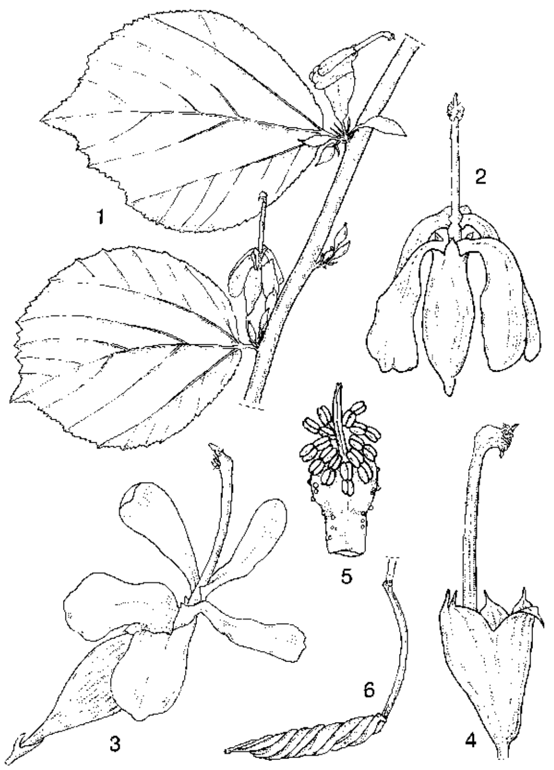
Properties Fibre from the bast of *H. isora* has a light brown to silver colour. The length of the ultimate bast fibre cells ranges from (0.7–)1.4–1.9(–2.6) mm, the width ranges from (7–)15–17(–23) μm, and the average cell-wall thickness is 6 μm. The lumen is irregular, compressed and obstructed. The fibre surface is also irregular, with frequent constrictions and depressions. The fibre contains 73–75% holocellulose, 13% hemicelluloses and pectin, 12–23% lignin and 1–2% ash. The intrinsic strength measured was 0.987 g/denier and the elongation at break was 5.6%. The fibre has been described as soft, silky and lustrous, but also as coarse, hard, with poor lustre and of poor quality. This difference may be due to the age of the harvested stems. The orientation of the fibre bundles is very irregular and the fibre is difficult to separate into individual strands.

The wood of *H. isora* is suitable for paper making. Pilot studies have shown that 35–36% easy-bleaching pulp can be obtained on a large scale from unbarked or barked material using the sulphate process. Printing paper may be produced from *H. isora* pulp only, but for the production of writing paper a 40% admixture with long-fibre pulp is considered necessary. Laboratory experiments have shown that the soda process can produce a pulp with satisfactory strength properties. The wood fibres are (0.4–)0.9(–1.3) mm long and (10–)17(–23) μm wide.

Though it has been suggested that the use of *H. isora* fruits against intestinal problems has more to do with their intestinal-like twisted appearance than with their medicinal properties (Doctrine of Signatures), recent in vitro and in vivo studies indicate that the fruits have antispasmodic activity. Water extracts of *H. isora* fruits have shown inhibitory activity against reverse transcriptase from avian myeloblastosis virus (AMV-RT) and activity against human immunodeficiency virus type 1 (HIV-1). Neolignans isolated from *H. isora* have shown some inhibitory activity against AMV-RT. Other compounds isolated from *H. isora* include flavonoids, cucurbitacins and rosmarinic acid derivatives.

Adulterations and substitutes The bast fibres of *Helicteres hirsuta* Lour. and *H. viscida* Blume are similarly used for making rough cordage, and their vernacular names and those of *H. isora* show some overlap, e.g. in Indonesia ('jelumpang' for *H. hirsuta* and *H. isora*; 'dlumpangan' for *H. isora* and *H. viscida*) and Vietnam ('du[oo]i ch[oo]n' for all 3 species).

Description A shrub or small tree, 2–4(–8) m tall, bark finely wrinkled, lenticellate, pale, all young parts often densely clothed with long, yellowish, stellate hairs. Leaves arranged in two vertical rows, simple; stipules filiform, 3–10 mm long, caducous; petiole up to 4 cm long; blade round to obovate, 5–21 cm × 3–18 cm, base rounded to subcordate, sometimes oblique, margins irregularly serrate, apex rounded to acuminate, palmately 3–5-veined, sometimes slightly lobed near the apex, variably covered with simple and stellate hairs, often densely so on underside. Inflorescence an axillary fascicle of usually 2(–5)-flowered cymes with small, sessile, basal glands; peduncle 2–5 mm long; bracts linear, 3–5 mm long; flowers bisexual, irregular, about 2.5 cm in diameter, fragrant; pedicel up to 1 cm long; bracteoles linear; calyx tubular, 1–2 cm long, yellow, with 5 triangular, unequal lobes, the 2 inferior lobes connate almost to the apex, the 3 superior lobes separate; petals 5, unequal, clawed, 3–4 cm long, bluish at anthesis but turning bright red, the 2 broader lower petals about 3 cm × 1.5 cm with a short claw which is winged or widened towards the apex, the 3 upper petals narrower, about 1 cm × 0.5 cm, with a claw up to 2.5 cm long which is auricled near the apex; gynandrophore 3–6 cm long with red apical glands; staminal tube 2.5 mm long, making an angle of 90° with gynandrophore, terminated by 10 stamens (filaments connate in lower 2/3) and, more inwardly inserted and often hidden by the stamens, 5 staminodes; filaments short, anther cells 2, parallel with each other; pistil with 5-celled, red-glandular ovary and 5 subconnate, short styles. Fruit consisting of 5 twisted follicles, 4–8 cm long, each follicle about 20–25-seeded. Seed angular-subrhomboid, about 2.5 mm × 1.5 mm × 2.7 mm, finely warty, glabrous, dark brown.



Helicteres isora L. – 1, flowering branch; 2, flower at anthesis; 3, one day old flower; 4, flower with corolla removed; 5, top of gynandrophore with stamens and pistil; 6, fruit.

Growth and development In Java *H. isora* flowers throughout the year; in Indo-China flowering and fruiting has been observed in June. Flowers open early in the morning (3–3.30 a.m.) and last for 2–3 days. At anthesis the petals are strongly recurved to a vertical position, blue-grey, turning violet in the afternoon, becoming dark red in the evening. The second day the petals have curved halfway upward to a horizontal position and the top of the style bears a sticky droplet. Flowering on the first day is functionally mainly male and on the second day female. *H. isora* flowers are pollinated mainly in the morning by birds, that are attracted by the flower colour and by the fragrant nectar. Both self- and cross-pollination are possible. *H. isora* coppices well and survives burning, with rapid regrowth after cutting or burning.

Other botanical information Based on the degree of hairiness several subclassifications of *H. isora* have been made which have no practical value. The genus *Helicteres* L. comprises 60 species, of which 38 are in tropical America, none in tropical Africa and 22 in tropical Asia and Australia, with none of the species occurring in both tropical America and Asia/Australia. The American species were revised taxonomically in 2001, but the Asiatic ones need a critical revision. In South-East Asia several other *Helicteres* spp. are or have been used as a source of bast fibre. Those mentioned include *H. angustifolia* L. (China, Taiwan, Japan, throughout South-East Asia to Micronesia; a shrub up to 1 m tall), *H. hirsuta* Lour. (South-East Asia, not in Borneo, Moluccas and New Guinea; see minor fibre plants), and *H. viscida* Blume (Burma (Myanmar), Thailand, Indo-China, Peninsular Malaysia, Java; see minor fibre plants).

Ecology *H. isora* is a gregarious species common in evergreen forest and secondary jungle along roads and forest edges. In Java *H. isora* is found in relatively dry areas up to 300 m altitude, the habitats including teak forest, brushwood and roadsides. In Thailand it is found in deciduous forest and scrub areas. Fertile soils rich in humus are preferred; in sandy and lateritic soils the plants are stunted, much branched, and with a very thin bark. In Hainan (China) *H. isora* is a common weed in sown pastures.

Propagation and planting *H. isora* is easily propagated by seed, but vegetative propagation with stem cuttings is also possible. Seeds may be sown in a nursery and the seedlings planted out into the field later. Close planting, with e.g. distances of 60–90 cm, results in long, straight stems, whereas wider planting leads to profuse branching and thus lower fibre quality.

Husbandry Material from *H. isora* is usually collected from the wild. *H. isora* can be grown as a coppice crop, with yearly cutting.

Diseases and pests In India the weevil *Myllocerus viridanus* (*Curculionidae*) can cause serious defoliation of *H. isora*. No information is available on diseases and pests of *H. isora* in South-East Asia.

Harvesting Traditional practice in India is to harvest *H. isora* stems about 2.5 cm in diameter for fibre extraction.

Yield Recent and reliable information on *H. isora* yields is not available.

Handling after harvest *H. isora* fibre is extracted from the stem by retting. For sack-making in West Java (Indramayu) the stems were tied into bundles and retted for 1–4 weeks, depending on water quality and stem age (older stems needing a longer retting period), yielding fibre ribbons of 2–3 m length. In India the traditional method is to remove the leaves and keep the stems submerged in a stream or pond for 18–24 days. Retted stems are taken out of the water and gently beaten with wooden mallets, after which the fibres are peeled off, washed and dried in the sun. Retting in running water is preferable to obtain fibre of good colour and quality. In an Indian study, *H. isora* stems, varying in age from 6 months to over 2 years, were cut in pieces 0.9 m long, tied in bundles and submerged in a tank, with the water being changed frequently to keep the fibre clean and white. It took 15–22 days for retting, with the younger stems being ready earlier than the older ones. When retting was complete the bundles were taken out, the fibre was stripped manually from the stems, cleaned, washed in clear water and dried in the sun. It was found that fibre obtained in this way from stems 1–2 years old was soft and strong, but that from stems older than 2 years was coarse and brittle.

Genetic resources No germplasm collections of *H. isora* are known to exist. *H. isora* does not seem threatened with extinction.

Breeding No breeding programmes of *H. isora* are known to exist, though it has been proposed in India to develop improved cultivars to meet the increasing demand for its range of useful products.

Prospects In view of the lower quality and more difficult processing of *H. isora* compared to jute, its prospects as a fibre crop are not bright. In South-East Asia its role will probably remain limited to a local source of rough cordage, though it may offer some potential for paper production and as an ornamental shrub.

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Hibiscus cannabinus L.

Syst. nat. ed. 10: 1149 (1759).
MALVACEAE
$2n = 36$

Synonyms *Hibiscus sabdariffa* L. var. δ (1753), *H. sabdariffa* L. subsp. *cannabinus* (L.) G. Panigrahi & S.K. Murti (1989).

Vernacular names Kenaf, Deccan hemp, Bimlipatam jute (En). Kénaf, chanvre de Bombay, chanvre de Guinée (Fr). Indonesia: kenaf, Java jute. Thailand: po kaeo (central), po daai (northern).

Origin and geographic distribution Kenaf is of African origin; in most countries south of the Sahara *H. cannabinus* is a very common wild plant and it is also widely grown as a vegetable or fibre crop. Angola may have been a primary centre of origin, but greatest morphological diversity is found in East Africa. Both kenaf and roselle (*H. sabdariffa* L.) may have been domesticated as early as 4000 BC in Sudan. The date of initial introduction into India is unknown. References to kenaf cultivation started to be published around 1800 and it first appeared on the London market as 'Bimlipatam jute' in 1901. India has remained the largest kenaf-producing country with concentrations of cultivation in West Bengal and in coastal areas around Visakhapatnam (Andhra Pradesh) and Madras (Tamil Nadu). Kenaf was introduced into Indonesia from India in 1904. An extensive programme of kenaf cultivation was initiated in the 1920s in the Caucasus region of the Russian Federation (former USSR) and from there it was introduced into China in 1935. Kenaf production was also initiated after 1945 in e.g. the United States, Cuba and South America. Kenaf is now widespread in the tropics and subtropics, often cultivated as a fibre plant. In Malesia it is cultivated but does not grow wild.

Uses Dry retted kenaf fibre is used in the manufacture of coarse textiles, such as sacking and hessian cloth for the packaging of agricultural and industrial commodities, and is also made into twine, rope and rope-soled shoes. In some countries the fibre is converted into carpets and rugs. Directly scraped and dried bast ribbons are also used by local artisans in Asia and Africa to make cordage and sleeping mats. Blends of cotton and kenaf fibres can be made into apparel and upholstery quality yarns and fabrics. The bast can be processed into high-quality long-fibre pulps, e.g for cigarette paper. It can be used in blends with short-fibred pulps (e.g. from hardwood) to impart high tearing strength to specialty papers. The stripped woody core material of the stem ('sticks') provides fuel, fences, cattle sheds, a substitute for cork stoppers (Taiwan), raw material for particle board and laminated sheets for panelling, packing materials, animal bedding, mulch, potting media and absorbents. Whole stems are suitable raw material for the pulp and paper industry, and the use of whole stems is often a more economical option than separating the bast and core.
In Africa kenaf is mainly grown for its leaves, which are eaten as a vegetable. The flowers and young fruits are sometimes eaten as well. Whole young kenaf plants are an excellent fodder for cattle. The seeds are also an animal feed. The seed oil can be used in the production of linoleum, paints and varnishes. Sometimes it is used as a lubricant. The seed cake is edible and suitable for use as livestock feed or fertilizer. Various plant parts have medicinal uses; old leaves are used as a laxative and the juice from the flowers is taken against biliousness in India, where the seeds are considered stomachic, appetizing and aphrodisiac; they are employed externally as a poultice for pains and bruises. Experiments indicate that kenaf is suitable for use in plant bed filters to remove nitrogen and phosphorus from wastewater.

Production and international trade The average annual world production in 1997–2001 of jute-like fibres, a group consisting of kenaf, roselle, Congo jute (*Urena lobata* L.), *Abutilon theophrasti* Medik. and other *Malvaceae*, and sunn hemp (*Crotalaria juncea* L.), was about 450 000 t, harvested from 335 000 ha. Separate statistics are not available, but kenaf is estimated to make up about 90% of the total. Important kenaf fibre producing countries are India, China and the Russian Federation. In South-East Asia sizeable quantities of kenaf fibre are produced in Indonesia and Thailand. Almost all kenaf fibre is processed domestically and there is very little international trade. The fibre is traded under the name kenaf, but sometimes this name is also used for roselle fibre.
Kenaf is growing in importance as a raw material for paper making in a number of areas, including South-East Asia, India, China, Africa, the Caribbean and the southern part of the United States.

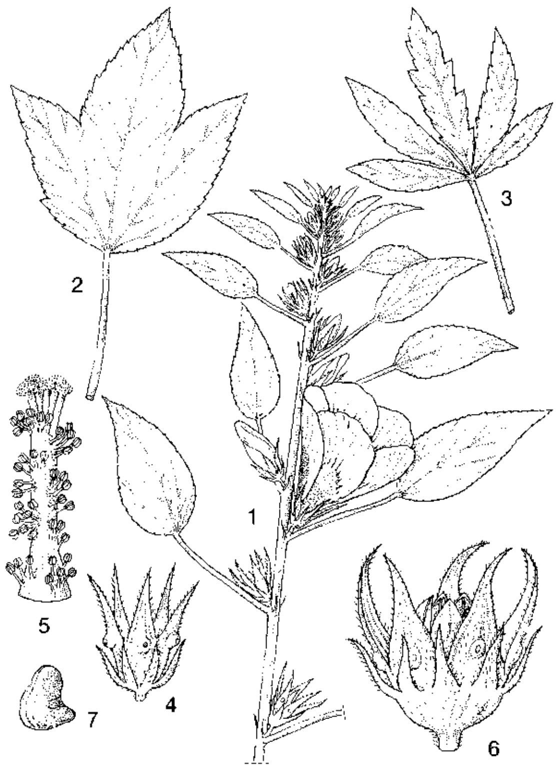
Properties Kenaf produces a bast fibre similar to jute (*Corchorus* spp.), except that it has a greater tensile strength and is somewhat coarser and more brittle. Kenaf fibre can be spun alone, or in admixture with jute, on machinery for jute spinning. The raw (retted and dried) bast fibre makes up 5–7% and the wood 15–21% of the freshly harvested and defoliated green stems. On a dry weight basis the bast fibre content of the stem ranges from 21% in wild accessions to 36% in modern cultivars. The ultimate bast fibres are (1.5–)2–3(–12) mm long and (7–)15–25(–41) μm wide, with an average cell wall thickness of 4–9 μm and lumen width of 7–13 μm. In cross-section they are polygonal to round or oval, with a varying lumen width and cell wall thickness. In longitudinal section the fibre cells are cylindrical. The fibre ends show great variation, but most often they taper into a blunt point. The fibre cells in the woody core are (0.4–)0.5–0.9(–2.4) mm long and 18–33(–37) μm in diameter, with an average cell wall thickness of 4–8 μm and a lumen width of 16–23 μm. The length of both bast and core fibre cells increases from the base to the top of the stem. The fibre strands of commerce, consisting of fibre cells cemented together by pectin and hemicelluloses, are 1.5–3.0 m long. Kenaf fibre contains 44–62% α-cellulose, 14–20% hemicelluloses, 4–5% pectin, 6–19% lignin and 0–3% ash.

Whole stems contain 77–79% holocellulose, 37–50% α-cellulose, 16–20% lignin and 2–4% ash. The bark fraction (depending on cultivar, but normally 31–39% of the stem) contains 62–81% holocellulose, 37–57% α-cellulose, 21–26% hemicelluloses, 6–12% lignin and 3–9% ash. The core fraction (61–69% of the stem) contains 65–72% holocellulose, 34–39% α-cellulose, 24–29% hemicelluloses, 14–20% lignin and 2–6% ash. In general, kenaf bast chemical pulps are stronger than softwood pulps; whole stalk chemical pulps have strength properties between those of softwood and hardwood pulps; and core chemical pulps have lower tear strength but higher tensile and burst strength than hardwood pulps. Paper made from whole kenaf stems is relatively tight and nonporous compared to that of wood.

Seeds contain up to 22(–26)% oil, with an average fatty acid composition of palmitic acid (14–20%), stearic acid (3–7%), oleic acid (28–51%) and linoleic acid (23–46%). The press cake contains 9% moisture, 32% crude protein, 8% oil, 8% crude fibre and practically no antinutritional components. The 1000-seed weight of most cultivars is 25–27 g, but for some semi-wild accessions of African origin it is only 9–12 g.

Adulteration and substitutes For many purposes, such as coarse packaging fibres and cordage, jute, kenaf and roselle may be substituted for each other. However, as kenaf and roselle are coarser and therefore cheaper than jute, they are considered more as a substitute of jute than the other way round. Other bast fibres that can serve as substitutes for jute, kenaf and roselle include those of *Abroma augusta* (L.) L.f., *Helicteres isora* L., *Malachra capitata* (L.) L. and *Urena lobata* L. For sack-making kenaf also has to compete with synthetic fibres such as polypropylene.

Description An erect annual herb, up to 2 m tall in the wild, up to 5 m in cultivars. Taproot well developed, up to 25 cm deep with lateral roots spreading horizontally to 1 m and adventitious roots on lowest stem section. Stem slender, cylindrical, in cultivation unbranched and glabrous, prickly on wild accessions, entirely green, green with red or purple pigmentation, or red, sometimes lower half green and upper half pigmented. Leaves alternate; stipules filiform, 5–8 mm long,



Hibiscus cannabinus L. – 1, flowering upper part of plant; 2, 3, leaves from the lower part of the stem; 4, epicalyx and calyx; 5, staminal column; 6, fruit with enlarged epicalyx and calyx; 7, seed.

pubescent; petiole 3–30 cm long, finely pubescent on the adaxial surface and bristled on the abaxial surface, green to red; blade 1–19 cm × 0.1–20 cm, very shallowly to very deeply palmately 3–7-lobed on lower stem, often unlobed on upper stem or even bract-like near the apex, base cuneate to cordate, margins serrate or dentate, apex acuminate, upper surface glabrous but with a prominent, 3 mm long nectary at the base of the midrib, lower surface hairy along the veins. Flowers axillary, solitary or sometimes clustered near the apex, bisexual, 5-merous, 7.5–10 cm in diameter; pedicel 2–6 mm long, articulated at the base; epicalyx of 7–8 linear bracteoles, 7–18 mm long, persistent; calyx campanulate with 5 acuminate to subcaudate lobes 1–2.5 cm long (up to 3.5 cm in cultivars), persistent, green, bristly and with a characteristic white, woolly, arachnoid tomentum especially near the base and margins, with a prominent nectary gland on each midrib; corolla large and showy, usually cream to yellow with red inner base, sometimes blue or purple; petals free, usually spreading, twisted clockwise or anticlockwise, obovate, 4–6 cm × 3–5 cm, outer side stellate-pubescent; staminal column epipetalous and surrounding the style, 17–23 mm long, dark red, with numerous 1–2 mm long filaments and 1-celled yellow or red anthers; pollen spiny, spherical; pistil with superior, 5-locular, ovoid, pointed, villose ovary, each locule containing many ovules arranged in 2 vertical rows, a single red style, branching into 3–5, hairy arms 2–4 mm long, each branch ending in a capitate stigma. Fruit an ovoid, beaked capsule, 12–20 mm × 11–15 mm, densely appressed pubescent, the beak 1 mm long, containing 20–25(–35) seeds. Seed subreniform to triangular with acute angles, 3–4 mm × 2–3 mm, ash grey or brown-black with light yellowish spots, hilum brown. Seedling with epigeal germination.

Growth and development Kenaf seeds have no dormancy and will germinate within 2–3 days after sowing in moist and warm soil. Growth rate increases gradually and is at its maximum, 7–8 cm of stem length per day, between 2 and 3 months after germination. Maturing time, defined as the period between seedling emergence and flowering under normal growing conditions, may vary from 80 days for very early cultivars to 120 days for medium ones and 140 days for late ones. Early cultivars may have a plant height of only 2.5 m at maturity versus 4.5 m for late types. Flowering in most cultivars lasts about 4 weeks with maximum flush in the second week. In some African accessions, the period of flowering may be more than 8 weeks. Flowers of kenaf are short-lived, opening before sunrise and closing by noon of the same day. The pistil is already receptive before anther dehiscence starts shortly after sunrise. The stigmatic lobes hang down initially, almost touching the unopened anthers, but become turgid later in the day and soon stand out above the anthers. Kenaf is mainly self-pollinated, but up to 12% cross-pollination has been recorded. Cross-pollination is mainly effected by bees and other insects. Seeds are mature within 32–35 days after anthesis. Under normal weather conditions most kenaf cultivars have indehiscent fruits, but in many African accessions the fruit wall bursts and the seeds are shattered.

Other botanical information *Hibiscus* L. comprises 200–300 species, found mainly in the tropics and subtropics, many of which are grown as ornamentals. The estimated number of species varies because opinions differ about inclusion or exclusion of several related groups of species in the genus. In a recent revision (2001), for instance, 22 *Hibiscus* spp., formerly grouped under *Hibiscus* sect. *Azanzae* DC., have been excluded from *Hibiscus* and placed in the segregate genus *Talipariti* Fryxell. These include some trees of which the bark is made into good-quality rope and other cordage items in South-East Asia, such as *T. macrophyllum* (Roxb. ex Hornem.) Fryxell (synonym: *H. macrophyllus* Roxb. ex Hornem.) and *T. tiliaceum* (L.) Fryxell (synonym: *H. tiliaceus* L.), both treated in PROSEA 5 'Timber trees'. *H. floccosus* Mast., the bast of which is made into rope in Peninsular Malaysia, has not been removed from *Hibiscus*.

Kenaf belongs to *Hibiscus* section *Furcaria*, a group of about 100 species which have in common a pergamentaceous calyx (rarely fleshy) with 10 strongly prominent veins, 5 running to the apices of the segments and bearing a nectary, and 5 to the sinuses. The section *Furcaria* has $x = 18$ as basic chromosome number. Interspecific hybridization has been attempted with varying success between *H. cannabinus* and other species within the same section, e.g. *H. acetosella* Welw. ex Hiern, *H. diversifolius* Jacq., *H. radiatus* Cav., and *H. sabdariffa*. *H. cannabinus* can easily be distinguished from the related species *H. radiatus* and *H. sabdariffa* by the white, arachnoid tomentum on the calyx. In the Philippines, *H. cannabinus* as listed by Merrill has to be referred to *H. radiatus*, since the specimens quoted belong to that species.

H. cannabinus is highly variable and various sub-

classifications have been proposed, but none is generally accepted. Best known are the so-called 5 botanical varieties that have been distinguished in India, but which are in fact cv. groups:
- Purpureus: stem purple, leaves palmate with purple petiole;
- Ruber: stem red below and greenish above, leaves palmate with green petiole;
- Simplex: purple stem, entire leaves with purple petiole;
- Viridis: green stem, entire leaves with green petiole;
- Vulgaris: stem green, leaves palmate with green petiole.

The majority of kenaf cultivars belong to the cv. groups Viridis and Vulgaris.

H. radiatus, possibly an allotetraploid of *H. cannabinus* and *H. surattensis* is grown as an ornamental, vegetable and medicinal herb in South-East Asia and as a fibre plant in Brazil. *H. surattensis* L. is sometimes grown for its fibre.

Ecology Kenaf has a wide range of adaptation to climate and soil, and is grown between 45°N and 30°S. Kenaf plants are tolerant of daily temperature variation between 10°C and 50°C, but are killed by frost. It grows best where mean daily temperatures during the growing season are higher than 20°C and average monthly rainfall is 100–125 mm during the growing season. These conditions are met during the rainy season in the tropics and the wet summer season of the subtropics. Kenaf is a short-day plant: regardless of the time of planting, most cultivars remain vegetative until the daylight period falls below 12.5 hours. Cultivars planted at a latitude of 20°N will, therefore, not start flowering before early September. At higher latitudes flowering commences progressively later, whereas at the equator plants flower early and attain insufficient height, except when the grown cultivar is photo-insensitive. Kenaf can be grown on a wide range of soils, but thrives best on free-draining sandy loams of alluvial or colluvial origin, with pH 6–6.8. It is salt-tolerant, but sensitive to waterlogging.

Propagation and planting Kenaf is normally propagated by seed. It may also be propagated from stem cuttings, especially for the production of breeder and basic seed. Kenaf seeds deteriorate quickly under humid conditions, but high viability can be maintained for more than one year by storing dry seeds (< 10% moisture content) in airtight containers and for several years by storing at sub-zero temperatures (–10°C). The optimum temperature for germination of kenaf seeds is 35°C, with a base temperature of 10°C and a maximum temperature of 46°C.

Kenaf is mostly a rain-fed crop sown directly in the field at the start of the rainy season. Time of planting is very important, as the crop should grow during long days. The longer the period of vegetative growth before first flowering, the higher the yield of biomass and fibre and also the better the fibre quality. In Java, Indonesia (8°S) kenaf is sown during October-November with the onset of the rainy season and flowers in March-April, while in north Thailand (18°N) the cropping season is between April and September. A deep cross-ploughing is usually desirable for thorough tillage, followed by harrowing to subdue weeds and to obtain a fine state of tilth. Most kenaf is grown by smallholders, who plant by broadcasting at seed rates of 15–25 kg/ha, followed by harrowing or laddering to cover the seed with 1–2 cm soil. Such plots require thinning by hand to reduce plant density to about 400 000 plants per ha. Row plantings require less seed and result in more uniformity and higher yields at lower establishing and maintenance costs (e.g. by mechanical drilling and weeding). Recommended spacings for row planting vary between countries. They are generally similar to those for jute, i.e. 20–30 cm between and 5–10 cm within rows, when grown for fibre, but a somewhat wider spacing to produce pulp for paper making. Seeds can be produced on plants left in the field after harvesting the main crop. However, the amount and quality of seeds is much higher on special seed plots sown late in the season, as profuse flowering is induced by declining daylengths.

Husbandry Kenaf grows rapidly and requires little additional weeding after a few rounds of thinning and weeding during the first month after sowing. Nutrient requirements depend on soil type, initial soil fertility and yield levels. The uptake of major nutrients by one ha of kenaf producing 36 t green plants (1.7 t dry retted fibre) is estimated at about 94 kg N, 26 kg P, 121 kg K, 138 kg Ca and 29 kg Mg. Part of this is usually returned to the soil when stems are left to defoliate on the field after harvesting. In field trials kenaf often shows large yield responses to N fertilizers, sometimes significant responses to P and K and almost never to Ca fertilizers. Smallholders seldom apply fertilizers to a kenaf crop, but still get a reasonable yield due to residual fertility from a previous food crop or inherent fertility of the soil (e.g. alluvial flood plains). Kenaf is a rain-fed crop, but receives supplementary irrigation in some countries to boost yields. Out-of-season seed plots may require irrigation for proper seed set and quality.

Diseases and pests The economic importance of kenaf diseases varies among countries. Stem and seedling rots caused by *Macrophomina phaseolina* and leaf spot by *Cercospora hibisci-cannabini* are serious kenaf diseases in several Asian countries. *Fusarium* sp. is a major disease in Indonesia causing damping-off in young seedlings and black or brown stem lesions resulting in lodging and death of older plants. Collar-rot caused by *Phytophthora nicotianae* var. *parasitica* is the most serious soil-borne disease of kenaf in Thailand, in particular during the peak growing period. Other diseases in kenaf in Asia are a leaf spot caused by *Phoma* sp., anthracnose (*Colletotrichum* spp.), virus A (leaf curl) and virus B (mosaic).

Kenaf harbours numerous insects, but only a few cause serious damage to the crop. Flea beetles (*Podagrica* spp.) and the jassid leaf hopper (*Amrasca biguttula*) are among the most important insect pests in Asia. Other insect pests of kenaf in Asia include the spiral borer (*Agrilus acutus*), cotton bollworm (*Helicoverpa armigera*), black cutworm (*Agrotis ipsilon*), the cotton stainer (*Dysdercus* spp.) and stink bug (*Tectocoris* spp.).

Kenaf is particularly susceptible to root-knot nematodes (*Meloidogyne* spp.), which may cause severe damage, especially in light-textured soils. Flooding of the land prior to kenaf cultivation and regular crop rotation help to reduce nematode attacks. Some difference in tolerance to nematodes exists among kenaf cultivars.

Harvesting In kenaf the quantity and quality of fibre depend very much on the time of harvesting. Harvesting at the flower bud stage produces the best quality but less fibre, whereas at the pod (immature capsules) stage fibre yield will be higher but of poor quality. Thus, the recommended time to harvest for an optimum balance in fibre yield and quality is when about 50% of the plants are flowering. In Asia, kenaf is generally harvested by hand, cutting the stem close to the surface of the soil with a sickle. On sandy soils whole plants may be pulled up, and the lower end with roots cut off. The plants are then tied into loose bundles, which are placed upright against each other for 2–3 days in the field to induce defoliation and desiccation. After shaking off all remaining leaves the stems are first graded before assembling bundles of about 10 kg each, containing stems of uniform thickness. These are tied with bark strips and transported to the nearby retting pool.

Yield World yield of kenaf is about 1.2 t dry fibre per ha, averaged over the period 1997–2001. Average yields per country are: Indonesia 1.4 t/ha, Thailand 1.6 t/ha, India 1.7 t/ha and China 2.4 t/ha. The potential yield of kenaf, as obtained in experimental fields with improved cultivars, is 3–5 t dry fibre per ha. Seed yields of 1–1.5 t/ha can be obtained from late-sown kenaf plots.

Handling after harvest Kenaf stems are usually retted in water for a period of 10–15 days at warm (>30°C) temperatures to liberate the fibres from the bark tissues by enzymatic action of micro-organisms. The bundles are steeped in shallow water in 2–3 layers, which are kept submerged by the weight of bundles of water hyacinth (*Eichhornia crassipes* (Martius) Solms) or rice straw, bricks or concrete slabs. The retting progress is monitored towards the end of the process by testing a few stems removed from the centre of the bundles. Retting efficiency depends on factors such as cultivar, maturity, water quality, microbial activity, and day and night temperatures. Retting should be carried out in clear and slow moving water at the optimal proportion of 1:20 for plant biomass to water quantity. In case of stagnant water, addition of urea (0.01% of the green weight of kenaf plants) may enhance the retting process and removal of brown colour. When retting is complete, the fibres are stripped manually from the stem, washed thoroughly in clean water and dried well in dust- and sand-free conditions. As in jute, the fibre quality is very much determined by correct retting, cleaning and drying. Ribbon retting, whereby the bark is stripped from freshly harvested stems by manual or machine decorticators ('ribboning') and only the ribbons are steeped in water, requires much less water and reduces the retting time by half. It is a method generally applied in areas with chronic water shortage during the harvesting season, but it also reduces handling and transport costs from the field to the retting pools and tends to produce fibre of more uniform and higher quality. The dried fibres are transported in crude bales to local centres for initial grading and packing in low compression bales of 60–150 kg before transportation to the spinning mills. Whole kenaf stems may also be transported directly from the field to pulp- and paper-making factories.

Kenaf has been successfully pulped with a range of chemical, semi-chemical and mechanical processes. The choice of the pulping process depends mainly on the plant part used (bark, core or whole stems) and the type of paper to be produced. Kenaf kraft (sulphate) and soda pulps have similar yields and strength properties, but soda pulps have better initial drainage characteristics (freeness). Kenaf bark fibres pulped with the kraft, kraft-anthraquinone, soda and soda-anthraquinone processes give pulp yields of 51–63%, and kenaf core fibres give yields of 40–54% with the same processes. With the cold soda and alkaline sulphite processes kenaf bark gives high pulp yields (72–88%) with satisfactory strength properties, brightness and opacity. The alkaline sulphite-anthraquinone process is well suited for kenaf bark and whole stems, giving better yield, strength, viscosity and brightness than soda and soda-anthraquinone pulping. The alkaline sulphite-anthraquinone-methanol process gives even better results. For the production of high-quality newsprint chemi-thermo-mechanical pulping of whole stems is effective. Nonchlorine bleaching processes have been successfully applied on kenaf pulps, e.g. using ozone and peroxide.

Genetic resources The existing kenaf cultivars are based on a narrow range of genetic variability and are constrained by low adaptability to agro-ecological conditions and susceptibility to several diseases and insect pests. The former International Jute Organization (IJO) has therefore mandated the genebank of the Bangladesh Jute Research Institute (BJRI) in Dhaka, Bangladesh, to become also the world germplasm repository for kenaf. The present collection consists of some 920 accessions, including old and new cultivars, landraces, wild and semi-wild accessions of kenaf and related species from Africa. The wild accessions of kenaf and other *Hibiscus* species from East Africa appear to be especially promising sources of genetic variation, as these were collected from a diverse range of habitats and soil types. A duplicate set of seed samples for all accessions is stored at the Commonwealth Scientific Industrial Research Organization (CSIRO) in Canberra, Australia. Research centres in India, China, Thailand, Indonesia and other kenaf-producing countries have unrestricted access to genetic resources present in the genebank of the BJRI.

Breeding Methods of selection and breeding common to self-pollinating crops are applied to kenaf, mostly line selection within landraces or after intervarietal crosses and backcrosses. Higher yield is an important breeding objective in kenaf, but in South and South-East Asia the on-farm yields of improved cultivars are often less than half the on-station (potential) yields. This gap is caused partly by inadequate cultural practices and low inputs at farm level, but also by the fact that the available cultivars are often inherently poor achievers in marginal ecosystems. Breeding for new cultivars with the potential of high yields under suboptimal conditions is all the more urgent because the kenaf crop is being pushed increasingly into marginal environments due to pressure from food and other crops. Earlier maturing and photo-insensitive kenaf cultivars also fit better in systems of multiple cropping. Other breeding objectives are plants without prickly stems and bristly capsules to facilitate manual harvesting, and host resistance to diseases, insect pests and nematodes. Resistance to diseases such as anthracnose (*Colletotrichum* spp.) and stem rot (*Macrophomina phaseolina*) is available from *H. cannabibus* accessions, but adequate levels of resistance to root-knot nematodes (*Meloidogyne* spp.) are mostly restricted to related species, such as *H. acetosella*, *H. rostellatus* Guill. & Perr., *H. sabdarrifa*, and *H. surattensis*. Introgression of target characters into kenaf from these species is being attempted by conventional as well as advanced techniques (e.g. protoplast fusion) of interspecific hybridization.

Prospects Despite the fact that kenaf, like jute, is being pushed onto marginal land under pressure from food and other crops, and is also under strong competition from synthetic fibres, prospects for increased production of both fibre and whole stems are promising in view of growing concerns about environmental pollution and dwindling forest resources. Kenaf fibre is biodegradable and an environment-friendly raw material suitable for many applications, such as specialty paper (either alone or in blends with hardwood), non-woven fabrics, geotextiles and semi-rigid and laminated sheets for packaging and panelling. Furthermore, whole kenaf stems are an excellent substitute for softwood as raw material for paper making. It is therefore likely that the importance of kenaf as a raw material for paper making will continue to increase.

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Hibiscus sabdariffa L.

Sp. pl.: 695 (1753).
MALVACEAE
$2n = 4x = 72$

Synonyms *Hibiscus digitatus* Cav. (1787).

Vernacular names Roselle, Siam jute (En). Roselle (Fr). India, Bangladesh: mesta. Indonesia: rosela (general), gamet walanda (Sundanese), kasturi roriha (Ternate). Malaysia: asam susur. Philippines: roselle (Tagalog), kubab (Ifugao), talingisag (Subanon). Cambodia: slök chuu. Laos: sômz ph'oox dii. Thailand: krachiap, krachiap-daeng (central), phakkengkheng (northern), paw keao. Vietnam: day nh[aaj]t, b[uj]p gi[aas]m, c[aa]y d[aas]m.

Origin and geographic distribution Roselle is probably of tropical African origin and was domesticated in ancient times first for its edible seeds and subsequently for its leaves, young shoots and flower parts as well. Both roselle and kenaf (*Hibiscus cannabinus* L.) may have been domesticated as early as 4000 BC in Sudan. As a vegetable (*H. sabdariffa* cv. group Sabdariffa) it reached the Americas and Asia in the 17th Century. Its use as a fibre plant (*H. sabdariffa* cv. group Altissima) is of more recent date. *H. sabdariffa* cv. group Altissima was unknown outside Africa until 1914, when seeds from Ghana were received in the Philippines, where its potential as a source of fibre was recognized. Experimental plantings started in Cuba in 1919. In Asia, *H. sabdariffa* cv. group Altissima was introduced into Java in 1918 and experimental work soon started, to be followed in other countries, including Malaysia (1921), Sri Lanka (1923) and India (1927). It remained a relatively unimportant fibre crop in most countries, except Thailand where it expanded after 1958 into a large bast fibre industry with considerable annual exports. Roselle was introduced into Vietnam in 1957. Nowadays roselle is widely distributed in the tropics and subtropics, usually in cultivation as a fibre plant or vegetable, sometimes as an escape.

Uses The fibre extracted from the bast of roselle has similar applications to that of jute (*Corchorus* spp.), including gunny bags and hessian cloth. In Indonesia bags made from roselle were formerly extensively used for packing sugar. Roselle is also used, alone or with jute, in the manufacture of carpet and linoleum backing, cordage, tapes, upholstery, wall coverings, cable cores and interior car panelling. In the handicraft industry the fibre is made into cordage, carpets, rugs and handbags. The woody central core material or 'stick' (also often referred to as 'hurd' or 'shiv') left after decorticating can be used for paper making and serves for fencing and window shutters and as fuel. Whole stems have been processed to some extent into pulp for paper making in Thailand, Indonesia, Bangladesh and India.

The fleshy calyces of cv. group Sabdariffa are made into beverages, jams and jellies. Young leaves and tender shoots are eaten raw or cooked as a vegetable or condiment. In Africa the seeds of *H. sabdariffa* are eaten roasted or ground into meal. The leaves are considered emollient and leaf poultices are applied on abscesses and ulcers. Decoctions of the whole plant, and especially the calyx, are considered diuretic, tonic and antiscorbutic.

Production and international trade World production of jute-like fibres, a group consisting of kenaf, roselle, Congo jute (*Urena lobata* L.), *Abutilon theophrasti* Medik. and other *Malvaceae*, and sunn hemp (*Crotalaria juncea* L.), was 450 000 t per year from 370 000 ha averaged over the period 1997–2001. Separate statistics are unavailable but roselle is estimated to make up only about 10% of this total. In Thailand roselle is an important bast fibre crop, constituting 85% of total bast fibre production there. Roselle production in Thailand reached its peak of 660 000 t retted fibre per year in 1966, with exports of 475 000 t of raw fibre and gunny bags to over 60 countries, at a value of over US$ 810 million, making roselle the second largest foreign exchange earner of the country. About 70 000 t of the fibre was used locally by 10 gunny bag mills. However, production in Thailand gradually decreased to 120 000 t in 1994 and 35 000 t in 2000. Only 10% of Indonesia's bast fibre production is from roselle and during 1995–1999 the average production of roselle was 700 t from 440 ha. Roselle fibre is sometimes traded under the name kenaf, but this name is normally restricted to the fibre derived from *H. cannabinus*.

Properties Roselle produces a bast fibre similar to jute (*Corchorus capsularis* L. and *C. olitorius* L.), except that it is whiter and somewhat coarser. The raw (retted and dried) fibre makes up about 5% and the dry wood 18% of the freshly harvested and defoliated green stems. The commercial fibre has a length of up to 2.1 m. The ultimate bast fibre cells are (1.2–)1.9–3.1(–6.3) mm long and (10–)12–25(–44) μm wide, with maximum length and width in the middle portion of the stem. Lumen width and cell wall thickness vary from 3–15 μm and (4–)8–15 μm, respectively. Most fibre cells have tapering rounded ends. The wood consists of fibre cells 0.5–1.0 mm long and about 24–26(–32) μm wide, with a lumen width of 9 μm and a cell wall thickness of 3–7 μm. The chemical composition of roselle stems is not as well known as that of kenaf stems. The bast fibres contain about 32% α-cellulose, 10–15% lignin and 1% ash.

Roselle seeds contain 17–20% oil. The main fatty acids are palmitic acid (9–25%), oleic acid (26–38%) and linoleic acid (35–46%), but sometimes a combination of a much higher oleic acid and much lower linoleic acid content is found. The oil also contains 3–5% cyclopropenoid acids, which are toxic. The oil has shown antibacterial and antifungal activity. The press cake has a nitrogen content of 4.7% or the equivalent of 29% crude protein. The defatted seed contains antinutritional factors such as protease inhibitors, phytic acid and gossypol, making proper processing necessary before use in human nutrition. The flowers contain anthocyanins with, among others, hypotensive, diuretic and chloretic effects, whereas the extract of dried flowers showed antioxidative properties. Calyx extracts have shown hypotensive and antimutagenic activity.

The 1000-seed weight is 15–25 g.

Adulterations and substitutes Roselle fibre is coarser than jute and hence less valued. For many purposes, such as coarse packaging fibres and cordage, jute, kenaf and roselle may be substituted for each other. However, as kenaf and roselle are coarser and cheaper, they are considered more as a substitute of jute than the other way round. In some jute-producing countries the traders mix roselle with jute fibres in an effort to obtain higher prices. Bast fibres which can serve as substitutes for jute, kenaf and roselle include those of *Abroma augusta* (L.) L.f., *Helicteres isora* L., *Malachra capitata* (L.) L. and *Urena lobata*.

Description An erect, annual herb, up to 5 m tall. Taproot well developed, 18–30 cm deep, lateral roots few, occasionally with adventitious roots. Stem terete, beset with prickles or bristles, entirely green, green with red nodes, green with red patches or entirely red. Leaves alternate, polymorphic; stipules filiform, 5–13 mm long; petiole 0.3–12 cm long, green to red; blade 2–15 cm × 2–15 cm, entire to deeply 3–5(–7)-palmately lobed, base cuneate to truncate, margin finely to coarsely serrate, apex obtuse to acuminate, lobes lanceolate, middle one longest, subglabrous to pubescent with simple hairs, midrib with numerous mucilaginous glands on lower surface and ribs sometimes bearing prickles. Flowers solitary, axillary, bisexual, 5-merous; pedicel 5–20 mm long, articulating near the base to halfway between the base and the epicalyx, glabrous to hispid; epicalyx with 8–12 persistent bracts, fused at base, the free parts subulate to triangular, narrow, up to 7 mm long, apex pointed, green or red, leathery and with short bristles (cv. group Altissima) or fleshy and glabrous (cv. group Sabdariffa); calyx persistent, campanulate, 5-lobed, lobes triangular to ovate, up to 2.2 cm long in fruit, leathery and bristly (cv. group Altissima) or fleshy and glabrous (cv. group Sabdariffa), the nectaries inconspicuous, green, red or whitish; corolla bell-shaped and spreading with 5 free petals; petal asymmetrically obovate, up to 3 cm × 2 cm, base narrow, fleshy, apex rounded, glabrous to pubescent dorsally, yellow or yellow with deep red inner centre; stamens arranged in a column 7–20 mm long, yellowish-green to pink or red, free part of filaments 1 mm long, anthers most densely at the apex of column, dorsifixed, reniform and unilocular, pollen spiny and yellowish; pistil with superior, ovoid to globose ovary, 4–6 mm in diameter, densely silky hairy, 5 chambered with many ovules in each chamber, arranged in 2–3 rows, style included in staminal column, 5 branched, each branch ending in a capi-

Hibiscus sabdariffa L. – 1, flowering shoot; 2, flower; 3, fruit surrounded by a fleshy calyx.

tate, hairy, red or yellow stigma. Fruit an ovoid capsule, 13–22 mm × 11–20 mm, deeply embedded within calyx, dehiscing by 5 valves when ripe with 30–40 seeds per fruit. Seed subreniform, 3–5 mm × 2–4 mm, reddish-brown with many small yellowish-brown warty spots, hilum reddish-brown. Seedling with epigeal germination.

Growth and development Roselle seeds germinate within a few days after sowing in warm and moist soil. The young seedlings have a taproot, a hypocotyl of 5–9 cm and petiolate, cordate cotyledons. The first true leaves are petiolate and entire, oval-shaped, but subsequent leaves become increasingly lobed to palmate. Total duration from sowing to first flowering varies from 150–210 days, depending on photoperiod and temperature. Flowers of roselle are short-lived, remaining open for not more than three hours, closing at about noon of the same day they open. Roselle is almost entirely self-pollinating, though some cross-pollination by insects may occur. The stigmatic lobes remain drooped over the staminal column, and the anthers shed their viscous balls of pollen shortly before the flowers open so that any movement of the flower by wind or insects will transfer the pollen to the stigmatic surface. Fruit ripening takes 2–3 months from pollination. Roselle fruits are dehiscent as the fruit wall bursts at maturity and the seeds are scattered.

Other botanical information *Hibiscus* L. comprises 200–300 species, found mainly in the tropics and subtropics, many of which are grown as ornamentals. The estimated number of species varies because opinions differ about inclusion or exclusion of several related groups of species in the genus. Roselle belongs to *Hibiscus* section *Furcaria*, a group of about 100 species which have in common a pergamentaceous calyx (rarely fleshy) with 10 strongly prominent veins, 5 running to the apices of the segments and bearing a nectary, and 5 to the sinuses. The section *Furcaria* has $x = 18$ as basic chromosome number. *H. sabdariffa* is an allotetraploid ($2n = 4x = 72$) with *H. asper* Hook.f. as one of the likely parental species, and perhaps *H. mechowii* Garcke as the other. Within *H. sabdariffa* two main cultivar groups are distinguished:

- cv. group Altissima (synonym: *H. sabdariffa* L. var. *altissima* Wester): plants with single stem, usually branching only at the top, 3.5–5 m tall; epicalyx and calyx leathery and strongly hispid or bristled, enlarging little after anthesis, usually inedible; cultivated for its bast fibre.
- cv. group Sabdariffa (synonym: *H. sabdariffa* L. var. *sabdariffa*): plants branching profusely, 1.5–2 m tall; epicalyx and calyx fleshy and glabrous, enlarging considerably after anthesis; edible; cultivated mainly as a vegetable.

In Africa forms, usually branched and with bristly or aculeate plant parts, occur which do not seem to be part of either of these 2 groups. Some are cultivated for their seeds, whereas others seem wild.

Ecology Roselle is cultivated between 7°S (Java, Indonesia) and 23°N (Bangladesh). Climatic requirements during the growing period are mean monthly temperatures of 25–30°C, a rainfall of 140–270 mm per month and high air humidity (>70%). Although the crop requires abundant rainfall during the vegetative period for maximum fibre yield, roselle is also grown in areas with lower monthly rainfall since the crop is known to be drought-resistant once established. A drier period is also required for flowering and seed production. Roselle, like kenaf, is sensitive to frost, which is the main constraint to its cultivation in temperate zones. Roselle is a short-day plant, requiring a photoperiod of 12–12.5 hours for flowering and fruiting. In Java, for instance, no flowering is typically observed during the period December-March. The length of the vegetative period and fibre yield can thus be manipulated through the sowing date. Roselle can be grown on many soil types, provided these are deep, light textured and have good drainage. It tolerates both highly acid and moderately alkaline soils, but is intolerant of waterlogging.

Propagation and planting Roselle is usually propagated by seed, but can also be grown from stem cuttings. Seed rate and planting distance vary from country to country. In Indonesia 12–14 kg/ha is recommended for line sowing, at 20 cm between and 15 cm within row plant distances, and 18–20 kg/ha for broadcast sowing. In Thailand most farmers drill roselle at 5–10 seeds per hole (to be thinned to 4–5 plants per hill) at 40 cm between and 30 cm within row spacing, using about 10 kg/ha, even though higher yields of fibre are obtained by single plants at closer (30 × 10 cm) spacing, using 18 kg/ha. For leaf or calyx production, plants are spaced more widely, e.g. 60 cm × 100 cm and 120 cm × 90 cm, respectively. Deep cross-ploughing and thorough tillage are important for unrestricted growth of the taproot and good crop establishment in general. The proper time for planting roselle as a fibre plant is October-November in South Kalimantan (Indonesia) and May in Thailand and Vietnam.

Roselle is mostly a smallholder crop and usually part of a cropping system with rice or maize. In north-eastern Thailand it is cultivated as a sole crop in upland areas. Because it occupies the land for a large part of the year, roselle is often not popular with farmers.

Husbandry A single round of weeding and thinning to final plant density is usually performed 20–30 days after emergence of roselle. However, if weed infestation is high farmers carry out a second weeding. In Indonesia supplementary water for irrigation is often available, whereas in Thailand roselle is mainly a rainfed crop. The uptake of major nutrients by one ha of roselle producing 48 t green plants (2.1 t dry retted fibre) is estimated at about 106 kg N, 52 kg P, 148 kg K, 154 kg Ca and 35 kg Mg. As with kenaf, part of this is usually returned to the soil when stems are left to defoliate on the field after harvesting. The recommended rate of fertilizer application for irrigated roselle in Indonesia is 40–120 kg N per ha and for rainfed roselle 90 kg N, 50 kg P and 60 kg K per ha. In Thailand the recommended fertilizer dose is 15 kg N, 15 kg P and 15 kg K per ha in a single application, 20–30 days after seedling emergence.

Diseases and pests The most important disease of roselle in South-East Asia is collar rot (*Phytophthora nicotianae* var. *parasitica*), which attacks plants at all growth stages. It becomes particularly serious in densely planted crops and during heavy rains. Roselle cultivars with red stem are more resistant than those with green stem. Phytosanitary measures help to reduce incidence of the disease. Vascular wilt caused by *Fusarium oxysporum* is an important disease of roselle in Malaysia.

Roselle has many pests in common with other malvaceous crops such as cotton (*Gossypium* spp.) and okra (*Abelmoschus* spp.). In Indonesia and Thailand, the main pest is the jassid leaf hopper (*Amrasca biguttula*). It attacks the plants by piercing the stems and then sucks the cell sap, ultimately killing the plants. Severe infestations occur when there is a long dry spell. Early planting can minimize the damage, because older plants are more tolerant to attacks. Seed treatment with systemic chemicals can protect the seedlings. The farmers usually do not use insecticides so it is important to breed insect-resistant cultivars. Other common pests are cotton stainer bugs (*Dysdercus superstitiosus*), bollworms (*Earias biplaga*, *E. insulana*) and flea beetles (*Podagrica* spp.).

Root knot nematodes (*Meloidogyne* spp.) can cause serious crop losses. Attack by this nematode is usually followed by secondary infection with fungal diseases caused by *Fusarium*, *Rhizoctonia* and *Sclerotium* spp. Roselle genotypes are available with resistance against *Meloidogyne incognita* and *M. javanica*.

Harvesting Opinions vary with respect to the optimal time for harvesting, ranging from before the onset of flowering to the full flower stage. An important consideration is that, unlike in kenaf, the quality of roselle fibre deteriorates rapidly after initial flowering. In Thailand it is usually harvested between 140–160 days after sowing, before flowering has started. In Indonesia the crop is harvested within 150–160 days. Roselle plants may be harvested by hand using a sickle to cut the stems near ground level, but in sandy soils whole plants may be pulled up. Sometimes the root ends are removed before retting, or the crop may be retted with the roots remaining, with the root material removed afterwards. The harvested crop is usually sorted into thick- and thin-stemmed plants before bundling. In Thailand the plants are shaken to defoliate; elsewhere the plants are left on the ground to defoliate or they are tied into loose bundles, which are placed upright against each other for 2–3 days. When grown as a vegetable, the leaves or young shoots are harvested from the third month onwards and the calyces at about 15–20 days after flowering.

Yield National average yields of dry roselle fibre over 1997–2001 were 1.9 t/ha for India, 1.6 t/ha for Thailand and 1.4 t/ha for Indonesia. Maximum yields obtained experimentally on-farm or on research stations were 4 t/ha in Bangladesh, 3.5 t/ha in Indonesia, 3 t/ha in India and 2.5 t/ha in Thailand. In experiments in India dry stalk yields up to 17 t/ha have been obtained. Seed yields may reach 1.7 t/ha. For roselle grown as a vegetable, leaf yields up to 10 t/ha have been recorded, whereas calyx yields vary from 5–15 t/ha.

Handling after harvest After defoliation the roselle plants are tightly bundled and transported to the retting pool. Not more than 10 kg of stems should be in one bundle. Larger-sized bundles ret irregularly and produce poor quality fibre. The water in the retting pools should not be deeper than about 1 m; it should be clean and preferably flowing slowly to accelerate the retting process. The bundles of stems are arranged in 3–5 layers, each at right angles to the other, and tightened into a raft or 'jak'. The rafts are then submerged using weights, generally logs of woods or concrete blocks, but they should not touch the bottom of the pool, as this leads to discoloration of the fibre. Aquatic plants such as water hyacinth (*Eichhornia crassipes* (Martius) Solms) may also be used to cover the rafts. The time required for retting depends on factors such as maturity and thickness of the stems, temperature and pH of the water and amount of inoculum present. Usually it takes 8–17 days, but more time is needed in the case of fresh and non-defoliated stems. Where water is plentiful or flood water is present during the retting period, roselle is stripped and washed directly at the site of the retting pools. Otherwise, the retted bundles are removed from the pool and taken to a nearby stripping area, as is common practice in Thailand. The bundles are opened and the bottom ends beaten with a heavy stick or mallet to loosen the bast from the woody stem. The fibre is partly peeled from individual stems, after which the fibre is stripped in a single operation from 10–15 stems together, and rolled up into a hank. The washing operation consists of holding the hank at the bottom and jerking it through the water, and then reversing the process holding the tip ends. A skilled worker can strip and wash the equivalent of 35–45 kg of dry retted fibre per day. Drying of the washed hanks over bamboo poles takes 1–2 days in warm, sunny weather. Drying must be thorough with no damp spots in the fibre. Thai roselle growers prepare highly uniform bales ('barrels') by hand weighing 50–80 kg each. In Thailand retted roselle fibre is graded according to length, colour, softness and purity.

Nowadays, a considerable amount of roselle is ribboned directly after harvesting, especially when retting facilities are far from the growing area or when the supply of retting water is limited. The raw ribbon is about 30% of the green weight of stem. Freshly harvested green roselle plants are easier to ribbon than kenaf.

The bark, core and whole stems have been pulped using the soda-process, giving yields of 52–54%. The strength properties (breaking length, burst factor and tear factor) were better for bark pulps than for core and whole stem pulps. Cores as well as whole stems have been pulped using the soda-anthraquinone process, giving 47–54% pulp, with whole-stem pulp having better mechanical properties.

Genetic resources In South-East Asia the existing cultivars of roselle have a narrow genetic base and are constrained by low adaptability to agro-ecological conditions and susceptibility to several diseases and pests. Through mediation of the (former) International Jute Organization (IJO) a total of 140 accessions of *H. sabdariffa* of African and other origins have been added to the Centralized Germplasm Repository (CGR) in the Gene Bank of the Bangladesh Jute Research Institute (BJRI) in Dhaka, Bangladesh. Maintenance and characterization of these accessions is duly performed by the BJRI in Dhaka and all IJO member-countries have unrestricted access to these genetic resources.

Breeding Cultivar improvement in roselle follows breeding methods commonly applied to self-pollinating crops, such as line and pedigree selection after intervarietal crossing and backcrossing. Crossing techniques include emasculation in the afternoon and pollination the following morning. In addition to conventional breeding objectives of higher yields and better quality fibre, much attention is now also given to adaptation to abiotic and biotic stress factors. This is necessary because roselle is being pushed increasingly into more marginal environments due to pressure from food and other crops. Selection criteria include shorter growth duration to fit roselle into multiple cropping systems, tolerance to soils with low pH and high aluminium and iron content, host resistance to diseases (e.g. collar rot) and pests (the jassid leaf hopper in particular). Roselle cultivars for paper pulp require selection for high total biomass production, without too much emphasis on fibre yield or quality.

Prospects Like jute and kenaf, roselle is being pushed onto marginal land under the pressure of food and other crops and is also under strong competition from synthetic fibres, but prospects for increased production for both fibre and whole stems are promising, in view of growing concerns about environmental pollution and decreasing forest resources. Roselle fibre is biodegradable and an environment-friendly raw material suitable for many applications (non-woven fabrics, semi-rigid and laminated sheets for packaging and panelling, geotextiles). Whole stems seem to have potential as raw material for paper making, though much less research has been carried out on pulping of roselle than of kenaf.

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Shamsuddin Ahmad & H.A.M. van der Vossen

Juncus effusus L.

Sp. pl.: 326 (1753).
JUNCACEAE
$2n = 40$

Synonyms *Juncus communis* E. Mey. (1819), *J. sundaicus* Ridl. (1935).

Vernacular names Soft rush, common rush, mat rush (En). Jonc à lier, jonc épars (Fr). Indonesia: sumpu, udulan (Javanese). Philippines: sudsud (Igorot), pingot, balili (Bontoc). Vietnam: c[aa]y b[aas]c, b[aas]c d[ef]n, d[aw]ng t[aa]m th[ar]o.

Origin and geographic distribution *J. effusus* is widely distributed in the temperate zones of the world, especially in the northern hemisphere, and the mountainous parts of the tropics, but it is not found in Australia. It is native to South-East Asia where it is found in Malaysia (Sabah, Sarawak), Indonesia (Aceh, Java, Kalimantan), the Philippines (from Luzon to Mindanao), New Guinea, northern Thailand and Vietnam. *J. effusus* is cultivated in Japan, China, Taiwan, the Philippines and northern Vietnam. It is sometimes considered a weed, for instance in pastures.

Uses The stems of *J. effusus* are widely used for making mats, for instance in Japan ('tatami' floor mats), Taiwan, China, Korea, the Philippines and Vietnam. They served for basket weaving in Roman times and are still used for this purpose. They are also made into bags, hats, chair seats and other products, for example in the Philippines. The stems are used for tying parcels in China and have been imported into Peninsular Malaysia for this purpose. The pith was formerly made into lamp-wicks in Europe and Japan and may still be used for this purpose in China and Vietnam. *J. effusus* can be pulped for paper making.

In Peninsular Malaysia the pith is imported from China and used as a drug ('sumbu china'), e.g. against urinary problems. In China and Vietnam it is credited with antilithic, pectoral, discutient, refrigerant, diuretic, depurative and sedative properties and it is used to keep fistulous sores open. The root is also considered to be diuretic. *J. effusus* is readily eaten by goats but rarely by sheep, and is reported to be poisonous to cattle. It may have potential for wastewater treatment, but in comparative studies it showed less biomass production and nutrient accumulation than species such as *Phragmites australis* (Cav.) Trin. ex Steudel and *Schoenoplectus lacustris* (L.) Palla.

Production and international trade In 1989 and 1990 the production of *J. effusus* stems in Japan was 90 000–100 000 t per year from an area of about 8 400 ha. Statistics on production in other countries and international trade are not available.

Properties The stems of *J. effusus* consist of outer layers of sclerenchyma, providing durability to the weaving material, and an inner core of spongy tissue, providing elasticity. Commercial dried stems (7% moisture) contain 33% fibre. Air-dried stems contain about 35–40% cellulose and 3.5–4.5% lignin.

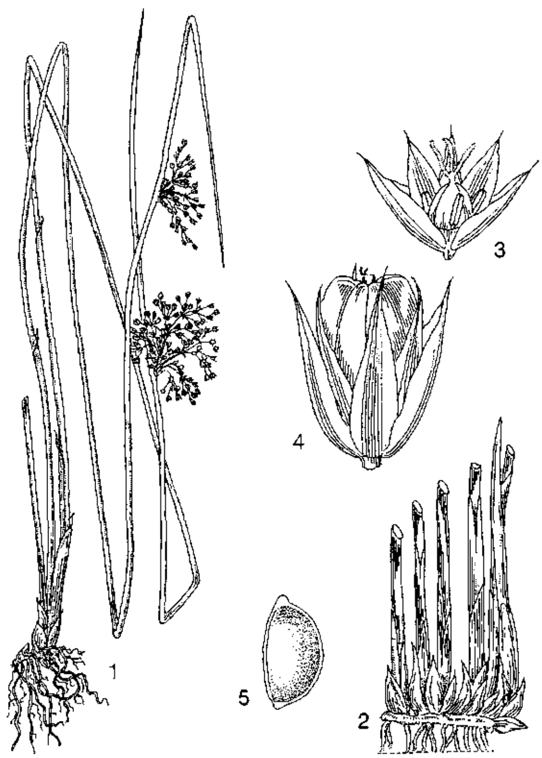
A range of free and glucosylated dihydrophenantrenes have been isolated from the aerial parts of *J. effusus*, with the free dihydrophenantrenes showing strong antialgal activity against *Raphidocelis subcapitata* (synonym: *Selenastrum capricornutum*) and cytotoxic activity in the brine shrimp assay. Dihydrophenanthrenes from *J. effusus* showed varying levels of toxicity to other freshwater organisms. Other compounds isolated from the aerial parts include cycloartane glucosides and cycloartane triterpenes. Phenanthrene derivatives and phenolic compounds such as p-coumaric acid and vanillic acid have been isolated from the pith. An ethylacetate pith extract has shown antioxidant and antiviral activity. The dry matter digestibility is about 33% and the N concentration of dried plants is 1.2–1.4%.

The 1000-seed weight is about 10 mg.

Adulterations and substitutes Various *Cyperaceae* and *Pandanaceae* may be used for weaving instead of *J. effusus*.

Description A semi-aquatic, sedge-like, densely tufted, erect, glabrous, rhizomatous, perennial herb, 40–120 cm tall. Rhizome tough, creeping-horizontal, short, very short-jointed, scaly. Stem terete with continuous pith, 1–3 mm thick, not or hardly ribbed (when dried very closely-set faint longitudinal ribs are visible). Leaves represented by basal scale-like sheaths; sheaths several, stem-embracing, red-brown, bladeless, obtuse, 5–12 cm long, often with a deciduous awn at apex. Inflorescence a pseudolateral, dense or lax, usually many-flowered cymose panicle 1–10(–15) cm long; bract of the inflorescence erect, terete, acute at apex, simulating a continuation of the stem, overtopping the inflorescence by 14–25 cm; flowers partly sessile, partly stalked with petiole up to 8 mm long; floral bracts 2, very close together, ovate, about 0.7–0.8 mm long, thin; perianth segments 6, subequal, narrowly ovate-lanceolate, 2–3.5 mm long, firm with transparent thin margins, apex very acute, yellowish to pale green; stamens 3(–6), much shorter than the tepals, anthers scarcely 1 mm long, equalling or shorter than the filaments; pistil with sessile ovary, very short style, stigmas 3, filiform, long, erect. Fruit a 3-valved capsule, trigonous-oblong, 2–3 mm long, brown, with numerous seeds. Seed broadly ellipsoid, about 0.4–0.5 mm long, apiculate, finely reticulate.

Growth and development The time to flowering of *J. effusus* cultivars in Japan is influenced by the photoperiod, with longer photoperiods resulting in earlier flowering. The extent of the photoperiod response differs among cultivars. Cultivar choice and cultural methods in Japan are aimed



Juncus effusus L. – 1, habit flowering plants; 2, basal part of stems with rhizome; 3, flower with one tepal removed; 4, fruit in perianth; 5, seed.

at preventing flowering, because the stem becomes more fragile when flowering starts. In Japan *J. effusus* is sown in early December and harvested 7–8 months later, in July. In Java *J. effusus* flowers year-round. *J. effusus* seedlings have shown autotoxic sensitivity to extracts of dead aboveground tissues of adult plants.

Other botanical information *Juncus* L. contains about 225 species, widespread over both hemispheres but particularly in temperate and cold regions. *J. effusus* is extremely variable and many varieties and forms have been distinguished. *J. effusus* L. var. *decipiens* Buchenau (synonym: *J. decipiens* (Buchenau) Nakai) is a form with fruits that are less obtuse at the apex. This variety is cultivated in Japan and its many cultivars have been classified into 3 types:
- elongate type, with long, thick and firm stems, less tillering but flowering abundantly; mats made of it are durable but inferior in colour, lustre, uniformity and elasticity;
- tiller type, with short, thin and soft stems, more tillering and flowering poorly; mats made of it have a good colour, lustre, elasticity and dye-absorbing capacity;
- intermediate type, with intermediate characteristics between the elongated and tiller types.

There is no information as to whether other *Juncus* species found in South-East Asia, such as *J. inflexus* L. and *J. prismatocarpus* R. Br. are used as fibre plants. *J. inflexus* has distinctly ribbed stems and its flowers have 6 stamens; it occurs in Europe, Africa and Asia. *J. prismatocarpus* has slightly smaller stems up to 1 m tall and a terminal inflorescence with its bract not continuous with the stem; it occurs from India throughout South-East Asia to Australia and New Zealand.

Ecology *J. effusus* is found in wet locations, such as pools, swamps, lake borders and river banks. In South-East Asia, where it occurs at 1200–3000 m altitude, it is locally abundant, but generally rare. The base and optimum temperatures for tillering of *J. effusus* var. *decipiens* have been found to be about 3°C and 16°C, respectively, with adequate tillering occurring in a temperature range of 11–21°C. In cultivation *J. effusus* prefers fertile clay, clay-loam or loam soils with pH 6. The rhizomes are less tolerant of low oxygen conditions than those of *Schoenoplectus lacustris* (L.) Palla and *Typha* spp. In Europe natural stands of *J. effusus* are often indicative of disturbed, nutrient-rich soils which are low in lime.

Propagation and planting *J. effusus* is mainly propagated through clump division after the stems have been harvested; it can also be propagated by rhizome parts and seed. In Japan a common method is to divide a parent plant into 10 parts, which are planted 15 cm × 15 cm apart in heavily fertilized nursery beds. After 4–5 months they are subdivided into 10 pieces again, each with 7–10 tillers. These pieces are planted out in flooded and puddled fields at a spacing of 15–18 cm × 15–18 cm, resulting in a plant density of 300 000–450 000 plants/ha. In Japan *J. effusus* is often grown in rotation with rice, the former in the winter and the latter in the summer.

In vitro plant regeneration of *J. effusus* is possible. Transplanting of 6–8 day old seedlings on Murashige and Skoog (MS) medium gives multiple shoot formation within 4 weeks. Addition of benzyladenine (BA) or 2-isopentenyladenine (2iP) improves regeneration. Rooting is induced by transferring the shoots to MS medium with NAA (naphthalenacetic acid).

Husbandry In Japan *J. effusus* is weeded 3–4 times and heavily fertilized with about 400 kg N, 40 kg P, 270 kg K. About 60 kg N and 35 kg P per ha are applied at planting, whereas most N, some P and all K are given in 5–6 top dressings. In addition 10 t manure is applied per ha. The crop is grown in a waterlogged culture with frequent draining to prevent rotting and to promote tillering. Sometimes the tops of the plants are clipped to a height of 40–45 cm to promote simultaneous tillering, and to decrease tip rot and lodging. Lodging is also prevented by covering the field with nets at a height of 80–100 cm. The field is drained 10 days before harvesting.

Diseases and pests Information on diseases and pests affecting *J. effusus* in South-East Asia is not available. In Japan the most serious disease is stem rot or sheath blight caused by *Rhizoctonia*. Damage can be reduced by planting resistant cultivars. Minor diseases in Japan are blight caused by *Leptosphaeria juncina* and frog-eye spot caused by *Cercospora juncicola*.

Serious pests in Japan are the stem worm *Bactra honesta* and the mat rush sawfly *Eutomostethus juncivorus*.

Harvesting In Japan *J. effusus* stems are usually harvested at dusk. Here, harvesting comprises cutting, selecting and bundling. At harvest time the number of tillers per clump has increased from the original 7–10 to about 100.

Yield Average *J. effusus* yields in Japan have been stable at about 10 t/ha of weaving material (dried stems) for a long time. Yields of 14 t/ha are considered good.

Handling after harvest In Japan the harvested stems of *J. effusus* are coated with soil to ensure they do not lose their natural colour. Coating is done by soaking the stems in muddy water, after which the coated bundles are placed upright to drain. The stems are then spread on the ground for 2–3 days and dried in the sun from 9 a.m. to 3 p.m. The stems may also be dried artificially, sometimes after initial drying in the sun for 1 day. In Japan the material is graded into 3 length classes for mat-weaving: A (over 110 cm long), B (97–110 cm) and C (70–97 cm). Stems 60–70 cm long are used for other articles, such as hats, cushions and bags, whereas shorter stems are discarded at harvest.
A fine straw for weaving can be prepared by splitting the stems, removing the pulp and drying the remaining part quickly in the sun to make it curl up. Flat straw can be made by removing the pulp, flattening the stems and drawing them between the thumb and a piece of wood. Sometimes the stems are heated in boiling water for 10 minutes to give the product more elasticity and resistance. For medicinal use in Vietnam stems are steamed and peeled, leaving the pith.

Genetic resources It is probable that germplasm collections of *J. effusus* are kept in Japan and perhaps in other countries where the crop is cultivated, but information is not available.

Breeding Breeding and selection work on *J. effusus* is carried out in Japan. Japanese lines that produce high straw yields of good quality have been introduced, tested and registered in China.

Prospects In view of the availability of other weaving and tying material, e.g. from various *Pandanaceae* and *Cyperaceae*, the role of *J. effusus* in South-East Asia will probably remain very limited, though it may have some potential as a local source of weaving material for domestic use in high-altitude regions, for instance in the Philippines.

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Y. Umi Kalsom

Lepironia articulata (Retz.) Domin

Biblioth. Bot. 85: 486 (1915).
CYPERACEAE
$2n$ = unknown

Synonyms *Restio articulatus* Retz. (1786–1787), *Lepironia mucronata* L.C. Rich. (1805), *L. compressa* Boeckeler (1896).

Vernacular names Brunei: purun. Indonesia: purun (Bangka), purun danau (Kalimantan), tekor (South Sumatra). Malaysia: purun, purun danau. Thailand: kra chuut (central, Satun).

Origin and geographic distribution *L. articulata* occurs discontinuously from Madagascar through Sri Lanka, China and South-East Asia (Thailand, Indo-China, Peninsular Malaysia, Sumatra, Bangka, Borneo, Sulawesi, the Moluccas, New Guinea) to Australia, the Caroline Islands, New Caledonia and Fiji. It is cultivated in Thailand, Sumatra, Borneo, India and China and sometimes escapes from cultivation can be found (e.g. in India).

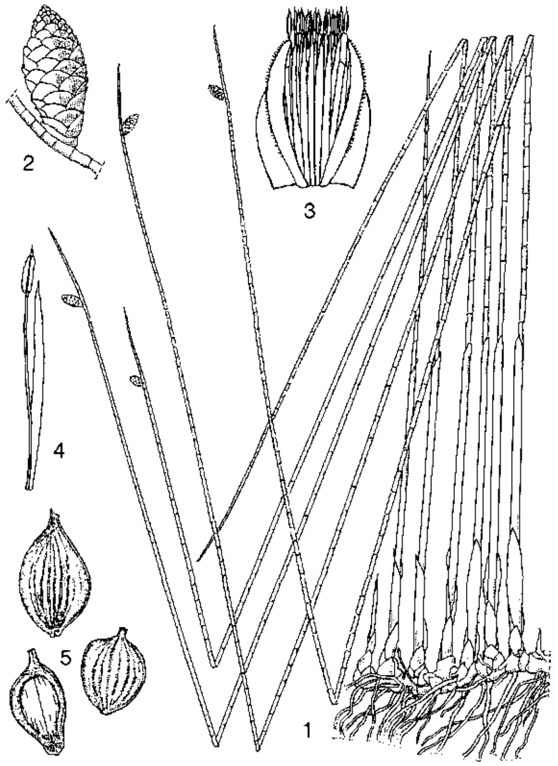
Uses The stems of *L. articulata* are made into mats, bags and baskets, e.g. in Indonesia, Cambodia and Papua New Guinea, and into window blind materials. In Borneo and South Sumatra strong and completely closed *L. articulata* mats have been used as packing material for tobacco, rubber, kapok, cotton, cane sugar and other products, for drying paddy and for the transport of food products such as rice, salt and dried fish. In China *L. articulata* is used to make mats and sails for junks. In Australia the still fleshy, thickened rhizomes are eaten by aboriginals.

Production and international trade The main production area of *L. articulata* mats in Indonesia at the beginning of the 20th century was the hinterland of Banjarmasin (South Kalimantan), where about 1400 ha were planted. In the period 1918–1925 between 3.5 and 7 million *L. articulata* mats were shipped annually from this region to Java, Sumatra, northern Borneo and elsewhere, whereas local use was estimated at about

1.5 million mats per year. Production in South Sumatra was for local use only and was estimated at 40 000 mats and 300 000 'mat-bags' per year. No recent production or trade figures are available.

Properties The stems of *L. articulata* are very good weaving material, but detailed information on their morphological, chemical and mechanical characteristics is lacking.

Description A subaquatic, rush-like, leafless, rhizomatous, perennial herb, up to 2.5 m tall, often growing in large clumps. Rhizome creeping horizontally a few cm below the mud surface, up to about 15 cm × 0.5–1 cm, fleshy at first but becoming woody, many-noded, internodes about 1 cm long, dark brown, covered with brown, ovate-acute, striate scales and bearing numerous stout roots. Stems (culms) close together, arranged in one row along the rhizome, each one erect, slenderly cylindrical, 0.4–2.5 m × 2–8 mm, smooth and hollow but transversely septate (clearly visible when dried), glaucous or grey-green, clothed at the base with about 3 sheaths and 4–5 scales. Leaves reduced to bladeless sheaths, 3–30 cm long, upper one longest, split on one side, margins overlapping, brownish or reddish. Inflorescence consisting of a single spike-like cluster, apparently lateral owing to the single, erect, culm-like, involucral bract 2–6 cm long which extends the stem, gradually acute at apex; spike-like cluster ellipsoid, 1–4 cm × 0.5–1.5 cm, purplish-brown, many-flowered; rachis thick, spongious, conical, persistent, bearing spirally arranged, tightly and densely imbricated, red-brown glumes; glumes ovate to obovate-orbicular, 3–7 mm × 3–6 mm, coriaceous with cartilaginous margin, glabrous, caducous with the fruit, each subtending a bisexual flower cluster (cyme) except some empty lower ones; each cyme with a terminal pistillate flower and up to about 15 small, hyaline, hypogynous scales, each subtending a single staminate flower but the upper few often empty, the lowest pair opposite, folded, lanceolate, 4–6 mm × 0.5 mm, ciliolate on the keel, the remaining ones fascicled, linear-oblanceolate, 4–6 mm × 0.3 mm, acute, flat and glabrous; staminate flowers with only one stamen, anther linear, 2–3 mm long, shortly apiculate; pistillate flower consisting of a naked pistil, style continuous with the ovary and ending in 2 long stigmas, its slightly thickened base persistent in fruit as a short beak 0.5 mm long. Fruit a double achene-like, strongly flattened obovoid to subglobose nut, 3–4 mm × 2–3 mm, longitudinally striate, brown, glabrous but margins scaberulous at the top.



Lepironia articulata (Retz.) Domin – 1, habit flowering plant cluster; 2, inflorescence; 3, cyme in axil of glume; 4, male flower in axil of scale; 5, three fruits.

Growth and development In the Tasek Bera swamp in Peninsular Malaysia it takes about 3 months for *L. articulata* culms to start flowering and 7 months to reach their maximum dry weight of about 3.5 g. Here, reed swamps dominated by *L. articulata* contain on average 30 clumps and 140 culms per m^2 with a standing biomass (including rhizomes) of up to 850 g dry weight per m^2. Up to 7 m rhizomes were found per m^2, at 5–7 cm below the mud surface.

Other botanical information Within the subfamily *Cyperoideae*, *Lepironia* L.C. Rich. belongs to the tribe *Hypolytreae*, which also includes *Mapania* Aublet, *Scirpodendron* Zipp. ex Kurz and *Thoracostachyum* Kurz. *Lepironia* has often been considered a monotypic genus, with *L. articulata* being the only species, but at present *Lepironia* and *Chorisandra* R. Br. have been united into a larger genus *Lepironia*, with 1 species in subgenus *Lepironia* (characterized by an inflorescence consisting of one spike-like cluster and by a digynous pistil), and 4 species in subgenus *Chorisandra* (characterized by a head-like inflorescence with several spikes and by a trigynous pistil).

Anatomically, *L. articulata* can be distinguished from most other *Cyperaceae* by the tetracytic stomata and the absence of silica bodies in the leaf epidermis cells.

Ecology *L. articulata* is found in shallow water (usually less than 0.8 m deep) in open swampy locations, open marshes, swamps in savanna-forests and along quiet streams, often near the coast. It grows in oligotrophic, slightly acid (pH 5.0–6.5) water. In Sumatra it occurs up to 1000 m altitude, in Peninsular Malaysia (Terengganu) at 1200 m and in Papua New Guinea up to 1750 m altitude. *L. articulata* often forms extensive communities.

Propagation and planting In Borneo planting material of *L. articulata* is obtained through clump division and transplanted into ponds about 30 cm deep with black mud at the bottom. The planting distance is 30–40 cm, with each pocket containing 20–30 shoots. Before planting, the area is cleaned of weeds, but soil preparation is not practised. Natural reproduction of *L. articulata* in the Tasek Bera swamp is mainly vegetatively through rhizomes, with new shoots arising from the rhizome every 51–55 days.

Husbandry Usually no special care is given to plantings of *L. articulata*.

Harvesting *L. articulata* in Borneo can be harvested from a year after transplanting onwards, but material from 2–3 year-old plantings is superior. Harvesting is year-round and is done by pulling up 10–20 flowering stems together and cutting them to the required size. More recent reports from Borneo indicate that *L. articulata* is harvested twice a year. Cutting must preferably be done a few cm away from the rhizome because if the rhizome is damaged the plant will need more time to produce new culms.

Yield No yield data are known. Total living biomass production for *L. articulata* in the Tasek Bera swamp in Peninsular Malaysia has been estimated at 2.2 g per m^2 per day (8.2 t per ha per year). This is much lower than the biomass production of other tropical aquatic sedges, such as *Cyperus papyrus L.*, which may be due to the low emergence rate of new stems in *L. articulata*.

Handling after harvest The harvested stems of *L. articulata* are dried for 3 days, after which they are tied into bundles that measure 10 cm in diameter. These bundles are pounded with rice pestles until they are flat and ready for weaving.

Genetic resources and breeding *L. articulata* beds in Tasek Bera are sometimes damaged due to burning by people hunting for turtles or clearing navigation paths, but it does not seem to be threatened with extinction. No germplasm collections or breeding programmes of *L. articulata* are known to be underway.

Prospects Because of the wide range of packaging materials available nowadays, mats and other products made from *L. articulata* will remain of limited importance.

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S. Brotonegoro

Linum usitatissimum L.

Sp. pl.: 277 (1753).
LINACEAE
$2n = 30, 32$

Vernacular names Flax, textile flax (when grown for fibre), linseed (when grown for seed) (En). Lin (Fr). Indonesia: linum. Thailand: linin (central), huu-mua (central). Vietnam: c[aa]y lanh.

Origin and geographic distribution The primary centre of origin of *L. usitatissimum* has not been established beyond doubt. The large diversity of forms around India suggests that it may have originated there and been spread northwards and westwards by early domesticators. The Mediterranean has also been suggested as a possible centre of origin. The distribution and domestication of

L. usitatissimum on a global basis occurred principally as a fibre crop. Flax provided the fibres needed for cloth and cordage, and linen was used by the Egyptians, Greeks and Romans. The crop has been cultivated for thousands of years; it was commercially traded by the Egyptians by 4000 B.C. and remnant seed has been found in prehistoric settlements in the Swiss Alps. The high oil content of the seed was also appreciated and a degree of specialization occurred: Mediterranean and European types developed into the principal flax forms, and short-season variants adapted to the warmer climates of West and South Asia developed into linseed types.

L. usitatissimum is now grown widely in many parts of the world, including the tropics. Flax is typically grown in cool, temperate regions including Russia, Northern Ireland, Belgium and other northern and eastern European countries. Linseed prefers warmer climates and is cultivated in parts of South America, the United States, Canada, Africa, India, Bangladesh and Australia. In South-East Asia *L. usitatissimum* is cultivated in northern Thailand (Chiang Mai) and locally on a small scale in Indonesia (Java). After successful experimentation with flax in the mountains of Java in the first half of the 20th Century, interest in flax cultivation in Indonesia was revived in the 1970s and 1980s with the objective of reducing flax fibre imports for paper making.

Uses Linen is the most important product made of the bark fibre of flax and is used variously for household textiles (towels, table cloths etc.), furnishings (curtains, wall coverings and upholstery fabrics) and clothing. The properties making it ideally suited for these applications are high moisture absorption, strength, launderability, excellent colour fastness and resistance to shrinkage. A disadvantage is that it creases easily.

The bark fibre is also used in the manufacture of fine papers such as cigarette, art, currency, archival and security papers, often in blends with other wood and non-wood pulps. The fibre used for paper typically comes from one of three sources:

- waste material from spinning and weaving mills and linen rags, representing the purest form of flax fibre, free of core material and used for the highest paper grades;
- short bark fibre or waste product left over from the processing of the high quality textile fibre ('flax tow');
- mechanically decorticated straw of flax that has been grown primarily for seed ('seed flax tow'), which is the least pure form of fibre, producing pulps that are usually weaker and less durable than flax tow pulps.

Straw from seed flax is also utilized in the manufacture of twine, bagging and insulating wallboards. The waste woody core resulting from bark fibre extraction is used in the manufacture of chipboard or, in combination with bark fibre, for paper making.

Linseed oil contains linolenic acid, which makes it ideally suited as a drying agent in protective coatings such as paint, stains and varnish or by itself as a raw or boiled oil. Linseed oil is also used in the manufacture of window putty, soaps, printing ink, erasers and linoleum, and as waterproofing for raincoats and tarpaulins. A number of edible 'Linola' lines have been bred with reduced linolenic acid content and high levels of linoleic acid, valued for human consumption. Linola oil is used in the manufacture of margarine and cooking oil. Other cultivars have been bred for mucilage production from the seed. This mucilage, formed on the outside of the seed when large epidermal mucilaginous cells swell upon exposure to water, is used in treating a range of digestive complaints. Linseed cake and meal are the by-products of oil extraction and are used as protein supplements in livestock rations after prior removal of anti-nutritional and toxic substances.

Production and international trade According to FAO estimates the average annual world flax (fibre and tow) production in 1996–2000 was about 500 000 t from an area of about 490 000 ha. The main producers in this period were China (181 000 t/year), France (67 000 t/year), Spain (58 000 t/year), the Russian Federation (38 000 t/year) and Belarus (34 000 t/year). The average annual flax (fibre and tow) exports amounted to 124 000 t, with a value of US$ 228 million. The principal exporters were France (54 000 t/year) and Belgium (45 000 t/year), the main importing countries Belgium (27 000 t/year), China (25 000 t/year) and Italy (15 000 t/year). In the 1980s Indonesia imported about 15 000 t of flax fibre per year for the production of high-quality paper, but in 1996–2000 the average annual imports were only 70 t.

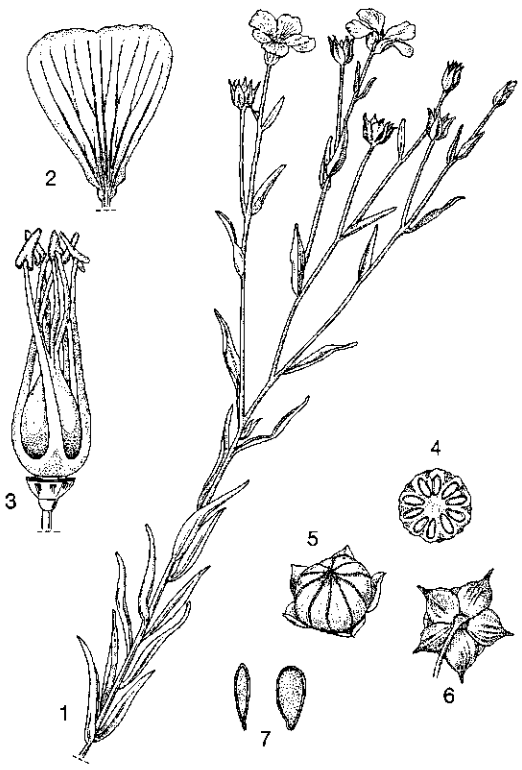
The estimated average annual world linseed production in 1996–2000 was about 2.5 million t from 3.1 million ha, with the main producing countries being Canada (0.9 million t/year), China (0.4 million t/year), India (0.3 million t/year) and Germany (0.2 million t/year).

Properties Embedded within the stem cortex of *L. usitatissimum* are approximately 30 groups of

flexible fibre bundles. Each of these bundles (referred to as 'bast') represents a single strand of commercial fibre. The proportion of bast in the whole dry stem is influenced by both genotype and growing conditions and ranges from 28–36%. Each fibre bundle is made up of 10–40 fibre cells. The fibre cells are (1–)10–40(–85) mm long with a diameter of (5–)10–30(–38) μm and a narrow lumen. They are tapered at either end, round to polygonal in cross-section and interlock longitudinally to form the bundles. The fibre cells of the linseed genotypes tend to be shorter and coarser with a smaller lumen. The chemical properties of unretted and retted raw material are, respectively: cellulose 56.6% and 64.1%, hemicelluloses 15.4% and 16.7%, pectin 3.8% and 1.8%. Unretted material contains 2% lignin. Flax fibre has a high moisture absorbency and is stronger than that of cotton, rayon and wool, but weaker than ramie fibre. It is soft, lustrous and flexible, but not as flexible or elastic as cotton and wool fibres. Typical values of the tensile strength, elongation at break, and Young's modulus of flax fibre are 345–1035 N/mm^2, 2.7–3.2% and 27.6 GPa, respectively. The fibre cells in the xylem surrounding the pith and hollow central cavity of the plant have a mean length of 0.5 mm and a mean diameter of 16 μm.
Per 100 g the seed contains 35–44 g oil and about 20 g protein. The approximate fatty acid composition of linseed oil is: linolenic acid 30–60%, linoleic acid 10–25%, oleic acid 13–36% and stearic and palmitic acids 6–16%. In the breeding of edible Linola lines, linolenic acid levels were dramatically reduced to about 2%, with an accompanying increase in the level of linoleic acid. The proportion of the other fatty acids remained relatively stable. The seed or cake contains the cyanogenic glucoside linamarin which, in the presence of the enzyme linase, hydrolyses to form poisonous hydrogen cyanide. To counter this problem, the feed should be boiled in hot water prior to consumption. Linseed cake and meal are said to have a regulative effect on the digestive system, to increase the butterfat yield in dairy cows and promote a healthy sheen in the coats of show livestock.
The weight of 1000 seeds is 3–12 g.

Adulterations and substitutes Because of its similar physical and chemical fibre properties, hemp (*Cannabis sativa* L.) is often used in place of or in a blend with flax fibre in paper and textile manufacture.

Description An erect annual herb, up to 1.2 m tall. Root system consisting of a taproot with subsequent branching to a depth of up to 60 cm. Stem slender, erect, usually solitary, up to 120 cm × 4 mm (shorter in seed cultivars), glabrous, greyish-green, slenderly branched in the upper 12–24 cm (more richly branched in seed cultivars). Leaves subopposite to spirally arranged, sessile, simple; blade narrowly elliptic, linear or linear-lanceolate, (10–)25–35(–50) mm × (2–)3–5 mm, 3-veined, glabrous, greyish-green. Inflorescence a loose, terminal, leafy corymb, with flowers leaf-opposed; pedicel erect, 1–3.5 cm long; flowers bisexual, 2–3 cm in diameter, 5-merous; sepals free, broadly elliptic-ovate, 5–10 mm × 2–5 mm, entire, acuminate; petals free, obovate, 8–15 mm × 4–11 mm, shortly clawed at base, margin dentate-crenate, white to pale or purple-blue with hues of pink; stamens 5, united at base in a glandular ring, alternating with the petals, free part about 2–6 mm long; styles 5, often shortly connate at base, about 2–3 mm long, each one ending into a linear-clavate stigma 1–2 mm long. Fruit a globose capsule, 7–10 mm in diameter, 5-carpellate and 5-



Linum usitatissimum L. – *1, habit of flowering and fruiting stem; 2, petal; 3, flower with sepals and petals removed; 4, cross section ovary; 5, fruit from above; 6, sepals at underside of young fruit; 7, seed in front and side view.*

loculed but often each one divided by a secondary septum, each locule with 2 seeds, up to 10 seeds per fruit. Seed compressed, (4–)6–10 mm × 2–3 mm, yellow to dark brown, beak about 1 mm long; testa with a shiny, slippery appearance.

Growth and development In warm and moist conditions, flax seeds germinate and emerge within 7–10 days after sowing. True leaves appear within 2–3 days of emergence, when the stalk is about 3–4 cm long and the tap root about 15 cm. The first pair of true leaves are almost opposite, after which phyllotaxis changes to spirally alternate. While there is normally a single stem, tillering is stimulated by difficult emergence, low plant population or damage due to pests, frost or chemicals. Initial growth can be slow if early growing conditions are cool. Flowers open shortly after dawn with predominantly self-pollination occurring by mid-morning. Some cross-pollination is possible through bees. The petals fall shortly thereafter, with complete loss by about noon. The plant reaches its maximum height towards the end of flowering. At this time the crop is particularly susceptible to lodging. Flowering is indeterminate, resulting in uneven formation of the capsules and subsequent maturation. As the capsules mature, they begin to turn brown at the same time as the lower leaves and stem turn yellow. Eventually the leaves senesce and drop. Seed in the capsules becomes light brown, plump and pliable, indicative of maximum dry matter content. Seed ripeness is reached when the seeds are free and can be heard to rattle within the capsule. Flax genotypes typically produce about 80 leaves per plant and seed genotypes about 60. Fruit number per plant varies with genotype, management and climatic conditions but will typically range from 5–15 per plant. Total crop duration of fibre flax is normally 90–120 days, with 30–45 days from first flowering to harvest. The duration from sowing to seed maturity is 140–200 days.

Other botanical information *Linum* L. contains about 200 species, mainly in the Mediterranean region, but only *L. usitatissimum* is an important fibre crop. *L. usitatissimum* is only known from cultivation. It is thought to have been derived from *L. bienne* Miller (synonym *L. angustifolium* Hudson), a wild biennial or perennial species from western and southern Europe (same chromosome number, crossing is easy and hybrids are fertile).

L. usitatissimum is a highly variable crop and to classify this variability numerous subclassifications have been made, making its taxonomy confusing. In a cultivated crop it is more appropriate to distinguish only cultivar groups and cultivars, and to refrain from subclassifications primarily developed for wild species. Unfortunately, a generally accepted cultivar classification for flax does not exist yet. Two main groups are obvious: cultivars grown for the stem fibres and those grown for the seed. In both groups numerous cultivars exist. For the seed a distinction can be made between cultivars grown for the oil of the seed (linseed) and others for the high mucilage potential of the seed coat. There is also a small group of cultivars that are grown both for the fibre and the seed.

Some well-known fibre flax cultivars are:

- 'Ariane' (France): medium to early maturing; seed yield low; flowers blue; resistant to lodging.
- 'Viking' (France): maturing like 'Ariane', but with higher fibre and seed yield; resistant to lodging; excellent resistance to rust, moderate resistance to wilt, susceptible to pasmo.
- 'Belinka' (the Netherlands): medium maturation; higher straw and fibre yield than 'Ariane'; good seed yield; flowers white; susceptible to lodging.
- 'Marina' (France): cross between 'Belinka' and 'Natasja'; medium to early maturing; good fibre and seed yields; susceptible to lodging.
- 'Regina' (the Netherlands): medium to early maturing; susceptible to lodging.

Other fibre flax cultivars are 'Arc' and 'Ciel' (developed in Belgium); 'Fany' (France); 'Wiera' (the Netherlands); various Liral, Stormont and Norfolk cultivars (United Kingdom); 'Minerva' (Poland); 'Milenium' (Roumania, Hungary); 'Progress' (Russia); 'Giza 2 and 4' (Egypt); 'Tainung No 1 and No 2', 'Taichung Special No 1' (Taiwan); 'Banner', 'Flag' and 'Standard' (Australia); and 'Cascade' (United States).

Some well known linseed cultivars are:

- 'Dufferin' (Canada): very late maturation; yield high when sown early, but not recommended for late sowing; plant height variable, flowers blue, seed brown; oil content high; resistant to rust and wilt.
- 'Rahab' (United States): medium maturation; yield high; oil content high; flowers blue, seed brown; good resistance to lodging; resistant to rust, moderately susceptible to wilt and pasmo.
- 'Verne' (United States): early maturation; yield high, particularly when sown late; good resistance to lodging; flowers blue, seed brown; with excellent resistance to rust and wilt, and moderate resistance to pasmo.
- 'Antares' (France): medium to early maturation;

plant height medium; yield-potential high; susceptible to *Botrytis* and rust.
- 'Atalante' (France): later maturing and taller than 'Antares', but with similar yields; less resistant to lodging than 'Antares', but more resistant to rust.

Ecology *L. usitatissimum* is a long-day plant. The crop requires moderate to cool temperatures and adequate moisture during the growing season to achieve optimum fibre yield and quality. Optimum results in Europe are achieved with a temperature range of 10–30°C, a midday relative humidity of 60–70%, and a rainfall of 150–200 mm distributed over the typical 3-month growing period. Hot dry days prior to and during flowering tend to cause branching and hasten flowering, resulting in shorter, more woody stems, lower fibre yield and harsh, dry fibres. Heavy rains and strong winds may cause lodging. Temperatures of −6°C may kill the crop in the seedling stage and frost may also cause injury during the flowering and green capsule stage. Warm, dry conditions from early capsule development to maturity are particularly beneficial for curing the seed as well as for threshing and for drying the straw after retting. Rainfall during this time may cause secondary flowering and hence uneven maturity. Where dew retting is performed, there must be sufficient moisture during the post-harvest period to ret the straw. Experiments in Java in the 1930s indicated that reasonable yields of good quality fibre can be obtained at 1000–1600 m altitude. In experiments in the early 1980s at altitudes from 800 to 1400 m, the 13 cultivars involved grew best, in terms of plant height and straw dry weight, at 1200 m altitude.

Optimal soils for flax are well drained but moisture retentive and medium to heavy textured, such as clay loams and silty clays. The soil should be of a fine tilth and not prone to capping or crusting. Flax is particularly sensitive to saline soils and will not perform well on soils with pH less than 5 or above 7.

Propagation and planting Flax is propagated by seed. Because of the small seed size and poor competitive ability of flax seedlings, a finely prepared, weed-free seed bed with adequate moisture is essential for successful crop establishment. The seed may be broadcast by hand and then covered by discing or harrowing, but this method results in uneven sowing depth, emergence and maturation. Therefore, sowing with a grain drill is preferred. The optimal sowing depth depends on soil type and moisture level. In heavy soils, 1.5 cm is usually enough, whereas on lighter soils, a depth of 2 cm ensures imbibition. The seed rate depends on genotype, planting method, expected moisture conditions during the season and production objective (fibre, seed or both). With a drill, seed rates for fibre crops under optimal water supply are 80–110 kg/ha. Higher rates (up to 150 kg/ha) are recommended for hand-sown crops. Seed rate recommendations for linseed are variable, ranging from 17 kg/ha under low-rainfall conditions to 55–90 kg/ha under wetter conditions. Row spacing for fibre flax ranges from 6–15 cm, with a plant density of 1800–3300 plants/m^2. On some soils, crusting will occur after heavy rain, making emergence difficult. A light harrowing is advisable for breaking the crust. Seed for planting should be freed from all light, shrivelled, scaly or diseased stock and treated with a fungicide to kill surface-borne diseases.

An experiment in the 1980s in Manoko Experimental Garden (near Bandung in Java, at 1200 m altitude) with 12 flax cultivars showed that stem yields were higher when seeds were sown in November or January than when sown in March. In another experiment at the same location, with 12 plant spacings, the highest straw yields were obtained at densities of 2.5 cm within the row and 10 or 15 cm between rows.

Husbandry Flax is a small plant and is not very competitive, so good weed control is important and can be achieved through a range of pre- and post-emergent herbicides. Early working of the soil to stimulate weed seed germination, followed by shallow preparation prior to planting may help to obtain a clean seedbed. Weed control is not only vital for maximizing fibre and seed yields, but also for avoiding impurities when processed.

Seed quality and yield are adversely affected by water stress during flowering and early seed development. In areas where rainfall is likely to be limiting during this period, irrigation is suggested from budding until late grain filling. Later watering may cause secondary flowering and uneven ripening. The best results are obtained with light irrigations, owing to the shallow-rooted nature of the crop.

Flax requires relatively small amounts of nutrients and excessive fertilization can result in a serious decrease of fibre quality. Hence, fertilizer rates should be such as to achieve a balance between maximizing yield without adversely affecting quality. Nutrient uptake depends on a range of factors including soil type, cultivar and weather conditions. Typical uptake figures for a fibre flax crop yielding 5–6 t straw and 0.6–0.8 t seed per ha are: 50–75 kg N, 10–16 kg P, 40–60 kg K, 18–36 kg Ca and 8–11 kg Mg. The actual quantities removed at harvest are somewhat less, owing principally to leaf detachment. High nitrogen rates promote lodging and have an adverse effect on fibre quality through promotion of branching, lignification of the fibre and reduction of fibre wall thickness. Therefore, flax never receives high rates of inorganic nitrogen and responds better to split applications. Ideally, the crop should draw most of its nitrogen from soil organic matter. Ample phosphorous is required for good seed yields and high-quality fibre, but excessive rates can result in reduced fibre quality. Sufficient potassium is essential for both fibre yield and quality. Adequate potassium nutrition promotes fibre strength, flexibility, elasticity, and suitability for spinning. It also tends to prevent lodging and disease damage through the promotion of longer and thicker stems. Recommended rates of application for mineral fertilizers vary widely, depending on yield level, soil type and seed rate. Organic manures should ideally be applied to the preceding crop, as direct organic manuring may promote lodging and cause uneven growth.

Flax should preferably not be grown in the same field more than once every 5–6 years and is best grown in a rotation which reduces weed infestation and disease development, ensures adequate soil organic matter and enables the preparation of a fine seedbed. It does well after beans, maize, potatoes and peas, but weed-free land previously sown to lucerne, wheat or barley is also suitable.

Diseases and pests The majority of diseases afflicting *L. usitatissimum* are caused by soil- or seed-borne fungi and can usually be controlled by thorough seed disinfection, rotation or the use of disease resistant cultivars. The principal seed-borne diseases are anthracnose (*Colletotrichum lini*), stem break and browning (*Polyspora lini*), grey mould (*Botrytis cinerea*) and pasmo (*Mycosphaerella linorum*). Typical symptoms of these diseases are stem or leaf lesions usually appearing early in the life of the plant. Key soil-borne diseases include sclerotinia (*Sclerotinia sclerotiorum*), wilt (*Fusarium lini*), foot rot (*Phoma* sp.) and scorch (*Pythium megalacanthum*). These diseases attack the root system or the lower part of the stem resulting in either lodging or the cessation of growth and gradual death of the plant from the crown downward. Another disease, rust (*Melampsora lini*) is characterized by the occurrence of bright red pustules (containing uredospores) on aboveground plant parts, later in the season replaced by black encrustations (teliospores). The spores are carried with the seed and on chaff fragments and can survive in the soil for up to two years. In infected areas rust-resistant cultivars should be used; if susceptible cultivars are grown, infection can be controlled through seed cleaning and a rotation of 3–4 years.

L. usitatissimum attracts a wide range of pests, but most are not considered to be of economic importance. Some may cause severe damage, however, if left unchecked: cutworms (*Agrotis* sp.) gnaw through young stems at ground level; red-legged earth mites (*Halotydeus destructor*) suck the sap from young seedlings, resulting in low vigour and possible seedling death; various aphids cause damage through direct feeding or disease transmissions; sap-sucking thrips may retard growth and kill the plant; the larvae of flea beetles (*Aphthona euphorbiae* and *Longitarsus parvulus*) can damage roots while the adults feed on leaves, stem and seed; the caterpillar of *Heliothis* spp. penetrates the young seed bolls and cause substantial damage in Australian crops. Control is achieved either through the use of insecticides or by sowing the crop at a time of the year that is out of synchronization with the pest's life cycle.

Various birds may graze on (and remove) the growing point of young plants, resulting in tillering and subsequent non-uniformity of maturation and a decline in yield. Bird control measures such as scarecrows, humming lines and gas guns, and a rapid establishment of the crop are recommended.

Harvesting The optimum time for harvesting textile flax is when the straw is green-yellow and the capsules are still forming, at which time the fibres are long and supple. Flax harvested too early and still green produces fine and weak fibres. Conversely, over-ripe, brown to dark brown flax yields brittle fibre with a high proportion of tow. Flax is typically pulled out of the ground rather than cut, to preserve the full length of the fibres. This can be done by hand, lifting and binding the straw into sheaves, which are left to dry and, if conditions are suitable, ret in the field, before being collected and stored under shelter. This process is labour-intensive and in most producing countries harvesting is done mechanically with pulling machines, which pull and lay the crop on the ground in swathes. The seed-bearing capsules can be removed during pulling or left on the plant during retting and baling and removed in the processing factory ('rippling'). Subsequent threshing

of the seed is usually done concurrently with 'scutching' of the fibre.
Industrial flax or dual purpose crops are often harvested with conventional combine harvesters to avoid the cost of specialized pulling and turning equipment. Successful combining of the seed requires a seed moisture content of 10–15%. Recent advances have been made in the development of mobile decorticators/harvesters which simultaneously pull, separate and bale the bark fibre in one pass with the core returned as mulch to the soil. Manufacturers claim success both with retted and unretted stem material. This mechanically decorticated fibre is usually of a poorer quality than that required for textile production and is typically used for paper manufacture.

Yield Average world flax (fibre and tow) yields in 1996–2000 were estimated at about 1 t/ha per year and average world linseed yields at 0.8 t/ha per year. In an experiment with 7 flax cultivars in Tasmania (Australia), stem yields ranged from 4.7–8.8 t/ha, bark yields from 1.3–2.6 t/ha and seed yields from 1.6–2.2 t/ha. In Indonesia, experiments with 12 cultivars and 3 sowing dates resulted in an average yield per cultivar ranging from 2.0–3.9 t/ha dry stems and 0.2–0.5 t/ha dry seeds, whereas dry stem yields up to 7.8 t/ha were obtained in a plant density experiment.

Handling after harvest Retting is most commonly performed in the field in a process called 'dew retting'. The duration and uniformity of dew retting depends on weather conditions. Ideally, harvesting needs to be followed by rain and periods of dry weather: there must be sufficient moisture to ret the straw, but continuous rain can lead to over-retting and loss of fibre quality. To improve the uniformity of dew retting, it is necessary to carefully turn the crop to expose the underside of the crop. Turning can be done up to 3–4 times depending on crop yield. Once retting is complete and the crop is dry, it can be baled and stored. A range of off-field retting methods exist which are faster and provide greater uniformity of separation, but these are generally more expensive.
Dried and retted stem material is 'broken', which involves rolling and/or crimping the stem to loosen the core from the bark. Residual core is then removed via a process known as 'scutching'. The separated bark fibre is 'hackled' by passing the fibre through a series of comb-like devices of increasing fineness, comprised of metal teeth that scrape and buff the fibre. The end products are 'line flax', ready to be spun into yarn and subsequently used in textile manufacture, and 'tow', the by-product of hackling often used in the manufacture of paper and other industrial applications. In the past these processes were performed manually but they are now generally mechanized. Flax fibre quality is usually assessed by visual and manual evaluation, whereas yarn quality is evaluated with the help of instruments, measuring strength, elongation, evenness, etc.
Harvested linseed can be dried, cleaned and stored using the same equipment and techniques used for other grain crops. A safe seed moisture content for long-term storage is 9% and below.

Genetic resources *L. usitatissimum* does not seem to be threatened with extinction owing to its widespread cultivation. Large germplasm collections are kept in France (Institut National de la Recherche Agronomique (INRA), Versailles), Belgium (Gembloux), the Netherlands (Centre for Genetic Resources (CGN), Wageningen), Germany (Bundesforschungsanstalt für Landwirtschaft (FAL), Braunschweig), the United States (United States Department of Agriculture (USDA), Beltsville) and the Russian Federation (N.I. Vavilov Research Institute of Plant Industry, St Petersburg).

Breeding The breeding objectives for *L. usitatissimum* vary with the end use of the crop. As fibre yield is strongly influenced by management and environmental factors, breeders use fibre content or fibre wealth (the ratio of fibre weight to total stem dry weight) as breeding objectives. Fibre quality is particularly important for flax grown for textile fibre, and quality traits that have been bred for include homogeneity, degree of lignification, strength, fineness and water uptake. Selection for industrial fibre flax may emphasize productivity rather than quality traits, given the normally negative correlation between these two traits.
For dual purpose flax, seed yield and oil content are key considerations. Seed quality breeding has largely focused on fatty acid composition and has led to the development of the low-linolenic acid Linola cultivars. Some efforts have been made to breed these low-linolenic acid characteristics into a fibre type of flax. In cultivars developed for non-food purposes, on the other hand, the linolenic acid content needs to be high.
Substantial breeding efforts have been made to improve lodging resistance via straw stiffness and fibre content. In the absence of chemical control methods for *Fusarium* wilt, breeding efforts have been focussed on developing disease resistance, with limited success to date. Breeding for toler-

ance or resistance to various pests has not received much attention, principally because of the availability of effective insecticides. Given the severity of weed competition often experienced in flax crops, efforts have been made to screen new cultivars for herbicide tolerance and to incorporate herbicide resistance genes.

The breeding objectives described above are difficult to achieve via conventional breeding methods because the traits involve polygenically inheritance, low heritabilities and unreliable assessment techniques. Consequently, a range of biotechnological techniques are being employed to supplement classical breeding, including somaclonal variation, in vitro selection, anther and microspore culture, protoplast culture, genetic mapping and recombinant DNA technology.

Prospects Worldwide, *L. usitatissimum* is going through somewhat of a resurgence after a period in which it was felt that the development of synthetic fibres and drying agents within the petroleum industry might bring about the extinction of the crop. This resurgence can be attributed to a range of factors, including:

- the fact that flax is seen as a suitable alternative to over-produced food crops in the European Union, with subsidies to encourage flax production;
- a trend towards 'environmentally friendly' and natural textiles;
- the development of stronger, more fashionable linoleum products at a competitive price to vinyl;
- new markets for oilseed flax straw in construction and fertilizer formulations;
- the development of genetically modified (GM) oilseed cultivars, rich in linoleic acid and with a fatty acid profile comparable to premium sunflower oil.

L. usitatissimum is grown commercially from 22–65° N and 30–45° S; the extremes of these latitudes are not noted for high fibre or seed yields. The apparent lack of suitable genotypes for the high temperature and rainfall conditions in South-East Asia suggests that flax has limited potential, at least not without substantial investment in a breeding programme to develop better adapted cultivars. However, there may be some scope for flax production at higher altitudes, e.g. in Java. The high cost of machinery for harvesting and processing flax fibre is likely to be a further impediment to flax development in this region.

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S.N. Lisson

Malachra L.

Mant. pl.: 13 (1767).

MALVACEAE

$x = 7$; *M. capitata*: $2n = 56$; *M. fasciata*: $2n =$ c. 112

Major species and synonyms

- *Malachra capitata* (L.) L., Syst. nat., ed. 12, 2: 458 (1767), synonyms: *Sida capitata* L. (1753),

Malachra alceifolia Jacq. (1789), *Napaea latifolia* Blanco (1845).
- *Malachra fasciata* Jacq., Collectanea 2: 352 (1789), synonyms: *Malachra lineariloba* Turcz. (1858), *Malva horrida* (Span.) Miq. (1858), *M. fasciata* (Jacq.) Merrill (1918).

Vernacular names General: wild okra, malva (En).
- *M. capitata*: gombo bâtard (Fr). Philippines: bakembakes (Ilokano), lapnis, paang-baliwis (Tagalog).
- *M. fasciata*: Philippines: paang-baliwis (Tagalog), bakembakes (Ilokano), sutuyo (Subanon).

Origin and geographic distribution *Malachra* comprises about 10 species which are native to tropical America, of which 2 or 3 have been introduced as weeds in the Old World, including South-East Asia. *M. capitata* is found as a weed throughout the tropics. In South-East Asia it occurs in Indonesia (West Java, Timor), the Philippines (Luzon, Panay) and Thailand. It is cultivated as a fibre plant in India, where it is known as 'bhanbendi', and Central and South America. *M. fasciata* has also widely naturalized. In South-East Asia it is widely distributed in the Philippines and rare in West Java, Madura, Timor and New Guinea.

Uses The bast fibre of *M. capitata* and *M. fasciata* is utilized in the Philippines for making strong rope, suitable for clotheslines and general purposes. The fibre of *M. capitata* is also suitable for use in coarse textiles, e.g. for sacks. It can be used as a substitute for jute (*Corchorus* spp.) in some applications or in admixture with jute.

In the Philippines root and leaf decoctions of *M. capitata* are considered emollient in enemas and for bathing purposes. Leaf decoctions of *M. fasciata* are used in the Philippines against gonorrhoea and rheumatism, and as a demulcent and diuretic. Leaf poultices are applied to ulcers and other sores. The roots and leaves may serve as general tonic and against haemorrhoids, fever and impotency.

In the United States *Malachra* spp. are considered noxious weeds.

Production and international trade No statistics on production or trade of *M. capitata* and *M. fasciata* are available.

Properties Fibres obtained from the stem of *M. capitata* are located in the secondary phloem, which is arranged in generally rectangular-shaped wedges radiating from the cambium. The fibre bundles are more or less regular, radially separated from each other by 3–4 parenchyma layers and tangentially by 1–2 layers. Each bundle contains (2–)8–20(–25) cells. The ultimate fibre cells are polygonal and prosenchymatous. They are (1.6–)2.1–2.9(–4.5) mm long, and (7–)15–16 (–29) μm in diameter, with a lumen width of (2–)7(–11) μm. The dry fibre makes up about 5% of the defoliated green stem. The fibre reportedly contains 88% holocellulose, 10% lignin and 0.5% fat and wax. The quality of *M. capitata* fibre is good. It is long (up to 2 m or more) and generally softer, whiter and more lustrous than jute fibre. Like jute, it dries with a counter-clockwise twist. The fibre bundles are easily separated into individual strands. The elongation at break is 4.3%, which is much higher than that of jute (1–2%). The mean tenacity was found to be 0.27 N/tex, with the tenacity of fibre from the middle part of the stem (0.30 N/tex) being greater than that from the base and top sections (0.24 N/tex and 0.28 N/tex, respectively). *M. capitata* fibre can be spun on jute mill machinery.

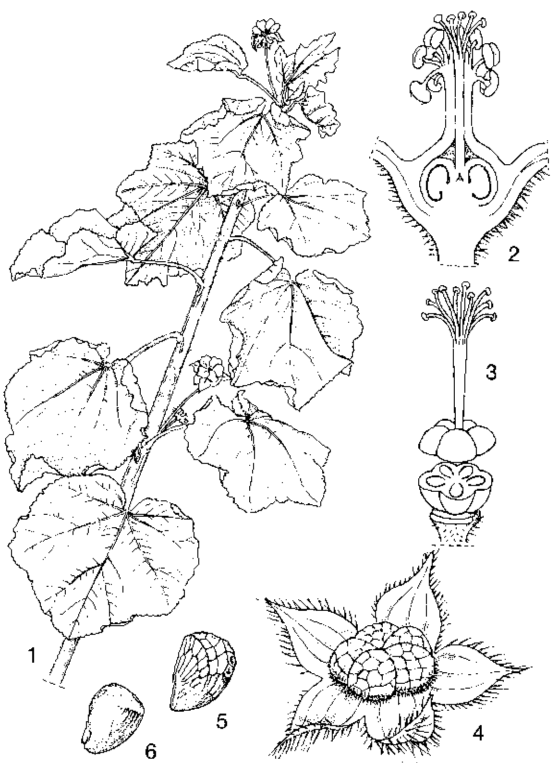
The ultimate fibre cells of *M. fasciata* are (1.2–)2.0(–5.1) mm long and (6–)16(–42) μm in diameter, with a lumen width of (3–)7(–15) μm. The fibre of *M. fasciata* is white to olive-buff coloured and strong. Rope made of the bast of *M. fasciata* in the Philippines had a tensile strength of about 640 kg/cm^2 when dry and 540 kg/cm^2 when wet. The elongation at break of dry and wet rope was 8% and 10%, respectively.

The dipeptide derivative aurentiamide acetate has been isolated from the leaves of *M. fasciata* and has been shown to have antimutagenic and antimicrobial properties. Other antimutagenic compounds isolated from the leaves of *M. fasciata* are stigmasterol and loliolide (a monoterpene).

The 1000-seed weight of *M. capitata* is 3.7–4.3 g.

Description Annual or subperennial herbs, often partly woody, often with prickly hairs. Leaves alternate, simple, palmatilobed to palmatifid, stipules narrow. Inflorescence axillary, head-like, with bisexual flowers in axils of large, cordate, involucral bracts; peduncle usually long, pedicel extremely short; epicalyx usually absent; calyx small, cupular, often with 5 aristate segments; corolla small, petals 5, red, yellow or white; staminal column usually shorter than petals, antheriferous throughout; carpels 5, each with one ovule, style above the middle divided into 10 arms, stigmas capitate, papillose. Fruit a reversed pear-shaped schizocarp, mericarps triangular-subovoid, with convex dorsal side, reticulately veined, indehiscent, 1-seeded. Seed in form and size about similar to the mericarps.

- *M. capitata*. An erect annual or perennial woody herb, up to 2 m tall, green parts with scattered, stiff, simple hairs and stiff, 2-armed, stellate hairs, prickly, about 2 mm long, for the rest densely covered with small many-armed stellate hairs. Leaves with petiole up to 9 cm long; stipules filiform, up to 1.5 cm long, hispid; blade orbicular to ovate, angular or slightly lobed, 2–9 cm in diameter, base cordate and 5-veined, margin crenate to serrate, apex obtuse to rounded, both sides densely clothed with grey, stellate hairs, glabrescent. Inflorescence a 2–10-flowered head; peduncle 1–5 cm long,; bracts 3–4, ovate to circular, 0.5–2 cm in diameter, folded along the midrib; calyx cup 3.5 mm long, segments oblong, 3 mm × 1.5 mm, obtuse, not aristate; corolla 1–1.5 cm in diameter, bright yellow, petals obovate; staminal column 3 mm long. Fruit 5–6 mm in diameter, mericarps 3 mm × 2 mm. Seed triangular-obovoid, 2.5 mm long, grey, densely stellate-hairy.
- *M. fasciata*. An erect annual woody herb, up to 2.5 m tall, green parts covered only with stiff simple hairs about 3.5 mm long, usually without minute stellate hairs. Leaves with petiole up to 12 cm long; stipules filiform, 2–3 cm long, ciliate with stiff hairs; blade circular to ovate, 3–15 cm × 2–14 cm, base rounded to shallowly cordate, 5-veined, margin coarsely serrate to crenate, apex 3–5-lobed or deeply 3–5–7-parted, both sides with scattered, appressed, simple hairs. Inflorescence a 6–9-flowered head; peduncle up to 1.5 cm long; bracts 3–4, triangular, 1–2.5 cm × 0.5–2 cm, folded along the midrib; calyx cup 4 mm long, segments ovate-acute-aristate, 2.5 mm × 1.5 mm; corolla 1–1.5 cm in diameter, white but turning red finally, petals obovate; staminal column 3 mm long. Fruit 3–4 mm in diameter, mericarps obovoid, 2.5–3 mm × 1.5–2 mm. Seed triangular-obovoid, about 2.5 mm long, black, glabrous but hilum stellate-hairy.



Malachra capitata (L.) L. – 1, flowering branch; 2, vertical section through staminal column and pistil; 3, pistil with ovary in cross-section; 4, fruit in the calyx; 5, mericarp; 6, seed.

Growth and development *M. capitata* is a slow-growing plant. In Java *M. capitata* and *M. fasciata* flower year-round. In the Philippines *M. fasciata* flowers from September to January.

Other botanical information *M. capitata* and *M. fasciata* are closely allied, which is reflected in the overlap of their vernacular names in the Philippines, where both are known under the names 'paang-baliwis' and 'bakembakes'. Sometimes *M. alceifolia*, here a synonym of *M. capitata*, is considered as a distinct species because its indumentum not only consists of minute stellate hairs as in typical *M. capitata*, but also of stiff, prickly, simple and stellate hairs. Differences in hairiness, which is a highly variable character depending mainly on circumstances, has led to numerous subclassifications without practical value. Based on the degree of lobation of the leaves, 2 varieties have been distinguished in *M. fasciata*:
- var. *fasciata:* leaves 3–5-lobed, segments ovate to triangular to oblong, 1.5–2 cm wide; found in Indonesia (West Java, Timor, Irian Jaya) and the Philippines (Luzon, Panay).
- var. *lineariloba* (Turcz.) Gürke (synonym: *M. lineariloba* Turcz.): leaves deeply 3–7-parted, segments linear to long-lanceolate, 0.5–1.5 cm wide; known only from Indonesia (West Java, Madura, Timor) and the Philippines (Luzon, Mindoro, Panay, Mindanao).

Malachra L. is in need of a new taxonomic revision, as the last one of Gürke (1892) is badly out of date.

Ecology In South-East Asia *Malachra* is generally found in waste places, fallow land, and in grassland subject to annual burning. In India *M.*

capitata often occurs on land that tends to be inundated during rains, but it also withstands the dry conditions between monsoons. It is frequently found with *Cyperus rotundus* L. In South-East Asia *M. fasciata* occurs in waste places and on roadsides at low altitudes, presumably under seasonally dry conditions. In the Philippines it is locally abundant in wet locations and it also grows as a weed in fallow rice fields. *M. capitata* is a short-day plant. When sown in April–June in India flowering starts in the middle of September, with April sowings giving the highest fibre yield. *M. fasciata* flowers from September to January in the Philippines.

Propagation and planting *Malachra* can be propagated by seed and by cuttings. Seed germination of *M. capitata* is often poor because of its hard seed coat, but it can be improved by seed treatment, e.g. with sulphuric acid. *M. capitata* must be grown at close spacings and protected from strong winds.

Husbandry Cultivated *M. capitata* requires little attention.

Diseases and pests *M. capitata* is a host plant of zucchini yellow mosaic virus (ZYMV), a virus causing much trouble in melon (*Cucumis melo* L.) and cucumber (*Cucumis sativus* L.).

Harvesting In India *M. capitata* cultivated for fibre is harvested 3–4 months after planting.

Yield *M. capitata* fibre yields of 1.9 t/ha have been obtained from experimental plantings in India. Natural stands of *M. fasciata* and *M. capitata* in the Philippines have been estimated to yield roughly about 0.2 t/ha and 1 t/ha of fibre, respectively.

Handling after harvest In the Philippines the fibre of *M. fasciata* is extracted by retting: the entire plant is cut and kept in fresh water for about 10 days, after which the bast is easily stripped and freed from the nonfibrous material by washing. In the Philippines *M. capitata* is sometimes made into cordage without retting: the bark is simply stripped from the plant, dried and twisted into cords. In India the roots and leaves are removed from harvested *M. capitata* and the green stems are retted for 6–8 days in small concrete tanks. The fibre is easily separated from the retted stems because the plants do not have many lateral branches.

Genetic resources and breeding No germplasm collections or breeding programmes of *Malachra* are known to exist.

Prospects Though *M. capitata* is a potential source of excellent jute-like fibre and adapted to a wider range of ecological conditions than jute, the present-day use of *Malachra* seems very limited. It is unlikely that its importance in South-East Asia will increase beyond the current usage as cordage material. Its noxious weedy nature in the United States will deter wider use.

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N.O. Aguilar & M. Brink

Miscanthus Andersson

Öfvers. Förh. Kongl. Svenska Vetensk.-Akad. 12: 165 (1856).

GRAMINEAE

$x = 19$; *M. floridulus, M. sinensis*: $2n = 38$; *Miscanthus* possibly originated as an amphidiploid between species with $x = 9$ and $x = 10$

Major species and synonyms

- *Miscanthus floridulus* (Labill.) Warb. ex K. Schum. & Lauterb., Fl. Deut. Schutzgeb. Südsee: 166 (1901), synonyms: *Saccharum floridulum* Labill. (1824), *Miscanthus japonicus* Andersson (1856), *M. formosanus* A. Camus (1924).
- *Miscanthus sinensis* Andersson, Öfvers. Förh. Kongl. Svenska Vetensk.-Akad. 12: 166 (1856), synonyms: *Saccharum japonicum* Thunb. (1794, p.p.), *Miscanthus purpurascens* Andersson (1856), *M. matsudae* Honda (1923).

Vernacular names General: miscanthus, silvergrass (En). Philippines: bilau (Igorot, Ifugao).

- *M. floridulus*: floret silvergrass (En). Indonesia: glagah (Javanese, Balinese)], toi (Halmahera), lolo (Ternate, Tidore). Philippines: bublung (Bontoc), buyao (Ifugao). Vietnam: c[or] ch[ef] v[ef].

- *M. sinensis*: eulalia (En). Indonesia: walana 'in cuntung (Minahasa). Philippines: rono (Ilokano), bigao (Bikol). Vietnam: ch[ef] v[ef] trung hoa.

Origin and geographic distribution *Miscanthus* originates from Asia and contains about 20 species, occurring in the Old World tropics, South Africa and East Asia. *M. floridulus* is distributed from East Asia through South-East Asia to Polynesia. *M. sinensis* is a more temperate zone species, native to China, Korea, Taiwan, Japan and eastern Russia, and introduced and established in Australia and North America. The extent of its distribution in South-East Asia is uncertain, but it seems to occur in the Philippines and Indo-China. Information on *M. sinensis* in Indonesia probably refers to *M. floridulus*. Both M. *floridulus* and *M. sinensis* are sometimes considered weeds.

Uses The stems of *M. floridulus* and *M. sinensis* are suitable for thatching and widely used for this purpose, for instance in Indo-China, eastern Malaysia, the Moluccas, the Philippines, New Guinea, and the Pacific. They serve for making house walls in the Philippines and New Guinea. In the Philippines the stems are also made into fences, floor-coverings, coarse baskets, children's toys, novelty and souvenir items, supports for climbing vegetables or beans and drying racks for tobacco. In Luzon split stems serve for making screens and window shades. In the Moluccas and Papua New Guinea the stems are made into arrow shafts. Both *M. floridulus* and *M. sinensis* can be used for paper making.

Miscanthus shoots are eaten as a vegetable in East Kalimantan. The leaves are fodder for water buffaloes in the Philippines. The stems serve as fuel in the Philippines and Indo-China. Medicinal uses include the application of the juice or a decoction of *Miscanthus* on bites from wild animals in Indo-China, whereas in the Philippines a shoot decoction is taken against cough. In the Philippines *Miscanthus* stems with leaves are sometimes arranged in front of houses or other property as a sign not to enter or disturb.

Outside South-East Asia *M. sinensis* is widely planted as an ornamental, and also in hedges and windbreaks. In Japan it is cultivated as a forage plant and it has been used as a source of a yellow dye. *M. floridulus* is grown as an ornamental. In Taiwan it is planted as a shelter. Because of its high productivity, *Miscanthus* is being investigated in Europe as a renewable source of energy and a potential source of fibre for composite materials like MDF (medium density fibreboard) and chipboard, pulp for paper and packaging, biodegradable geotextiles (e.g. for temporary protection of slopes and banks), filters and sorbents, and insulation. Most research has focused on *M.* ×*giganteus* Greef & Deuter ex Hodkinson & Renvoize, which is probably an allotriploid hybrid of *M. sinensis* and *M. sacchariflorus* (Maxim.) Hack., originating from East Asia and introduced into Europe in the 1930s.

Production and international trade *M. floridulus* and *M. sinensis* are used locally in South-East Asia. No production or trade statistics are available.

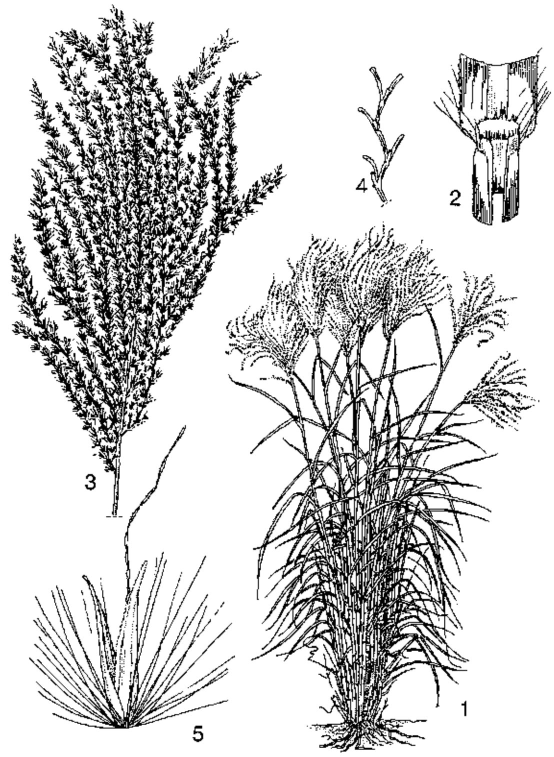
Properties The ultimate fibres of *Miscanthus* have an average length of 1.4–1.8 mm, a lumen width of 7 μm and a cell wall thickness of 6 μm. *Miscanthus* straw contains 38–48% α-cellulose, 26–34% hemicelluloses, 18–24% lignin and 2–6% ash. The α-cellulose and lignin levels of 2-year-old plants decrease from the base to the top of the stem, whereas the opposite occurs for hemicelluloses and ash. The lignin content of the leaves is lower than that of the stem tops, and the ash content higher, whereas the levels of α-cellulose and hemicelluloses in the leaves are similar to those in the stem tops. When separated into a chip fraction (mainly consisting of splintered internodes) and meal fraction (mainly ground leaves, nodes and husks), the chip fraction did not give better pulp quality than unfractioned material. In a comparative study in the United Kingdom, chemical (soda-anthraquinone) *Miscanthus* pulps were superior in yield (46–52%), tensile strength and tear strength to those of wheat straw, but inferior in brightness. Yields and tensile strength were similar to those of chemical (kraft) *Eucalyptus* pulp, but the tear strength and brightness were superior. Semi-chemical (neutral sulphite semi-chemical process) *Miscanthus* pulp did not compare favourably with semi-chemical hardwood pulp. Particle boards made of *Miscanthus* material were much inferior to those made of wood, but *Miscanthus* showed promise as raw material for MDF. Another study showed that good quality particle boards can be made of *Miscanthus* provided the glue used is PMDI (polymeric diphenylmethane-4,4-diisocyanate) instead of UF (urea formaldehyde), PF (phenol formaldehyde) or MUPF (melamine urea phenol formaldehyde).

Though the leaves of *M. floridulus* are sometimes used as fodder and appear excellent on chemical analysis, they are not very suitable because of their harshness. The scabrid-toothed leaf margins of *M. floridulus* can make severe cuts. The yellow colouring substance in *M. sinensis* is probably tricin. The glycoprotein fraction of a water extract of *M. sinensis* spikelets inhibited cutaneous allergic reactions in experiments with mice, and may be useful in the development of anti-allergenic therapies. The energy content of *Miscanthus* is about 16–19 MJ/kg dry matter.

Adulterations and substitutes Numerous other plant species are used for thatching in South-East Asia, such as *Imperata conferta* (J.S. Presl) Ohwi and *I. cylindrica* (L.) Raeuschel. As a source of pulping material, *Miscanthus* mainly competes with hardwoods.

Description Robust, tufted, rhizomatous, perennial grasses with erect, solid culms. Leaves expanded, sheathed, ligule membranous, ciliate, blade linear, flat. Inflorescence usually an open, large, plumose panicle with tough rachis, repeatedly branched on all sides into numerous racemes; spikelets in pairs, small, equal, lanceolate, unequally pedicellate, falling entire, 1-flowered, awned, with a spreading bundle of long silvery-white or coloured hairs at base; glumes equal, thin, 1–5-nerved; lemmas smaller, upper lemma with central nerve excurrent into long or short awn; palea nerveless; lower floret reduced to a sterile hyaline lemma, upper floret bisexual; lodicules 2, cuneate; stamens 2–3; styles 2, free; stigmas 2, plumose. Fruit a subcylindrical caryopsis.

– *M. floridulus*. A robust, tufted, erect, perennial grass, 1.5–3 m tall. Culm terete, filled with pith, glabrous, pruinose below the nodes. Leaf-sheath glabrous or outer margin with long hairs; ligule 1–2 mm tall; blade 60–150 cm × 1–4.5 cm, base attenuate, margins very rough, apex acute, long hairy above the base or only just behind the ligule, otherwise glabrous and smooth with wide midrib. Inflorescence 30–45 cm long; branches numerous, erect or nodding, lower ones 20–40 cm long, solitary or 2–6 together, often from near base already with 3–10 long, lateral branches; spikelets not crowded; pedicels slender, thickened upwards, those of a pair 2–4 mm and 4–9 mm long respectively, both, or at least the longer one, ultimately rather divergent or recurved; spikelet about 4 mm long; basal hairs 5–11 mm long, white or purple; lower glume 3–5-nerved, upper glume 3-nerved; lower lemma 2.2–4.2 mm long, finely ciliate in upper half, 0–1-nerved; upper lemma 2–3.5 mm long, 3-nerved, awn twisted, 6–11 mm long; palea 1.5–2.7 mm long; stamens 3; stigmas exserted near middle of spikelet.



Miscanthus sinensis Andersson – 1, habit. M. floridulus (Labill.) Warb. ex K. Schum. & Lauterb. – 2, part of sheath with ligule; 3, inflorescence; 4, part of inflorescence branch axis; 5, spikelet.

– *M. sinensis*. A robust, tufted, erect, perennial grass, 1.5–2.5 m tall. Leaves radical and cauline; blade 50–80 cm × 0.2–2 cm, stiff, very scabrous on the margin, pale or slightly glaucous beneath, midrib thickened toward base. Inflorescence a corymbose panicle, 20–30 cm long, main axis shorter than the 7–many raceme-branches; racemes 15–30 cm long; spikelets as in *M. floridulus* but longer, 5–7 mm long, tuft of hairs 7–12 mm long, awn 8–15 mm long.

Growth and development *Miscanthus* spp. are perennial grasses. The estimated productive life of *M.* ×*giganteus* is 10–20 years, but yields seem to decline after 10 years. *Miscanthus* follows the C_4-cycle photosynthetic pathway, thus using CO_2 and water more efficiently than C_3 plants and having higher potential biomass yields. Daily growth rates up to 3–4 cm have been recorded. Unlike other C_4-plants, e.g. maize (*Zea mays* L.), *Miscanthus* retains its high photosynthetic capacity at temperatures below 14°C. *Miscanthus* is wind-pollinated and in Java *M. floridulus* flowers throughout the year. *Miscanthus* roots extend to a depth of 1 m or deeper.

Other botanical information Literature on *Miscanthus* is often unreliable at the species level because the taxonomy of *Miscanthus* is not clear and is in need of revision. *M. sinensis*, for instance, has sometimes been grouped under *M. floridulus*. However, based on isozyme analysis it has been postulated that *M. floridulus* evolved from the more primitive *M. sinensis*. Hybridization between the now approximately 20 recognized *Miscanthus* species is common and has given rise to a large number of hybrids, many of which are sterile. *Miscanthus* is closely related to *Saccharum* L. with which it is able to hybridize. A specimen in the Linnean Herbarium annotated as *Saccharum officinarum* L. later appeared to be *M. floridulus*.

The soft-leaved *M. sinensis* var. *condensatus* (Hack.) Makino (synonym: *M. condensatus* Hack., by some considered as a separate species) occurs on seashores and sometimes on mountains in Japan; it is often cultivated as a fodder plant in the Ryukyu and the Idzu Islands. It also occurs in Korea, China, Indo-China and the Pacific. *M. ×giganteus* is a hardy perennial 2.5–3.5 m tall; leaves flat and linear, usually more than 50 cm × 3 cm, ligule truncate with hairs; inflorescence 30 cm long with 15 cm long rachis; spikelets 4–6 mm long with tuft of hairs about 2 times longer; lower glume 5–6 mm long, upper glume 4–5 mm; sterile and fertile lemmas 3.5 mm long, not awned. Numerous, mainly ornamental *Miscanthus* cultivars are known, particularly of *M. sinensis*; they differ in size and colour of foliage and inflorescence. Some well-known *M. sinensis* cultivars are 'Goliath', 'Purpureus', 'Sarabande' and 'Zebrinus'.

Other *Miscanthus* species recorded from South-East Asia are *M. nepalensis* (Trin.) Hack., occurring in Malaysia (Pahang), India and Burma (Myanmar) and *M. depauperatus* Merr., found in the Philippines. No information is available on their uses. *M. sacchariflorus* (Maxim.) Hack. (synonym: *Imperata sacchariflora* Maxim.) is an important source of pulp for paper making in China and is under investigation as a biomass crop.

Ecology *M. floridulus* occurs in South-East Asia almost from sea-level up to 3000 m altitude, but mostly at 1000–2000 m. It is frequently found on rocky mountain slopes, in swampy locations and in waste or disturbed land. It also forms gregarious clumps and thickets in open sites in oak and secondary forest, tree-fern and bog grasslands. In Java *M. floridulus* is locally abundant in sunny or partly shaded, humid or sometimes marshy places, in forest edges, young forest, scrub vegetation and grass jungles, at 1350–2100 m altitude. *M. floridulus* is aggressive and can form dense communities. It survives fire through quick regeneration from subterranean parts. *M. floridulus* withstands wind and can grow in coastal areas where salt spray occurs. *M. sinensis* occurs at medium and higher altitudes in the Philippines. After repeated fires it may dominate areas completely.

Propagation and planting *Miscanthus* is usually propagated vegetatively by division or rhizome cuttings. Rhizome cuttings for field planting are usually 8–15 cm long and can be stored between −1°C and 1°C. Not much success has been obtained with stem cuttings. *M. floridulus* and *M. sinensis* can be propagated by seed, though seed production has been difficult for *M. floridulus* in China and for some *M. sinensis* cultivars. The germination rate of *M. floridulus* increases with temperature between 15°C and 35°C, but the germination percentage is not affected by temperature in this range. The optimum temperature range for germination of *M. sinensis* seed is 20–30°C. In vitro micropropagation of various *M. sinensis* cultivars is possible with immature inflorescences on modified Murashige and Skoog (MS) medium with 9.0 μmol 2,4-D (2,4-dichlorophenoxyacetic acid) and 20 g/l sucrose, with organogenesis occurring 8–12 weeks after callus formation. Shoots can be rooted on half-strength MS medium and tillers will form, which can be separated for new rooting and tillering. Another micropropagation system for *M. sinensis* has been developed in which meristem tissue is removed from selected plants and cultured.

In Europe the practically sterile hybrid *M. ×giganteus* is propagated vegetatively by rhizome cuttings or in vitro micropropagation and planted at a density of 5 000–40 000 plants per ha.

Husbandry In South-East Asia *Miscanthus* is not planted but collected from the wild. Cultivated *M. ×giganteus* in Europe needs to be weeded in the establishment phase (the first 2 years), but later on the crop is competitive enough to overcome weeds. Because of the high productivity, and in spite of the high water-use efficiency, the water requirement is high and irrigation is beneficial under southern European conditions. The response to fertilizer application varies with soil type, but in general the nutrient removal at harvesting is relatively low: 5–8 kg N, 0.5–1.5 kg P and 6–9 kg K per t harvested dry matter.

Diseases and pests *Miscanthus* is attacked by rusts (*Puccinia* spp.), a wide-ranging species being *Puccinia miscanthae*, and smuts (*Sphacelotheca* spp. and *Ustilago* spp.). In Europe it is attacked by the Miscanthus streak virus. No information is available on diseases and pests affecting *Miscanthus* in South-East Asia.

Harvesting In Europe *M. ×giganteus* is harvested annually after nutrients have relocated to the rhizomes and the plants have dried to a dry matter content of at least 60%, and before new shoots occur. In northern Europe this is preferably in February or March, and in southern Europe in November. If it is harvested early, the biomass loss is low, but the moisture content is high. If it is harvested late, the moisture content is low, but biomass loss of up to 20% may occur. For the production of handicrafts in the Philippines, young stems are preferred.

Yield *Miscanthus* yields in South-East Asia are unknown, but for China possible dry matter yields of up to 40 t/ha have been recorded. In Europe *Miscanthus* yields from the third year onwards normally range from less than 10 t/ha dry matter per year in northern Europe to about 25 t/ha dry matter per year in southern Europe under irrigated conditions. Experimental yields up to 41 t/ha dry matter have been recorded.

Handling after harvest The stem is the most important part of *Miscanthus* as a source of fibre, and after harvest the stems must be separated from the leaves. In Indonesia the traditional way of preparing *Miscanthus* stems is to separate them and dry them in the sun. Young stems or shoots to be used for medicinal purposes are not dried.

Genetic resources *M. floridulus* and *M. sinensis* have a wide distribution and do not seem to be threatened with extinction. Some 14 accessions of *M. floridulus* are held at the Institute of Plant Breeding of the College of Agriculture UPLB in Laguna, the Philippines. Accessions of *M. sinensis* are held in Japan (Kumamoto Station National Livestock Breeding Centre, Kumamoto) and the United Kingdom (Institute of Grassland and Environmental Research, Aberystwyth).

Breeding In Europe some *Miscanthus* breeding work has been started, for instance on hybridization and polyploidization. Furthermore, *M. sinensis* and *M. ×giganteus* genotypes are evaluated with respect to biomass yield, responses to low temperatures and frost tolerance. *Miscanthus* species are used in breeding programmes of sugar cane (*Saccharum officinarum* L.), e.g. for bringing in disease resistance.

Prospects In South-East Asia *Miscanthus* will remain an important source of thatch. In the Philippines it is considered to have bright prospects as a material for handicrafts. Worldwide, it has potential as a non-wood source of fibre for composites such as MDF and pulp for paper making and packaging. Because of its high productivity, *Miscanthus* is a promising renewable source of energy.

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Musa textilis Née

Anal. Cienc. Nat. 4: 123 (1801).
MUSACEAE
$2n = 20$

Synonyms *Musa abaca* Perr. (1824), *M. mindanaensis* Rumph. ex Miquel (1859).

Vernacular names Abaca, abacá, Manila hemp (En). Abaca, chanvre de Manille, bananier à fibres

(Fr). Indonesia: abaka, pisang manila (general), Manila hennep (Dutch). Malaysia: pisang manila, pisang benang. Philippines: abaká, abacá, abaca. Vietnam: chu[oo]i soi.

Origin and geographic distribution Abaca originated in the Philippines. Wild plants have spread southward into Borneo and islands south of the Philippines, such as Sangihe Island (Indonesia). Until the 1920s, attempts to establish commercial abaca cultivation outside the Philippines did not succeed, thus abaca was obtained from the Philippines only. However, to decrease the dependency on the Philippines, the United States successfully introduced abaca into Central America in the 1920s. Abaca cultivation in Ecuador started after the Second World War. The crop has also been grown successfully in Malaysia (northern Borneo), Indonesia (Sumatra) and New Guinea.

Uses Abaca fibre, obtained from the pseudostem of *M. textilis*, is the principal fibre of the Philippines, where it was already widely used as raw material for clothing and footwear at the time the Spaniards arrived. Exports started in the early 19th Century, and abaca became known as one of the best materials for marine and fishing cordage. From the 1950s onwards synthetic fibres largely replaced abaca as cordage material, threatening the Philippine abaca industry. Technological breakthroughs in the 1960s, however, led to the discovery of new uses for abaca, especially in the production of pulp for specialty papers. The Philippine government also encouraged the development of the fibre craft industry, which became the second largest foreign exchange earner in the abaca sector (after raw fibre) in the 1970s. Nowadays, abaca fibre is made into pulp and specialty papers, such as currency notes, cigarette paper, meat and sausage casings, teabags, filter paper, stencil paper and capacitor paper. In 2000 the Central Bank of the Philippines approved the use of 20/80% abaca/cotton mixtures for banknotes. In the cordage industry, abaca fibre is used for making cables, cords, ropes, strings, twines, marine cordage and binders. Fibre crafts include items such as footwear, mats, curtains, rugs, bags, place-mats, hammocks, wallets and wall decorations. Abaca is suitable for textiles after it has been cottonized. It is becoming popular as a blending material with silk and piña (*Ananas comosus* (L.) Merr.) fibre in the production of high-end fabrics. Abaca ribbons and 'sinamay', a local Philippine fabric, are used as decorative and packaging materials. Abaca fibre is also used in the manufacture of construction material such as roofing and floor tiles, wallboards, ceiling boards and wallpaper sheets, and to reinforce concrete and asphalt. The dried outer leaf-sheath ('bac-bac') is useful in the manufacture of ceiling board, sliding board and wallpaper substitute. It is also utilized for making trays, baskets, bags, slippers, blinds, curtains, wall panelling and place mats. The inner leaf-sheaths are used for making roofs and for shading seedlings. They also serve as plates or food containers. The leaf blades are used for shading and wrapping. In traditional Philippine medicine, the sap of abaca is used in treating wounds, especially to induce blood clotting. Abaca is also used for reforestation.

In Indonesia abaca is traditionally used in islands north of Sulawesi (Sangihe, Talaud) for fabrics and fishing nets, but here it has never developed beyond local importance. Attempts to introduce abaca as a smallholders' crop into other parts of Indonesia have not been successful.

Production and international trade In 1996–2000 the average annual world production of abaca was about 98 000 t from 132 000 ha. The major producers were the Philippines (about 72 000 t/year from 112 000 ha) and Ecuador (about 24 000 t/year from 16 000 ha). Minor producers included Costa Rica (1100 t/year), Indonesia (600 t/year) and Equatorial Guinea (500 t/year). In 1996–2000 an annual average of 33 000 t abaca fibre was traded internationally, of which the Philippines exported about 19 000 t and Ecuador 13 000 t. The main importers were the United Kingdom (15 000 t/year), the United States (8000 t/year), Japan (7000 t/year) and Spain (2000 t/year).

The main production areas in the Philippines in 1996–2000 were Eastern Visayas (Samar-Leyte; 27 900 t from 32 000 ha), Bicol (21 300 t from 45 000 ha) and southern Mindanao (8500 t from 8900 ha). In this period, the domestic industry used about 47 000 t, of which 29 000 t (62%) was used for pulp and paper making, 12 000 t (25%) for cordage, and 6000 t (13%) for fibre crafts. During the period 1991–2000 the consumption by the pulp sector increased by 4.1% per year, whereas the consumption by the cordage sector decreased by 1.5% per year. The average annual export earnings of the Philippines from abaca fibre and products in 1996–2000 were about US$ 82 million, to which raw fibre contributed 23%, pulp 44%, fibre crafts 19%, cordage 13%, and yarns and fabrics only 1%. The main importers of Philippine abaca fibre were the United Kingdom (7400 t), Japan (5900 t) and the United States (4900 t). The annual export of abaca pulp from the Philippines amounted to 14 100 t, mainly to Germany (6100 t) and Japan (5200 t). In the same period, 7800 t cordage (and allied products) was exported annually, mainly to the United States (5400 t).

It is estimated that in the Philippines, where abaca is mainly a smallholders' crop, more than 1.5 million people depend on the abaca sector for a living, directly or indirectly. In 2000, there were about 68 000 abaca farmers, with an average 2 ha abaca plantation per farmer. There are 5 abaca pulp companies in the Philippines, with a combined capacity of about 21 400 t/year, and 7 cordage firms, with a combined capacity of about 12 000 t/year. The fibre craft sector, including paper making by hand, is mainly cottage-based.

Commercial plantation has been tried several times in Indonesia in the second half of the 19th Century and first half of the 20th Century, for instance in Java, but has seldom been successful, mainly because of the difficult fibre extraction. However, Indonesia is presently trying to develop an abaca industry, using the cultivar 'Tangongon'.

Properties Abaca fibre is obtained from the vascular bundles of the leaf sheaths that form a thick pseudostem. In cross-section, each leaf sheath consists of 3 layers: an outer fibrous layer with long and strong fibres ('primary fibre', the abaca fibre of commerce), a middle layer which has partitioned air canals and contains a small quantity of weak fibre ('secondary fibre'), and an inner layer which does not contain any fibre. Commercial fibres are 1–3 m long. The ultimate fibre cells are (2–)4–8(–12) mm long and (6–)13–29(–53) μm in diameter, with a lumen width of (1–)7–14(–33) μm. The fibre cells taper gradually to a pointed or rounded end. Irregular ends are rare. In general the tips are much finer and more pointed than those of sisal (*Agave sisalana* Perrine). Very fine dislocations and cross-markings are often present. In transverse section, the fibres are oval or rounded polygonal, often with 5 or 6 sides. Freshly cut pseudostems contain about 93% moisture and 1.5–3% fibre. Abaca fibre contains: 55–64% α-cellulose, 18–23% hemicelluloses, 5–18% lignin, 1% pectin and 1–2% ash.

Abaca fibre, classified among the hard fibres, is remarkable for its strength and resistance to fresh and salt water. It is three times stronger than cotton (*Gossypium* spp.) fibre and twice as strong as sisal, and also stronger than hemp (*Cannabis sativa* L.) and sunn hemp (*Crotalaria juncea* L.). It is more resistant to salt water than most other vegetable fibres. Commercial abaca fibre ranges from almost pure white, through cream to light or dark brown, depending on cultivar, position of the sheath in the pseudostem, and fibre extraction and processing.

Abaca fibre is excellent raw material for paper and dissolving grade pulps due to its low lignin, ash, silica and extractive contents, and high total cellulose content, all of which contribute to high pulp yield and low consumption of chemicals in the pulping and bleaching treatments. It also has a high pentosan content, which contributes to the high bursting, folding and tensile strengths.

Adulterations and substitutes The main competitors of abaca as cordage material are synthetics and sisal, which are both cheaper. However, abaca is still preferred in oil drilling, navy and merchant shipping, and construction, because of its non-slippage characteristics. The main competitors in the market for specialty papers are artificial fibres, such as viscose and polyester, which are also used in blends with abaca. Sisal is inferior to abaca for the production of specialty papers, except for filtration media, because paper made of sisal has a higher porosity but lower tensile and bursting strength. In the Philippines abaca is sometimes adulterated with 'canton', a natural hybrid of *M. textilis* and *M. balbisiana* Colla, and by 'pacol', obtained from *M. balbisiana*. Both canton and pacol are of lower quality than abaca.

Description A tufted perennial herb, up to 8 m tall, growing in a clump (hill), very similar to an edible banana plant, when mature and undisturbed consisting of 12–30 or more pseudostems in different stages of development. Corm cylindrical, short, bearing buds developing short rhizomes with suckers, and numerous slender adventitious roots extending 2–3 m and mostly confined to the top 25 cm of the soil. Pseudostem (formed by the leaf sheaths) cylindrical, 2.5–6 m tall, 15–20 cm in diameter at base, mostly green, sometimes irregularly streaked deep brown, red, purple or even almost black towards the base, bearing up to 12 leaves; petiole-like sheath 40–50 cm long, stiff; leaf blade narrowly oblong, 150–200 cm × 40–60 cm, cuneate and unequal at base, rounded or acute at top, generally of a uniform deep-green above, glaucous beneath. Inflorescence arising from the rhizome, borne on an erect, long peduncle which for its greatest part is included in the pseudostem, bearing a drooping racemiform spike, consisting of an axis with transversely arranged, 1–2-seriate groups (hands or combs) of 10–12 flowers, each group in the axil of a bract; bracts lanceolate, 30–35 cm × 10–12 cm, closely overlapping,

Musa textilis Née – 1, habit; 2, bract with male flowers; 3, male flower; 4, fruit.

deciduous, leathery, green, slightly shaded with pink outside, dull brown inside; perianth of 5 fused outer tepals and one adaxial inner tepal; male flowers in upper part of inflorescence, about 4 cm long, deciduous, with 5 slightly exserted stamens and one pistillode; female flowers in basal part of inflorescence (first 3–6 nodes); ovary inferior, 5 cm long, 3-locular, with numerous ovules. Fruit bunch horizontal, lax; fruit a berry, narrowly ovoid or ellipsoid, 5–8 cm × 2–5 cm, obsoletely curved at maturity, narrowed at base into a stout truncate stipe about 7 mm long, pericarp 1 mm thick, ripening green; pulp scanty, pale buff, inedible. Seeds numerous, subglobose-turbinate, very irregular in shape, about 2–3 mm × 3–4 mm, smooth, black.

Growth and development Emergence of abaca from seed is completed 2–4 weeks after sowing, but vegetative development is very slow. Growth accelerates after 2–4 months. Flowering normally starts 18–24 months after sowing. Plants raised from one-year-old suckers may flower 10–12 months after planting, whereas those grown from corms flower 16–18 months after planting. Flowering is year-round in the tropics. Time to fruit maturity ranges from 27–34 months under normal conditions but takes longer at higher altitudes. After the fruit has ripened, the stem dies if it has not been cut for fibre. Cultivated plants usually consist of 10–20 pseudostems in various stages of maturity, of which 4–8 reach the flowering stage within the same year. Abaca has typical bat-pollinated flowers; in Indonesia it is pollinated by small bats (mainly *Macroglossus minimus*). The stigmas are receptive for 2 days, and the pollen remains viable for 2 days. Self-pollination is impossible due to the separation of male and female flowers in the inflorescence and the earlier flowering of female flowers, but sib-pollination between pseudostems of the same clump is possible.

Other botanical information *Musa* L. comprises 30–40 species and the genus is often divided into 5 sections. *M. textilis* belongs to section *Australimusa*. Its general structure is similar to that of the edible banana cultivars, but it is more slender, the leaves are smaller and the fruits are seeded. Wild relatives of *M. textilis* include *M. acuminata* Colla subsp. *banksii* (F. Muell.) Simmonds ('agotay') and *M. balbisiana* ('pacol').

More than 400 cultivars of abaca are grown in the Philippines, but only about 20 of them are of commercial importance and these are distributed throughout the different regions of the country.

In Bicol, the most commonly grown cultivars are:
- 'Tinawagan pula': well-suckering, but with small stalks at maturity.
- 'Lausigon': hardy, does not lodge easily and withstands drought; fibre coarse and difficult to strip.
- 'Sogmad': thrives well on fertile soils; produces an average of 19 suckers per year; fibre white and fine, easy to strip.

In Eastern Visayas, the most commonly grown commercial cultivars are:
- 'Inosa': producing 5–7 suckers per hill; resistant to strong winds and drought; thriving well in medium fertility soils; fibres coarse and difficult to strip.
- 'Linawaan': widely grown because of its high fibre yield; producing 9–11 suckers per hill; deep-rooting and resistant to strong winds and drought; fibre white, lustrous and fine, but difficult to extract.
- 'Laylay': stooling freely, with well-developed stalks, which tend to grow very close to each other;

late maturing; shallow-rooted and susceptible to strong winds; easy to strip; fibres long, ivory white, lustrous and uniform from base to tip, thus suited for fibre crafts.

In Mindanao, the three commercial cultivars grown are:

- 'Tangongon': large, hardy and vigorous, 4.5–5.5 m tall; not exacting with regard to soil conditions, growing well on heavy clay soils; does not sucker freely; easily blown over because the corms often push through the soil surface; fresh pseudostems yield 2.5–2.75% of a strong, heavy, coarse fibre, which is difficult to extract.
- 'Bongulanon': stems medium-sized, leaves narrow; abundantly suckering; not readily lodged; early maturing, but with a short productive life and yields decline after 5–6 years; requires moist, well-drained alluvial soils and cannot be grown on heavy clays or dry sandy soils; fresh pseudostems yield about 2.3% of strong, white, good-quality fibre which is easily stripped. It used to be the most widely grown cultivar in Central America.
- 'Maguindanao': stems large; relatively hardy; first harvest 15–18 months after planting, with a long productive life of 15 years or more; can be grown on a wide range of soils, except heavy clays; root system shallow and plants are easily blown over; fresh pseudostems yield about 1.75% of strong, white, soft fibre, which is easily extracted.

The leaves of other *Musa* spp. are used as wrappers for food, and fibre may be obtained from their pseudostem for the production of cloth. In Indonesia, especially in Java, pseudostems of edible *Musa* L. cultivars recently started to be used in the production of pulp for handmade specialty paper and in the production of handicrafts such as handbags and placemats. *M. violascens* Ridl., endemic to Peninsular Malaysia, has been investigated for its fibre in the early 20th Century. The average length of its ultimate fibres was 2.5 mm; the strength was only half that of abaca. The fibre of the closely related *M. salaccensis* Zoll., found in Sumatra and Java, has been recorded as being suitable for tying

Ecology Abaca is a plant of the hot and humid tropics. The present zone of successful cultivation lies between approximately 5°S and 15°N latitude. In the Philippines it is usually grown in regions below 500 m with a well-distributed annual rainfall of 2000–3200 mm, an average temperature of about 27°C and a relative humidity of about 80%. Abaca is easily damaged by strong winds; in the Philippines windbreaks and cover trees are planted in typhoon-prone areas. It grows best on friable well-drained loams, rich in organic matter and potash, and is sensitive to waterlogging.

Propagation and planting Abaca can be propagated by suckers, corms or seed. Propagation by seed is not recommended because seedlings take longer to mature and are not true to type, since abaca is highly heterozygous. Seed propagation may, however, be used for the production of new clones. The use of suckers or corms (or corm sections: 'seed pieces') is recommended for commercial propagation. Corms are usually preferred over suckers since they are easier to handle and transport. In the preparation of corms, care should be taken not to destroy the bud eyes. Mature suckers are used to fill vacant spaces in established plantings. Mass propagation of abaca is now done through in vitro culture. Tissue-cultured abaca plants are used in replanting programmes, especially in Bicol.

On small farms in the Philippines, abaca is normally planted irregularly between felled trees. In large-scale operations, it is advisable to establish an abaca nursery to produce the planting material. A nursery of 1 ha, with plants in double rows 2 m apart, with 1 m between the rows of each pair and 1 m between plants within the rows, will produce approximately 40 000 seed pieces per year. This is enough to plant 15 ha at a spacing of 2 m × 2 m. Seed pieces are planted in 40–50 cm deep holes 2 m × 2 m apart for ordinary-sized cultivars and 2 m × 3 m or 3 m × 3 m for larger ones; the plant density is 1100–2500 plants/ha. Planting is best done at the onset of the rainy season for early germination and a vigorous start. In areas with no or only a short dry period, planting can be done throughout the year.

It is recommended that trees be planted, such as *Erythrina fusca* Loureiro, *Paraserianthes falcataria* (L.) Nielsen and *Leucaena leucocephala* (Lamk) de Wit, to provide shade, maintain optimal temperature and humidity, and protect abaca from strong winds. Fruit trees such as durian (*Durio zibethinus* Murray), langsat (*Lansium domesticum* Correa) and jackfruit (*Artocarpus heterophyllus* Lamk) can also be planted as shade trees, with the advantage of providing additional income to the farmers. Abaca is also intercropped with coconut (*Cocos nucifera* L.). Intercrops such as upland rice (*Oryza sativa* L.), mungbean (*Vigna radiata* (L.) Wilczek, cowpea (*Vigna unguiculata* (L.) Walp.), groundnut (*Arachis hypogaea* L.) and other leguminous short-season crops may be planted for additional income during the establishment of the plantation and to reduce soil erosion. At a later stage, ginger (*Zingiber officinale* Roscoe), which tolerates shade, can be planted as an intercrop.

Husbandry Compared with other crops, abaca requires little care and often the plants are just left to grow until maturity. Shallow cultivation and ring weeding may be carried out at 2–3 month intervals for up to a year. It has been estimated that 100 t/ha of fresh stalks and leaves of abaca remove 280 kg N, 13 kg P, 430 kg K and 89 kg Ca per ha. When the fibre is extracted in the field and all other plant parts are returned to the soil, the nutrient loss is considerably lower. Most smallholders do not apply chemical fertilizers. Drainage canals can be constructed to allow better soil aeration. Pruning and thinning may be done by removing excess young suckers, leaving about 8 vigorous suckers per hill to mature every year. The duration of profitable production varies according to cultivar and growing conditions. In properly maintained areas, production may not decline for over 20 years, but it is generally advisable to replant after 10–15 years.

Diseases and pests The most important diseases of abaca are the viral diseases known as bunchy top and abaca mosaic. Abaca bunchy top virus (ABTV) is transmitted by brown aphids (*Pentalonia nigronervosa*). Infected plants develop chlorotic yellowish-white streaks and transparent veins; the plants become stunted and the crown of the plant develops a bunchy rosette growth form; finally the leaf blades dry up and turn brown. Early symptoms, visible at 14–18 days after inoculation, include the dark green appearance of infected leaves and restricted growth of the youngest leaf. The main control methods are the use of non-infected plant material and the eradication of infected plants. Abaca mosaic is caused by the abaca mosaic virus (AbMV), a potyvirus transmitted by aphids such as corn aphids (*Rhopalosium maidis*) and cotton aphids (*Aphis gossypii*). The onset of abaca mosaic is characterized by mottling of the leaves, consisting of dark to pale green or yellowish streaks, which extend from the midribs to the margins; mottling also occurs on other parts of the plant. Affected plants do not grow to full size. The use of disease-free planting material, eradication of infected plants, and elimination of alternate hosts such as maize (*Zea mays* L.) and the weeds *Cyperus compressus* L., *Paspalum conjugatum* Bergius and *Senna tora* (L.) Roxb., are necessary for effective control of abaca mosaic.

An important fungal disease is Fusarium wilt, caused by *Fusarium oxysporum* f.sp. *cubense*. It starts with rotting at the base of the pseudostem, with the rot moving upward until it reaches the leaf blades; plants become yellowish and eventually wilt. When corms and pseudostem of wilted plants are cut crosswise, the reddish-violet colour of the vascular bundle becomes evident. The first noticeable symptoms of the disease are the inward curling of the leaf blades at or near the tip of the lower leaves and the slow growth of the plants. Fusarium wilt, which, in contrast to the virus diseases, spreads in the soil or by rainwater, can be controlled by digging out infected plants and burning them, and by strict implementation of quarantine measures. Some cultivars, e.g. 'Linawaan', seem less susceptible than other ones. Less serious fungal diseases include dry sheath rot caused by *Marasmius* spp. and a stem rot caused by *Deightoniella torulosa* (synonym: *Helminthosporium torulosum*).

Important abaca pests include the aphid *Pentalonia nigronervosa*, an important vector of viruses which can be controlled by using appropriate insecticides. Corm weevil (*Cosmopolites sordidus*) can be controlled by keeping the field clean, by spraying or dipping infested corms or seedpieces containing eggs with insecticide, or by applying insecticides around the base of the plant. Slug caterpillars (*Thosea sinensis*) can be controlled by handpicking and killing the larvae using protection gloves or by spraying with contact insecticides at 7–10-day intervals.

Harvesting Abaca pseudostems are considered mature and should be harvested when the flagleaf (a rudimentary leaf, much reduced in size) appears, which precedes the appearance of the inflorescence. The time to first harvest of abaca depends upon the cultivar used, environmental conditions and cultural methods employed. Normally the first harvest takes place 18–24 months after planting. Subsequent harvests are made every 3–4 months in more favourable areas and every 5–7 months under less favourable conditions. In general, yield from the first harvests is small, and high yields are obtained from 4–8 year old plants. Harvesting abaca consists of topping the plant by cutting the leaf crown at the base of the leaf blades, and then tumbling the topped pseudostems with a slanting cut near ground level.

Yield In the Philippines the annual fibre yield of abaca ranges from 0.3–1.7 t/ha, depending on cultivar and location, with an average of 0.6 t/ha over the period 1996–2000. In Ecuador abaca fibre yields averaged 1.5 t/ha over the same period.

Handling after harvest The 10–20 useable abaca leaf-sheaths harvested per harvest are peeled off the pseudostem. The outer, middle and inner sheaths are normally separated, because they produce fibre of different quality: from the outer to the inner leaf sheaths the fibre becomes softer, whiter and weaker. In a process called 'tuxying', the outer layers of the leaf-sheaths are torn off. From these strips or 'tuxies', the fibres are extracted by placing the strips between a wooden bar and a serrated knife and pulling them manually (hand-stripping), thereby stripping off the epidermis and parenchyma. This is hard work, which can be lightened by a semi-mechanized process (spindle-stripping), in which the tuxies are pulled by a wooden spindle which is driven by an engine. Mechanical decorticators can also be used; they crush the pseudostems, scrape off the fleshy material and brush and clean the fibre, which is known as 'deco fibre'. In mechanical decortication both the primary fibres from the outer layer and the secondary fibres from the middle layer are extracted. It is much faster than hand- and spindle-stripping, but gives an inferior fibre and is not used on a commercial scale. In the Philippines most farmers use hand-stripping, whereas in Ecuador almost all fibre is extracted by spindle-stripping. Fibre recovery with hand-stripping is about 1.2–1.5% of the weight of the freshly cut pseudostem, with spindle-stripping 1.5–2.5%, and with decorticators about 3.0–4.0%. The extracted fibre is sun-dried or air-dried under a roof, after which it is graded and baled. The standard grades in the Philippines are divided into 2 main classes: hand-stripped and spindle-stripped. Within each class the fibre is further graded according to strength, cleaning, colour, texture and length. The fibres are baled per grade into bundles of 125 kg, measuring 100 cm × 55 cm × 60 cm.

In the paper industry the best fibre grades are made into porous and strong specialty papers, such as tea-bag paper and meat casings. Fair to residual grades are made into pulp for specialty papers with high tear and tensile strengths, such as vacuum cleaner bags and wrapping paper. On a commercial scale abaca pulp is usually produced using the soda process or alkaline sulphite process, but kraft pulping has also been applied in the Philippines. CTMP (chemi-thermo-mechanical pulping) and cold soda pulping (CSP) of abaca give pulps with good strength and optical properties. Thermo-mechanical pulping (TMP) of abaca, however, resulted in pulps with inferior strength properties. Printing and writing papers produced from waste paper blended with 5% bleached CTMP or CSP abaca pulp have strength properties comparable with those of paper produced from waste paper blended with 20% softwood pulp. Biological bleaching of abaca kraft pulp with the white-rot fungus *Trametes versicolor* has been successful. Pulps suitable for the production of rayon viscose have been prepared from abaca fibre using the kraft and alkaline sulphite pulping processes.

Genetic resources The Philippines is the primary gene centre for abaca. The largest germplasm collection is maintained at the National Abaca Research Centre (NARC) based at the Leyte State University (formerly Visayas State College of Agriculture), Baybay, Leyte. More than 600 accessions (cultivars and wild types) are maintained, while duplicates of 100 accessions are maintained at the Institute of Plant Breeding, University of the Philippines Los Baños, College, Laguna. Accessions, especially threatened cultivars, are also conserved in vitro. Isozyme analysis and DNA fingerprinting are being done to eliminate duplicates. Part of the collection at NARC has been characterized with respect to fibre morphology, chemical composition, fibre qualities and physical properties.

Breeding The main objectives in abaca breeding are: high degree of resistance to diseases and pests, early maturity, high yield and fibre recovery, optimal fibre quality, and adaptability to varying climate and soil conditions, including drought and acid tolerance. Wild relatives available for improvement include 'pacol', 'agotay', 'alinsanay' (*M. textilis* × *M. acuminata* subsp. *banksii*), 'canton' and 'minay'. The latter two types are both putative hybrids between *M. textilis* and *M. balbisiana*. These wild relatives are possible sources of resistance to important diseases and pests, vigour, resistance to drought and other desirable agronomic characteristics.

Prospects The demand for abaca both by local processors and foreign users is expected to increase in the future, indicating promising prospects for the abaca industry, especially for the abaca pulp sector. As technology evolves rapidly, more varied uses of abaca are being discovered. In view of the growing environmental hazards posed by non-biodegradable materials, industrialized countries are beginning to consider more environment-friendly raw materials, such as abaca. At present, the supply of abaca fibre cannot meet the increasing demand. Moreover, each grade of abaca fibre has its own market, so fibre production should be tailored to the particular end use for which it is intended. Thus, both expansion and diversification are called for. Increased production through improved husbandry should be coupled with improved processing methods. Appropriate abaca-based cropping systems are needed to provide abaca farmers with a steady income especially during the establishment phase. Crop protection should be aimed at the development of environment-friendly biological control agents. Breeding should be geared towards development of high-yielding, disease- and pest-resistant and stress-tolerant cultivars with good fibre quality. As abaca is a perennial, the use of biotechnology should be explored to accelerate genetic improvement. The use of somatic embryogenesis for micropropagation holds promise especially in the production of disease-free encapsulated seeds.

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Nepenthes L.

Sp. pl.: 955 (1753); Gen. pl. ed. 5: 409 (1754).
NEPENTHACEAE
$x = 5$ (10?); *N. rafflesiana*: $2n = 80$

Major species and synonyms

- *Nepenthes ampullaria* Jack, Comp. Bot. Mag. 1: 271 (1835), synonym: *N. ampullacea* H. Low (1848).
- *Nepenthes rafflesiana* Jack, Comp. Bot. Mag. 1: 270 (1835), synonyms: *N. raflesea* Hort. (1869), *N. sanderiana* Burb. (1904), *N. hemsleyana* Macfarl. (1908).

Vernacular names General: pitcher plant, tropical pitcher plant, monkey pot (En). Indonesia: daun kendi (Moluccas), ketakong (Bangka), paku sorog (Sundanese). Malaysia: periuk kera, periuk monyet, periuk kerengga.

- *N. ampullaria*: Indonesia: kantong teko (general), ketakong betul (Bangka), katidieng boruak (West Sumatra). Malaysia: akar periuk kera, periuk kera, akar cerek-cerek. Thailand: cho mokaeng, mokaeng khaang (Pattani), blaa-ngo-kue-ko (Malay-Pattani).
- *N. rafflesiana*: Indonesia: periuk kera (Lingga), ketakong menjang (Bangka).

Origin and geographic distribution *Nepenthes* is believed to have originated in the western Indian Ocean region and comprises about 87 species, mostly in Malesia (Malaysia, Singapore, Brunei, Indonesia, the Philippines, Papua New Guinea), with most species found in Borneo and Sumatra. It is not known from the Lesser Sunda Islands and the northern tip of Sumatra. Some outlying species occur in Madagascar, the Seychelles, Sri Lanka, India, Indo-China, the Solomon Islands, New Caledonia and Australia. *N. ampullaria* is distributed in Thailand, Peninsular Malaysia, Sumatra, Borneo and New Guinea. *N. rafflesiana* is found in Peninsular Malaysia, Sumatra and Borneo. It is one of the most abundant *Nepenthes* spp. in northern Borneo, abundant in the Riau Archipelago (Indonesia) and in

Singapore, but rare in mainland Sumatra and Peninsular Malaysia.

Uses Although the major use of *Nepenthes* is as an ornamental, the stems of several species are used as rough cordage. They are, for instance, used in the construction of longhouses in Borneo. On Bangka (Indonesia) *N. ampullaria* is a substitute for rattans and dried or peeled stems serve for tying, for instance in pepper gardens, fence-making and house construction, and for carrying heavy loads. In Riau and the Lingga Archipelago (Indonesia) it is also often used for tying. In Peninsular Malaysia the stems of *N. ampullaria* and *N. rafflesiana* are reportedly used for tying fences, though the use of the latter species for this purpose is questionable. On Belitung (Indonesia) baskets are made of the stems of *N. ampullaria* and *N. rafflesiana*. Larger pitchers are used to cook rice in, e.g. those of *N. ampullaria* in West Sumatra.

In Peninsular Malaysia the roots of *N. ampullaria* are boiled and made into a poultice to treat stomach-ache and dysentery, whereas stem decoctions or infusions are drunk for remittent fever. The fluid in unopened *Nepenthes* pitchers is potable and has been used for eye inflammation, indigestion and other stomach problems.

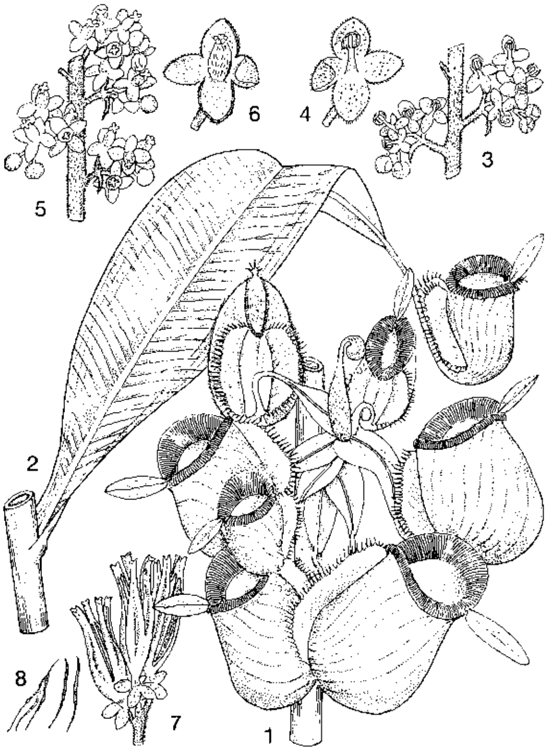
Production and international trade *N. ampullaria* and *N. rafflesiana* are used locally as fibre plants and no production statistics are available.

The main value of *Nepenthes* in international trade is as ornamentals, In the international horticultural trade on average about 1.2 million *Nepenthes* plants were traded annually in the period 1983–1987. The trade value has been estimated at more than US$ 15 million per year. Both *N. ampullaria* and *N. rafflesiana* are internationally traded as ornamentals.

Properties *Nepenthes* stems are resistant to moisture. Those of *N. ampullaria* are considered to be of very good quality because they are strong, supple and durable. Peeled *N. ampullaria* stems are said to be stronger and more durable than rattan.

Description Dioecious, woody or subwoody climbers or subshrubs, terrestrial or epiphytic. Young plants rosette-shaped, older plants always elongated, in climbing species often with elongated climbing stems, short non-climbing stems and with secondary, dense rosettes at the base of older stems. Stems terete, 2–4-angled or more or less winged as an effect of decurrent leaves. Leaves alternate, without stipules, petiolate or sessile, simple, papery or leathery, composed of a phyllodium-like blade, a tendril, a pitcher and a lid; blades of the rosettes always smaller than those of elongated and short stems, sometimes even absent; midrib extending into an unbranched tendril with an apex expanding into a variously coloured receptacle ('pitcher') containing digestive fluid; lower pitchers produced from rosettes or short stems, usually ovoid or globular, the mouth facing towards the stem, with 2 ventral fringed wings running from the base to the pitcher rim and with the tendril straight, not coiled; upper pitchers (not always present) usually more elongated and funnel-shaped, the mouth facing away from the stem, the wings absent or reduced to ridges and not fimbriate, and the tendril coiled; pitcher mouth apical or subapical, rimmed with a ribbed, often glossy red peristome, the inner edge often toothed and bearing nectar glands; lid usually held over the mouth when young, opening later, lower surface usually with a laterally flattened basal appendage; spur inserted on dorsal surface at junction with lid. Inflorescence a terminal, peduncled raceme or panicle; if a raceme then the pedicels 1-flowered or furcate and 2-flowered; if a panicle, then its lower branches corymbosely branched and 3–10-flowered, the upper ones fewer-flowered; male and female inflorescences quite similar, male ones usually larger and more floriferous; perianth imbricate, a single whorl of 4 free or basally united, patent, nectariferous, green, brown or red tepals; male flowers with 4–12 stamens, filaments united into a column (androphore), gynoecium lacking; female flowers without androecium, ovary superior, 4-locular with numerous ovules, stigmas 4, sessile. Fruit a fusiform, loculicidally dehiscent capsule with 4 valves. Seed filiform, 3–25 mm long, with long basal and apical appendages.

- *N. ampullaria*. A terrestrial climber up to 15 m tall, with many terrestrial and few aerial rosettes, with densely velvety indumentum of red-brown hairs in young parts. Stem cylindrical, 1–1.5 cm in diameter, internodes 1.5–8 cm long, at the foot of older plants lateral rosettes with pitchers are present. Leaves sessile; blade thickly leathery, lanceolate to spatulate, undersurface with red hairs; rosette leaves 2–5 cm × 0.5 cm, climbing leaves 12–25 cm × 3–6 cm; base attenuate, clasping the stem by half its circumference; lower pitchers obliquely urceolate, semicircular on dorsal side, almost flat ventrally, 2–10 cm × 9 cm, usually green, deeply flecked with maroon, rarely entirely red, sometimes whitish-yellow with pale pink flecks, with 2



Nepenthes ampullaria Jack – 1, part of stem with terrestrial rosette leaves with pitchers; 2, leaf with pitcher on climbing branch; 3, part of male inflorescence; 4, male flower; 5, part of female inflorescence; 6, female flower; 7, fruits; 8, seeds.

fringed wings up to 1.5 cm broad, fringe elements 0.5–1 cm long and 1–1.5 mm apart; mouth oval, almost horizontal; peristome flattened, 3–15 mm wide and sloping steeply inwards, ribs 0.2–0.3 mm apart; lid narrowly oblanceolate, up to 4 cm × 1.5 cm, lower surface without appendages, nectar glands sparse or absent; spur simple or branched, up to 1 cm long; upper pitchers generally not developed, rudimentary, broadly funnel-shaped, about 2 cm × 2 cm. Male inflorescence a panicle up to 40 cm × 4–5 cm; partial inflorescences usually 8–12 cm long and with 3–6 flowers; pedicel 7–8 mm long; tepals broadly elliptical, 4–5 mm × 3–5 mm, green to yellow; androphore 3–5 mm long. Female inflorescence and flowers about similar. Fruit 2–3 cm long, valves 2–3.5 mm wide in the middle. Seed 10–15 mm long.

- *N. rafflesiana*. A terrestrial climber 2–6(–15) m tall with white or grey arachnoid indumentum. Stem terete, those of short stems and rosettes 7–9 mm in diameter with internodes 0.5–1.5 cm long, when climbing 5–12 mm in diameter with internodes 4–17 cm long. Leaves papery, distinctly petiolate; petiole canaliculate, 4–17 cm long, in short stems sheathing; blade in short stems narrowly oblong, 12–45 cm × 3–11 cm, in climbing stems usually smaller, in both the lower surface with stellate hairs; lower pitchers ovoid to subglobose, 5–25 cm × 3–10 cm, white, mottled with purple-red, and with red sessile glands, with 2 fringed wings 1–3 cm wide, fringe elements 5–15 mm long and 1–4 mm apart; mouth strongly concave, rising gradually at the rear and tapering to a distinct column 3–5 cm high and 1–2 cm deep, inner surface bearing protruding teeth 3–5 mm long; peristome subcylindrical, 4–10 mm wide at the sides, ribs 0.7–1.5 mm apart, inner edge with conspicuous teeth 2–5 mm long; lid orbicular, ovate or elliptical, 4–9.5 cm × 3–7.5 cm, lower surface without appendages but with conspicuous glands; spur 8–30 mm × 1–2 mm, bifurcate at apex; upper pitchers funnel-shaped, 9–40 cm × 3–8 cm, pale green, without fringed wings but with 2 ridges, mouth at the rear with a short column 1–3 cm high; peristome cylindrical, 2–8 mm wide, striped yellow, green and red, ribs 0.5–1 mm apart, inner edge with 1–2 mm long teeth; lid ovate, elliptical or obovate, 3.5–9 cm × 3–7 cm, lower surface without appendages but with a dense band of nectar glands around the periphery; spur 8–26 mm long, entire. Male inflorescence 12–50 cm × 2–6 cm; pedicel 1–2 cm long, 1(–2)-flowered; tepals elliptical, 5–7 mm × 5 mm; androphore 4.5–6 mm long. Female inflorescence similar to male one but only a bit shorter. Fruit stipe 3–8 mm long, valves 16–50 mm × 5–10 mm. Seed 12–18 mm × 0.2–0.4 mm.

Growth and development *Nepenthes* seeds normally germinate 4–6 weeks after sowing. Initially the plants of most species have a short erect stem and short internodes ('rosette stems'), after which they become shrubby by producing stems up to 2 m long with longer internodes ('short stems'). These can become lianas with even longer internodes and with coiling tendrils supporting the stems ('climbing stems'). In some species, including *N. ampullaria*, the shrubby stage is negligibly short. Aerial branching of the stems is rare in *Nepenthes* but does occur in *N. ampullaria*.

The pitcher of *Nepenthes* functions as a trap for a wide range of invertebrates and sometimes vertebrates. *N. rajah* Hook.f., the species with the largest pitchers, even traps rats. The wall of the pitcher is thin but very strong. The upper third of the inner pitcher wall is called the 'waxy zone' and is covered with a dense coating of minute, easily detachable wax scales, which become attached to the suction pads or tarsi of prey, temporarily destroying their ability to grip any surface. The zone below the waxy zone is the 'glandular zone'. Prey is probably attracted by both the colour of the pitcher and the presence of nectar secreted by glands on the lower side of the pitcher lid, the inner edge of the peristome and the outer surface of the pitcher. The prey that falls into the fluid at the base of the pitcher is broken down by a combination of proteolytic enzymes secreted by the glands in the lower part of the pitcher and bacteria living in the pitcher fluid, and the products are absorbed by the same glands. Pitchers may also contain organisms which are able to live there without being killed and which may improve the trap function by breaking down trapped prey. Though ants are the main prey organisms, only a small fraction of the visiting ants are captured. Prey in the pitchers is an important source of nutrients for *Nepenthes*: studies of *N. rafflesiana* in its natural environment showed that plants deprived of prey for 18 weeks suffered from nutrient-stress and contained 78% less phosphorus and 67% less nitrogen in their leaves than control plants. The pitchers of *N. ampullaria* and some other *Nepenthes* may primarily function as devices for trapping water and litter.

Nepenthes is probably insect-pollinated, mostly during the day by generalist *Diptera* and *Hymenoptera*. The main visitors of *N. rafflesiana* flowers are day-flying chrysomelid beetles. Because *Nepenthes* is dioecious, it is outbreeding. Seed dispersion is probably by wind. In Singapore *N. ampullaria* and *N. rafflesiana* flower throughout the year, but fruiting is most abundant in April-June.

Other botanical information *Nepenthes* is usually considered the only genus in the *Nepenthaceae*, though some regard *N. pervillei* Blume from the Seychelles as forming a separate genus *Anurosperma* (Hook.f.) Hallier. Classification within the genus is very difficult, especially because of the heteromorphy of stems, leaf blades and pitchers. Within the genus 6 groups have been distinguished, but this division is not considered entirely satisfactory. The knowledge of most species is too limited to reliably distinguish infraspecific taxa.

All *Nepenthes* investigated to date have a chromosome number of $2n = 80$. It has been suggested that the basic number is low ($x = 5$, perhaps 10) and that all species in the genus have a high ploidy level ($16x$ or $8x$), though isozyme analysis has not supported this hypothesis. Interspecific hybridization is common in *Nepenthes*. *N. ×hookeriana* Lindl. is a naturally occurring hybrid between *N. ampullaria* and *N. rafflesiana*, whereas *N. ×trichocarpa* Miq. is probably a natural hybrid of *N. ampullaria* and *N. gracilis* Korth. Both hybrids occur in Sumatra, Peninsular Malaysia and Borneo, where they are widespread but scarce and only found near populations of the parent species.

The stems and roots of *N. alata* Blanco are chewed against toothache in the Philippines. The pitchers of *N. boschiana* Korth. have been used in Borneo for cooking in and as toys for children, whereas the water in unopened pitchers was considered a cure for eye-inflammation, but this species is only known by its type specimen. The boiled roots of *N. gracilis* are taken against dysentery and stomachache in Peninsular Malaysia, whereas in the Lingga Archipelago (Indonesia) extracts are taken in case of a sore mouth and a swollen tongue. In Java water from the pitchers of *N. gynamphora* Nees is drunk against cough. *N. distillatoria* R. Grah. is used for rough cordage in Sri Lanka.

Ecology *Nepenthes* is found in humid climates, mostly in exposed habitats on nutrient-poor soils. It is commonly found along river banks, ridge tops and in wet mossy forest. Usually it grows in locations with a sparse or thin canopy and it is not common in dense forest, though a few species, including *N. ampullaria*, can survive in quite dense shade. It is common on white podsolic soils, wet peaty soils or heavily leached volcanic soils, but is almost completely absent from rich alluvial or clay soils. In Malesia *Nepenthes* is mostly found up to 700 m altitude, in disturbed secondary forest, swamp or heath ('kerangas') forest, but in these habitats only a few species occur, including *N. ampullaria* and *N. rafflesiana*. More species but fewer individuals occur in montane habitats, at 1500–2500 m altitude, often in open mossy, stunted, ridge-top forest. A few species are found in montane or subalpine grassland, up to 3500 m altitude.

N. ampullaria grows in damp, shady forest, swamp and heath forests (Borneo), *Araucaria* forest (New Guinea), secondary forest, open microphyllous vegetation and swamp grassland, usually up to 200 m altitude, occasionally as high as 2100 m. *N. rafflesiana* occurs in swamp and heath forests, often with *N. ampullaria*, but also in secondary forest and old clearings, often on sand, at altitudes up to 300 m, sometimes up to 1500 m. It is often abundant in weedy regrowth along roadsides.

Propagation and planting *Nepenthes* can be propagated by layering, cuttings or seed. In the Botanic Garden in Bogor (Indonesia) *N. ampullaria* and *N. rafflesiana* cuttings have successfully been grown in water and moss media.

Husbandry *Nepenthes* is not cultivated as a fibre plant and stems for tying are collected only from the wild. It is, however, widely collected and grown as an ornamental. Ample moisture and high humidity are required for growing *Nepenthes*; good drainage is essential. Though *Nepenthes* plants absorb nutrients from prey in the pitchers, fertilization may be beneficial. Old plants benefit from heavy pruning.

Harvesting On Bangka the stems of *N. ampullaria* are cut near the ground. They are then pulled down and the top is removed.

Handling after harvest On Bangka (Indonesia) the harvested stems of *N. ampullaria* are cleaned by pulling them between two tree-trunks, cut, bundled and dried in full sun for 3–4 days, resulting in a change in colour from white to wine-red. Alternatively, the stems may be peeled and the central part used.

Genetic resources *N. ampullaria* and *N. rafflesiana* are not considered threatened, but several other *Nepenthes* spp. are endangered, especially those with a very limited distribution. The main threats are habitat destruction (especially for lowland species) and indiscriminate collection for horticultural trade (especially for montane species). *N. rajah* Hook.f. and *N. khasiana* Hook.f. are listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix I, which means that trade of wild material is prohibited and that of artificially propagated material is only allowed under licence. The rest of the genus is listed in Appendix II, which means international trade in wild and artificially propagated material is permitted subject to licence. In the Botanic Garden in Bogor (Indonesia) living collections of *N. ampullaria* and *N. rafflesiana* are kept in greenhouses.

Prospects The role of *Nepenthes* as a fibre plant will remain limited to local use. The real prospect lies in its use as ornamental plant. However, due to the very limited distribution of most *Nepenthes* species, care must be taken that collection does not lead to extinction.

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I.P. Astuti, Y. Umi Kalsom & R.M. Taha

Pandanus Parkinson

J. voy. South Seas: 46 (1773).

PANDANACEAE

$x = 30$; *P. furcatus*, *P. odoratissimus*: $2n = 60$

Major species and synonyms

- *Pandanus atrocarpus* Griffith, Not. pl. asiat. 3: 160 (1851), synonym: *P. caricosus* auct. non Sprengel.
- *Pandanus furcatus* Roxb., Hort. bengal.: 71 (1814), synonyms: *Rykia furcata* (Roxb.) De Vriese (1854), *Pandanus houlletii* Carr. (1868). Note: some authors consider *P. houlletii* to be a separate species.
- *Pandanus kaida* Kurz, J. As. soc. beng. 38(2):

148 (1869), synonyms: *P. siamensis* Williams (1904), *P. forceps* Martelli (1905).
- *Pandanus odoratissimus* L.f., Suppl. pl.: 64 (1782, excl. syn. *Keura* Forsskal), synonyms: *P. fascicularis* Lamk (1783), *P. sabotan* Blanco (1837), *P. tectorius* auct. non Parkinson.
- *Pandanus tectorius* Parkinson, J. voy. South Seas: 46 (1773) [ex Z. (J.P. du Roi), Der Naturforscher 4: 250 (1774)], synonyms: *P. bagea* Miquel (1855), *P. robinsonii* Merrill (1917), *P. veitchii* hort.

Vernacular names General: pandan, pandanus, screwpine (En).
- *P. atrocarpus*: Indonesia: mengkuang, bengkuang (Malay). Malaysia: mengkuang, bengkuang, pandan duri.
- *P. furcatus*: Indonesia: bengkuang (Malay), pandan kowang (Javanese), harashas (Sundanese). Malaysia: mengkuang hutan, pandan hutan. Thailand: kiang paa, kiang luang (northern), keng-luang.
- *P. kaida*: Malaysia: mengkuang. Thailand: toei (general), toei saan suea (Bangkok). Thailand: toei (general), toei saan suea (Bangkok). Vietnam: d[uwr]a (general), gi[uwr]a d[aj]i (Ha Son Binh).
- *P. odoratissimus*: Indonesia: pandan laut (Malay, Sundanese), pandan pasir (Javanese). Philippines: sabotan, sibutan (Tagalog), parauan (Gaddang). Cambodia: rumche:k (general). Laos: (do:k) ke:d (Louang Prabang). Thailand: kaaraket, toei thale, lam chiak (central). Vietnam: gi[uwr]a (d[uwr]a) d[aj]i (Ha Nam Ninh).
- *P. tectorius*: Indonesia: pandan pudak (general). Thailand: kaaraket, kaaraket daang, lam chiak nuu (Bangkok).

Origin and geographic distribution *Pandanus* contains about 700 species and is found from West Africa eastward through Madagascar, the Indian Ocean Islands, South and South-East Asia, southern China, Taiwan, Japan and Australia into the Pacific. Here it reaches its northern outpost in Hawaii, and its eastern and southern outposts in Pitcairn and Henderson Islands. Many endemic species exist. *Pandanus* is cultivated in other parts of the tropics and indoors in more temperate regions.

P. atrocarpus is common in Peninsular Malaysia, Singapore, Sumatra and Bangka. *P. furcatus* is found in India, Sri Lanka, Nepal, Burma (Myanmar), and in Peninsular Malaysia and Indonesia (Java, Sumatra) if *P. houlletii* is considered as a synonym. *P. kaida* probably originates from South-East Asia, or perhaps from India or Sri Lanka. It is not known for certain as a wild plant, but is widely cultivated from India and Sri Lanka to the eastern perimeter of continental Asia (Malaysia to China). *P. kaida* is often confused with *P. odoratissimus* or *P. tectorius*, but it is generally not found along beaches or even outside cultivation. *P. odoratissimus* is widely distributed on the Indo-Malaysian coasts from India and Sri Lanka throughout South-East Asia to Taiwan, the Ryukyu Islands and Micronesia. It is the predominant wild *Pandanus* of the sandy coasts in Malesia, but it is also often cultivated in the interior. *P. tectorius* is widespread in the Pacific Islands, particularly Polynesia and Melanesia, extending north to the Hawaiian Islands, and west to Australia, New Guinea, the Moluccas and the Philippines. In this vast area and elsewhere in the tropics, *P. tectorius* is also often cultivated. *P. tectorius* is closely related to *P. odoratissimus* and the two species may be regarded as Melanesian-Pacific-Australasian and West Malesian vicariants, respectively.

Uses *Pandanus* leaves, usually reduced to strips, are used for weaving a range of articles, from small handbags and containers to large floor mats or light interior wall panels. All long-leaved *Pandanus* spp. are potential sources of weaving material. The leaves also serve for thatching. The leaves, stems or prop roots may be retted to obtain fibres which are used for twine and ropes. Epidermal strips sometimes serve as substitutes for cigarette paper. Unfortunately it has been customary to ascribe the main littoral and cultivated *Pandanus* spp. to a single species, either *P. odoratissimus* or *P. tectorius* and it is often difficult to separate the recorded uses of these two species in literature sources. The leaves of *P. odoratissimus* and *P. tectorius* are made into hats, mats, sacks, cordage, baskets, umbrellas and other articles. In the Philippines 'sabotan fibre' from the leaves of *P. odoratissimus* is used for the manufacture of, for example, the strong and durable 'sabotan hats', high quality sleeping mats, hammocks, cushions, bags, slippers and picture frames. The leaves also serve for thatching. On Guam they have been used to make sails. Beaten prop roots are used as brushes for painting and whitewashing, and the roots serve for binding. The leaves are said to be good paper-making material. The large, very tough leaves of *P. atrocarpus* are used extensively in Peninsular Malaysia and Indonesia (Sumatra, Bangka) for the production of durable mats, including waterproof mats ('kajangs') to cover carts and boats. Cut into finer ribbons, they are made into hats. On Bangka the leaves have been used to make sails. *P. atrocarpus* also serves for thatching. *P. furcatus* is used for matting, for instance in Indonesia, Malaysia and Burma (Myanmar). Woven, untrimmed leaves have been made into covers for quivers in Malaysia. The leaves of *P. kaida* are woven into products such as mats, hats, baskets and sacks. In certain regions it is also used for the construction of houses.

Pandanus has a range of other uses. In India (mainly Orissa) and Sri Lanka the flavourings and perfumes 'kewda (keora) attar', 'kewda water' and 'kewda oil' ('rooh kewda') are prepared from the fragrant male inflorescences of *P. odoratissimus*. The most important use of kewda attar is in tobacco preparations, but it also serves to flavour betel, and to scent clothes, bouquets, lotions, cosmetics, soaps, hair oils and incense sticks. Kewda attar and kewda water are both used for flavouring food, sweets, syrups and soft drinks. Kewda oil is not produced in large quantities. In Indonesia the male inflorescences of *P. odoratissimus* are used to scent clothes, in the preparation of fragrant oils and in ceremonies. *P. tectorius* var. *laevis* Warb. is planted in Indonesia for its fragrant inflorescences, but the odour is less long-lasting than that of *P. odoratissimus*. In the Andaman and Nicobar Islands the leaves of *P. odoratissimus* are used as cigars and the inflorescences as a substitute for tobacco. *P. odoratissimus* and *P. tectorius* have edible seeds and the pulp is also consumed after the calcium oxalate has been removed by cooking. The soft and sweet edible fruits of *P. furcatus* taste like overripe pineapple. The young top leaves of *P. furcatus* are believed to be an antidote for poisoning and are used, after roasting over a fire, against cough, whereas the leaf sap is taken against diarrhoea and dysentery. In Papua New Guinea (New Ireland) the bark of *P. tectorius* is scraped into a wild ginger leaf, water is added, and the solution is squeezed into a cup and drunk to sedate mental patients. In Vietnam and Cambodia the roots of *P. odoratissimus* are considered diuretic. *P. odoratissimus* is used in living fences, coastal windbreaks and is planted for soil stabilization. The wood of *P. furcatus* is used in Burma (Myanmar) to make floats for fishing nets. Several *Pandanus* spp., especially cultivated forms of *P. tectorius*, are grown worldwide as ornamentals for their attractive yellow and green striped leaves, indoors in temperate regions and outdoors in the tropics.

Production and international trade In South-East Asia *Pandanus* spp. are usually household or village plants and not produced commercially, though products such as bags, hats and mats may enter the local economy, especially in the trade of tourist items. Woven products made of *P. odoratissimus* in the Philippines, however, cater to the export market. In the first half of the 20th Century large quantities of pandan hats (more than 11 million in 1925) were exported from Java. Because use is mainly local, it is hard to estimate present production.

On a monetary basis, the most important *Pandanus* products are kewda attar and kewda water. The demand has increased strongly since the early 1980s, due to the popularity of scented tobacco products. It is estimated that about 35 million inflorescences (about 3500 t), obtained from about 5000 ha of wild *P. odoratissimus* in Orissa (India), are processed annually to produce kewda attar and kewda water. Kewda oil is not produced on a commercial scale. The male inflorescences of *P. odoratissimus* are sold in markets in Java and Bali for high prices.

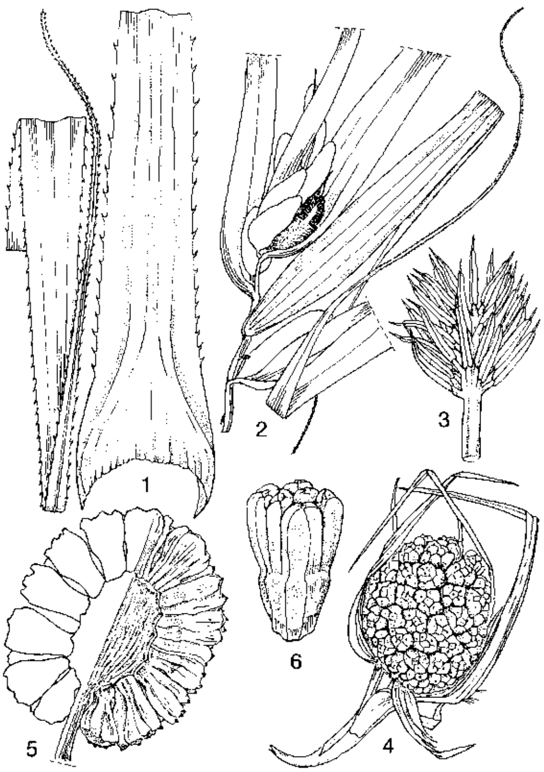
Properties The suitability of the *Pandanus* leaf for weaving is due to its anatomy: the veins run parallel along the length of the leaves, whereas the transverse, connecting veins are relatively weak. The strips get their strength mainly from the upper epidermis and the hypoderm below it. Material from *P. atrocarpus* is flexible and strong and can be distinguished from that of other *Pandanus* spp. by its light yellow colour. For the production of mats from *P. atrocarpus*, longer, older, but still green leaves are preferred, because the younger leaves are less supple. Material from *P. furcatus* is greenish and less supple but more durable than that of *P. atrocarpus*. In South-East Asia, particularly in Peninsular Malaysia, and probably also elsewhere in South-East Asia and in India and Sri Lanka, *P. kaida* is the preferred *Pandanus* species, because of its excellent fibre quality and utility. The leaves of *P. odoratissimus* are quite thick and stiff.

The characteristic aroma of kewda oil is due to 2-phenylethyl methyl ether, which is the major constituent (66–85%). Another major constituent is terpinen-4-ol (9–21%). The oil is considered to have stimulant and antispasmodic properties. Root extracts of *P. odoratissimus* have shown anti-oxidative activity. Pericarp flesh of *P. tectorius* contains per 100 g edible portion: water 80 g, protein 0.4 g, fat 0.3 g, carbohydrates 19 g, fibre 0.3 g.

Adulterations and substitutes *Cyperaceae* such as *Scirpodendron ghaeri* (Gaertn.) Merr. are used as lower-quality substitutes for *Pandanus*.

Description Dioecious, evergreen, often palm-like trees or shrubs with an erect to decumbent stem, usually with rigid prop roots descending from leaf axils (or scars when leaves have fallen). Stem often branched in a trichotomous or dichotomous pattern, often knobbly or prickly, with manifest leaf scars; bark thin, often green just below the epidermis. Leaves arranged in 3 spiral rows, usually amplexicaul, linear and undivided, usually M-shaped in cross-section, usually with prickles along the margins and the underside of the midrib, in some species leaf apex on the upper surface on each side of the midrib with a sharp fold which can be prickly (prickles present or absent on strict species basis), longitudinal parallel veins numerous, leaves often somewhat pale, sometimes very glaucous beneath, sometimes variegated with achlorophyllous bands (mutant forms often perpetuated as horticultural forms), some mutant forms with unarmed leaves. Male inflorescence bracteate, usually spicate, number of spikes usually more numerous than in female inflorescences and arranged in racemes, bracts mostly white to cream or yellow, sometimes orange to purplish; spikes consisting of perianthless, strictly unisexual flowers, each flower a cluster of stamens (staminal phalange), pollen mostly white to yellowish, often scented. Female inflorescence either a globose to cylindrical head (cephalium), or a spike of such heads, upper bracts early caducous; each head consisting of either a mass of unilocular and uniovulate carpels ripening as drupes or a mass of 2- to many-celled carpels (carpellate phalange) (the stone of each ripened carpel containing 2 to many seed chambers); style absent; stigmas always distinct on the apex of each carpel. Fruit a monodrupe or a syncarpous polydrupe resembling a pineapple, ripening to yellow, orange, red, or occasionally purplish-red, the exocarp of each carpel firm to fleshy, upper mesocarp often cavernose and containing a viscid fluid or gel, lower mesocarp always fibrous and fleshy, endocarp bony; in polydrupes the carpels (and endocarps) are fused from base to almost the apex or to about middle level of the upper mesocarp. Seed fusiform or obovoid, with thin and membranous seedcoat, containing endosperm, always retained within a thin to massive thick bony endocarp; germination within the fruit.

- *P. atrocarpus*. A massive, branched tree, stem 10–20 m × 15 cm, thorny. Leaves up to 6 m × 10–15 cm, keel and margin thorny. Male inflorescence 60 cm or longer; bracts white, lowest about 30 cm long; spikes 10–15 cm long, stamens free, filaments conical, very short, anthers much longer. Female inflorescence 90–120 cm long with woody, 3-angled peduncle 2.5 cm in diameter; heads 3–4, ovoid, 15 cm × 6 cm. Syncarp with drupes 2.5 cm long, free part conical angular, dark brown, stigma short conical-spiny, 3 mm long; mesocarp 3 mm wide, endocarp 1 cm long.
- *P. furcatus*. A very variable, usually unbranched tree, 4–12 m tall, trunk 15–17 cm in diameter with persistent leaf bases, usually with prop roots. Leaves 2–6 m × 4–14 cm, at base dark purplish-brown, margins and underside of midrib armed with sharp prickles; longitudinal veins conspicuous, particularly at underside. Male inflorescence pendulous, 50–120 cm long, spikes 15–20 cm long. Female inflorescence pendulous on an up to 80 cm long, bracteate peduncle; head solitary, cylindrical-trigonous, 23 cm × 12 cm; styles simple or forked (lower ones), 5–6 mm long. Syncarp 20–60 cm × 8–15 cm, yellow, fragrant, fleshy, with 29 drupes in a longitudinal row and 39 drupes around the circumference; carpels 2.5–5 cm long, 5–7-angular.
- *P. kaida*. A tree with an erect trunk 2–4 m tall, branched above with few short basal prop roots, but in cultivation usually shrub-like and kept short. Leaves 2–4 m × 6–9 cm, margins and underside midrib stoutly armed, apex long flagelliform, coriaceous, stiff, parallel veins 120–130. Male inflorescence a large raceme of spikes; each spike 8–11 cm × 3 cm, subtended by a white bract; spike composed of numerous, densely crowded, staminal phalanges 7–8 mm long, each one bearing an umbel of 12–25 white stamens. Female inflorescence with peduncle 40–50 cm long, bearing 1–3(–7) spicately arranged cephalia each one subtended by a bract; cephalia ellipsoid, up to 23 cm × 15 cm, composed of numerous, 1–4-celled carpellate phalanges; phalange 5–7-angled pyramidal, 45–50 mm × 10–20 mm; stigma 1–2 mm tall. Syncarp orange-red, individual carpels barely distinguishable; upper mesocarp 10–15 mm long, cavernose (as many chambers as carpels), lower mesocarp fibrous-fleshy, endocarp 12–15 mm long, bony, wall 1–2 mm thick, red-brown. Seed 8–10 mm long.
- *P. odoratissimus*. A coarsely branched tree, 12–14 m tall with open crown; trunk erect or more or less decumbent, up to 20 cm in diameter, grey, near the base with prop roots. Adult leaves usually 20–30 times longer than wide, up to 3 m × 9 cm, margins and dorsal midrib armed with usually forwardly directed, very sharp



Pandanus odoratissimus L.f. – 1, leaf; 2, male inflorescence; 3, staminate phalange; 4, fruit (cephalium); 5, schematic longitudinal section through fruit; 6, carpellate phalange.

prickles 5–10 mm long, apex gradually narrowed to an elongated flagella; youngest leaves erect, older ones drooping from the midpoint, glaucous, parallel veins 40–160 but not prominent. Male inflorescence 30–60 cm long, usually with 5–11 spikes 5–10 cm long; bracts less than 30 cm long; phalanges 10–15 mm long, bearing 19–26 stamens with filaments 0.5–2 mm and anthers 2–3.5 mm long with 0.5 mm long pointed apex. Female inflorescence usually with one single head on peduncle 10–30 cm long; bracts subfleshy, navicular with prickly midrib and margins; head globose to ellipsoid, 15–20(–30) cm × 12–18(–20) cm, containing (26–)50–70(–143) carpellate phalanges (and each cluster pentagonal or hexagonal); phalanges 3–8 cm × 2–5 cm, composed of 4–10 concentrically arranged, fused carpels; stigma U- or V-shaped. Syncarp drooping, orange-red, carpel clusters free from each other but tightly crowded, endocarp red-brown. Seed fusiform to obovoid, 10–12 mm long, with white, soft endosperm.

– *P. tectorius*. A pyramidal branched tree up to 8 m tall, with prickly prop roots up to 1 m long; trunk with brown to grey bark. Leaves 1–1.7 m × 6–8 cm, margins with backward directed prickles, apex gradually narrowed to an elongate flagella; midrib at underside also bearing similar prickles except in lower fifth; longitudinal veins 120–150 per leaf. Male inflorescence spicate with a raceme of about 6 spikes, each one subtended by a white, fragrant, navicular bract; spike cylindrical, 4–11 cm × 2 cm, composed of numerous staminal phalanges, each with a sterile base, upper part densely covered with about 18 stamens of which the basifixed anthers are longer than the filaments and end in a small point. Female inflorescence a solitary head, pendulous, subglobose-ellipsoid, obscurely trigonous, about 17 cm × 14 cm, composed of about 108 carpellate phalanges; phalanges 5 cm × 3–4 cm, 5–6-angled, 5–7-celled, apical 15 mm free. Syncarp with upper mesocarp of fruiting carpels cavernose-medullose-fibrous, about 12 mm long, lower mesocarp fibrous-fleshy, about 20 mm long; endocarp 2–3 mm thick, bony, red-brown.

Growth and development The natural propagation, dispersal, growth and development of many *Pandanus* species are not known. Growth of cuttings is often rapid, with establishment of a modest trunk (20–30 cm) and a rosette of large leaves in 3 years. Seed germination is often very slow. Seeds germinate within the bony endocarp with the seedlings exiting via the germination tube at the base of the drupe. Seedlings tend to produce erect trunks, while plants grown from cuttings may be permanently decumbent. Trees raised from cuttings bear fruits 2–3 years earlier than trees raised from seed. As a monocotyledon, *Pandanus* lacks secondary thickening-growth by means of a vascular cambium, but it is unusual because it is often branched. Flowering is very short (one day), and when depleted of pollen the inflorescence decays within 3–4 days. In general, male plants are rare and much smaller than female plants, and in sexual propagation pollination is mainly by wind but possibly also by small insects. In several species, e.g. *P. dubius* Sprengel, *P. furcatus*, *P. odoratissimus* and *P. tectorius*, female trees grown far from their native populations produce viable seed, which appear to be apomictic. *P. tectorius* is a facultative apomict, with asexual reproduction occurring in the absence of pollination. *P. kaida* plants in Peninsular Malaysia are apparently all staminate, though they seldom flower. *Pandanus* syncarps are usually dispersed by birds, mammals or water currents. In *P. odoratissimus* planted for kewda products in India, flowering of male plants starts 3–4 years after planting of cuttings or suckers. The inflorescences mature in about 2 weeks and a fully grown male tree produces 30–40 inflorescences per year. Syncarps of *P. odoratissimus* can be dispersed by currents because they are buoyant due to the drupes' fibrous mesocarp and the empty space around the seeds. However, germination is reduced by immersion in sea water.

P. tectorius develops according to Stone's model, characterized by continuous growth of the meristem of the orthotropic trunk, which produces orthotropic branches either continuously or diffusely, and with further branches developing sympodially below terminal inflorescences. Pollination in *P. tectorius* is by wind. The buoyant syncarps of *P. tectorius* are mainly dispersed by means of sea currents, but dispersal by crabs, birds and flying foxes has also been reported. *P. tectorius* displays a wide variety of fruit shapes and sizes. In swamp populations of *P. tectorius* in Fiji, plant ages were estimated on the basis of leaf production, stem and branch growth and the number and spacing of leaf and peduncle scars. The following growth and development patterns were deduced from these estimates: a semiprostrate juvenile phase of 4.5–9 years is followed by erect trunk growth for about 5–12 years and a flowering phase lasting 40 years or more. Male plants form about 30 branches and flower annually, whereas female plants form about 15 branches and flower biannually. Each syncarp has about 75 phalanges, each containing up to 8 embryos but the modal number is 2.

Other botanical information Together with *Freycinetia* Gaudich. and *Sararanga* Hemsley, *Pandanus* forms the palaeotropical plant family *Pandanaceae* which comprises 800–900 species. *Pandanus* is the largest genus and its infrageneric classification is still in progress. It has been tentatively divided into 8 subgenera, each of which with one or more sections. *P. tectorius* is the type species of the genus *Pandanus* and, together with *P. odoratissimus*, it is classified in subgenus *Pandanus*, section *Pandanus*; *P. atrocarpus* is placed in subgenus *Acrostigma*, section *Acrostigma*; *P. furcatus* is placed in subgenus *Rykia*, section *Rykia*; and *P. kaida* belongs to subgenus *Rykia*, section *Kaida*.

According to some taxonomists, *P. odoratissimus* is included in *P. tectorius* but here the view of B.C. Stone is followed that they are separate species. The two species probably hybridize where they meet. *P. odoratissimus* is rather variable and many varieties and forms have been distinguished. It is notable for its often very large leaf spines, which are generally white or very pale, whereas the leaf spines of *P. tectorius* tend to be fairly small and green. There seems to be, however, a mutant spineless form of *P. odoratissimus* which is very difficult to distinguish from the spineless *P. tectorius* var. *laevis*, and the two may be used in the same manner. *P. tectorius* is also highly variable and it seems better to consider it as a still unravelled complex. Numerous names have been used to describe the variability within the complex, which has resulted in numerous species names for local populations which have been selectively grown and developed into more or less distinct cultivars, varieties or forms. The best known of these in South-East Asia is *P. tectorius* var. *laevis* (synonyms: *P. inermis* Reinw., *P. laevis* Kunth, and *P. spurius* Miquel), known as 'pudak' or 'putat' and distinguished by its spineless leaves. Its leaves are somewhat more fragile and less durable than those of other cultivars and are employed for finer goods. Other cultivars of *P. tectorius* include the forms known in horticulture as '*P. baptistii*' (leaves unarmed and variegated), '*P. sanderi*' (leaves armed, yellow-striped), '*P. variegatus*' (leaves armed, variegated with white) and '*P. veitchii*' (leaves armed, white-striped). These four forms can probably be grouped under '*P. tectorius* var. *sanderi* hort'.

Other important South-East Asian *Pandanus* spp. include *P. brosimos* Merr. & Perry, *P. conoideus* Lamk and *P. leram* Jones ex Fontana, all three valued especially for their edible fruits or seeds, and *P. amaryllifolius* Roxb., the leaves of which are mainly used for food flavouring. In Burma (Myanmar) the dry drupes or phalanges of *P. scopula* Warb. are used as small brushes, after the exocarp has sloughed off or decayed, leaving the basal mesocarp fibres.

Ecology *P. atrocarpus* is found in edges of woods in lowland swamps, often together with *Pholidocarpus* Blume palms. *P. furcatus* is a forest species, occurring in humid, shaded sites. In India it can form dense impenetrable thickets; in Java it is locally abundant but scattered, from sea-level up to 1700 m altitude. *P. kaida* is cultivated in humid tropical regions, at low altitudes and in monsoon zones. *P. odoratissimus* and *P. tectorius* have similar ecological requirements. They are found on sandy beaches, in littoral thickets, on the edges of brackish marshes and mangroves and inland along watercourses at low altitudes. Rainfall should be high. They can grow on a wide range of soils, but heavy, poorly drained loams are not suitable.

Propagation and planting *Pandanus* is usually propagated vegetatively by sucker shoots (axillary branches detached as plantlets), stem segments or full-sized stems. Cleanly removed from the leaf axils, the sucker shoots can be planted straight away or rooted first in a sandy medium. Alternatively, stems with slightly developed prop roots are cut, the leaf crown trimmed but not cut off, and the cuttings inserted obliquely in the medium. *Pandanus* may also be propagated by seed, but seeds should be soaked for 24 hours before planting. Seedlings develop more rapidly from previously weathered drupes or syncarps, which suggests that removal of the exocarp and perhaps scarification of the outer endocarp may accelerate germination. Germination may take several months or even a year for some *Pandanus* spp. The recommended planting distance for *P. odoratissimus* in the Philippines is 2 m × 2 m, with suckers 40–45 cm tall planted out in holes 20–25 cm deep and 15–20 wide. However, *Pandanus* is seldom grown in regularly spaced stands, and domestic plantings tend to consist of a few plants intermixed with other species. A typical Malaysian homestead may have a dozen small plants of *P. amaryllifolius*, a few clumps of *P. kaida* Kurz, a single decorative plant of one of the variegated *Pandanus* forms, and if near the sea, some possibly wild or semi-wild clumps of *P. tectorius* or *P. odoratissimus*. In Java pandans are also planted in fields, in hedges around fields and homesteads, and along roads, usually at a spacing of 1–2.5 m. In the Philippines *Pandanus* is intercropped with coconut palms.

Husbandry In Indonesia some weeding may be done in the first year after planting *Pandanus*, but usually husbandry is minimal. In the Philippines it is recommended that plantations of *P. odoratissimus* be weeded every 3 months during the first year after planting and every 6 months during the second and third year, and that organic fertilizer be applied. It is also recommended that dead material be removed to prevent fire, and that old or unproductive trunks and branches be thinned or cut to promote the growth and development of axillary shoots.

Diseases and pests Few diseases and pests afflict *Pandanus* and these seem most evident amongst cultivated plants and least among wild ones. In *P. odoratissimus* in India a leaf blight caused by *Alternaria alternata* (synonym: *Alternaria tenuis*) has been recorded. The fungus covers large spots, which turn black, and perforations may appear, leading to premature defoliation and scanty flowering. A leaf blight caused by *Botryodiplodia theobromae* has also been recorded in India, the symptoms being yellowing of older leaves from the tip to the middle and the occurrence of coalescing yellow patches leading to leaf shedding.
Predation by large insects may lead to early leaf fall. Leaf miners do some damage, and occasionally large beetle larvae which consume the seed may be encountered in the endocarp chamber.

Harvesting In Tangerang (West Java) harvesting of *P. odoratissimus* and *P. tectorius* usually starts when plants are 2.5–3 years old, when the leaves are 0.75–1.5 m long. When the plants are about 10 years old, leaf production and quality decrease and they are usually replaced. In Tasikmalaya (West Java), however, trees reportedly remain in use for 60 years without loss of quality. In the Philippines leaf harvesting of *P. odoratissimus* starts at 3 years after planting. Here it is recommended that 8–10 leaves per branch per month be harvested and that good quality, middle-aged, uniformly light green leaves be selected. In India the male inflorescences of *P. odoratissimus* are simply plucked by breaking them off using a hook attached to a stick.

Yield No information exists on leaf or fibre yields of *Pandanus*. In India mature *P. odoratissimus* plants produce approximately 15–40 male inflorescences per plant per year. From 1000 inflorescences about 18 kg of kewda water is obtained, whereas about 100 000 inflorescences are needed to produce 1 kg of kewda oil, as the oil yield is only 0.03%.

Handling after harvest For the production of weaving material from *P. odoratissimus* and *P. tectorius* a leaf is usually cut, dried slightly, and the marginal spines, where present, are removed. The leaves are then split into two by removing the midrib, and the halves are cut into strips. These strips are then made supple by pulling them over a bamboo, or by rolling or beating. Then they may be soaked in water, after which they are bleached in the sun. They may be dyed, often with simple stains such as crystal violet, resulting in colourful and multicoloured articles. In Tangerang leaves intended for finer work are cut off and the spines and midrib are removed. A pile is made of 25–30 leaves which are subsequently cut to equal length and made into strips. Water is expressed from these strips by means of a piece of bamboo. The strips are bundled, boiled for about an hour, placed in, preferably running, water for about 12 hours and dried. Leaves intended for coarser work are usually not boiled, but only pounded and dried. In Tasikmalaya the spiny leaf margins are removed first and the leaf strips are split off, until only the midrib with some thick leaf material remains. The strips are boiled, placed in running water, and spread in the sun for drying and bleaching. For the preparation of 'sabotan fibre' from *P. odoratissimus* in the Philippines the spiny margins and midribs are removed, after which the leaves are divided into strips. This may be done with a device called a 'sizer', made of 6 or more sharp blades mounted on a wooden plane and spaced 0.5 cm apart. Excess water is removed by drawing the strips tightly around a piece of wood or by a device called a 'pounder', in which the strips are pressed between 2 wooden planes and gradually pulled through. After this the pounded strips should be air-dried for a day in a shaded place and bleached in the sun to produce a uniform white colour. The strips should not be sun-dried immediately after pounding, because this would result in discolouring. Finally the strips are sorted according to length and tied in bundles of 600–800 strips. To obtain weaving material from the leaves of *P. atrocarpus* on Bangka, the spines are removed by moving a sharp knife against the direction of the spines. After removing the tip, the leaves are made supple over a fire, pulled flat, folded, beaten and cut into strips of the desired width. These strips are tied together in bundles of 10, beaten, soaked, dried and trimmed, after which they are ready for weaving. Elsewhere, the leaves are simply dried in the sun before they are divided into strips. For the production of mats, the leaves of *P. atrocarpus* are dried over a low fire, placed in the sun for bleaching, and tacked together with split bamboo. Weaving material from the leaves of *P. furcatus* is prepared in the same way as that of *P. atrocarpus*.

Kewda attar is prepared from *P. odoratissimus* by distilling the ripe inflorescences for 4–5 hours. Prior to distillation, the bracts are removed from the fresh inflorescences. About 500–1000 inflorescences, each cut into 3–4 pieces, are put in a large copper still pot and water is added (60 l per 1000 inflorescences). The vapour is absorbed in sandalwood oil. Several grades are prepared depending on the number of inflorescences distilled per kg sandalwood oil, normally 1000–10 000, but sometimes up to 100 000. For cheaper grades, refined liquid paraffin ('white oil') is sometimes used instead of sandalwood oil. It is not only cheaper, but also absorbs more kewda aroma per inflorescence than sandalwood oil. However, the aroma retention is worse. Ripe, cream-coloured inflorescences give higher perfume yields of better quality than immature ones. Kewda water is obtained by simply distilling the inflorescences in water only. Kewda oil is very soluble in water and cannot be separated from the distillate by ordinary physical means. It may be prepared by extracting the flowers with a solvent, precipitating the fatty matter with alcohol and distilling the absolute under reduced pressure.

Genetic resources and breeding *Pandanaceae* are well known for their general endemism which is sometimes very narrow; thus many species are threatened with extinction. Habitat destruction and collection of fruits and leaves from the wild for economic exploitation endanger many *Pandanus* spp. Germplasm collection is needed. Plantations are recommended for economic exploitation of the most useful *Pandanus* spp. The only breeding activities carried out so far have been by local selection, which has led to the establishment of numerous local cultivars.

Prospects *Pandanus* spp. will remain primarily household or village plants with domestic and local barter value in Malesia, though a small cash market has developed for articles destined for sale to tourists. Ingenuity in discovering new uses for *Pandanus* fibres, fruits, seeds and flavourings could enhance their value. Their use as a windbreak and soil conservation plant in coastal regions may offer prospects. The prospects for *P. odoratissimus* as a source of kewda products in India are promising.

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M. Brink & P.C.M. Jansen

Phormium tenax J.R. Forster & G. Forster

Char. gen. plant.: 47, t. 24 (1776).

HEMEROCALLIDACEAE

$2n = 32$

Synonyms *Chlamydia tenacissima* Gaertn. (1788), *Phormium ramosum* Billb. (1833).

Vernacular names New Zealand flax, phormium (En). Lin de la Nouvelle Zélande (Fr). Harakeke (Maori).

Origin and geographic distribution *P. tenax* is indigenous to New Zealand and Norfolk Island. During the 19th Century it was introduced into many other countries, including Java where it is planted in gardens above 1200 m altitude. Today cultivars of *P. tenax* and the closely related *P. cookianum* Le Jolis are grown as ornamentals throughout the temperate regions of the world. Several countries other than New Zealand have grown *P. tenax* as a commercial fibre crop, including Argentina, Chile, Brazil, Japan, St Helena, the Azores, South Africa and Kenya. In some of these countries and in parts of the United Kingdom and Ireland it is now naturalized. In some areas of South Africa, the Hawaiian Islands, St Helena and the Azores, it has become a weed.

Uses In New Zealand *P. tenax* was a vital resource to early Maori. The leaves and extracted fibre were plaited and woven to make containers, cordage, nets, clothing, sandals and matting. The dry flower stalks were lashed together and used for temporary rafts. The copious nectar from the flowers was collected to serve as a sweetener. Some of these uses continue today, in particular the plaiting of baskets and mats, the making of a swinging skirt ('piupiu') worn in cultural ceremonies and dance, and the weaving of fine cloaks from hand-dressed fibre. Traditional techniques and patterns have been maintained by Maori weavers though *P. tenax* is also utilized in a variety of ways in contemporary arts and crafts. In the past fibre and tow from *P. tenax* were used commercially to make woolpacks, baler twine (used for tying up bales of hay), ropes, carpets, mats and carpet underfelt, as a binding in fibrous plaster, for padding in upholstery, and as insulation for hot-water cylinders.

Though *P. tenax* has many uses in traditional medicine, it is not so widely utilized today for such purposes. Most commonly, the rhizome was boiled and the liquid used as a purgative, an anthelmintic and for stomach disorders; the rhizome also was pulped to make a poultice; the gum found at the base of the leaf was used as an antiseptic for wounds, burns and taken internally for diarrhoea; and the dressed fibre was used as a bandage.

P. tenax is grown as a shelter belt and ornamental varieties are commonly planted in gardens. Leaves of coloured varieties are used by florists.

Production and international trade In New Zealand commercial production and export of hand-dressed *P. tenax* fibre began in the early 19th Century. By 1861 a machine had been developed which could mechanically strip the fibre and by the early 20th Century *P. tenax* was New Zealand's major export crop. After the First World War exports gradually declined and since 1942 production has only been for the domestic market. Government subsidies for *P. tenax* production, together with import restrictions on jute (*Corchorus* spp.) and other fibres, enabled about 15–20 mills to operate between 1950 and 1970, producing a total of 5000–6000 t of fibre per year. Government protection was removed during the 1970s and manufacturers replaced *P. tenax* fibre with cheaper synthetics and imports of sisal (*Agave sisalana*

Perrine) and jute. The last factory in operation closed in 1985. Today, there is a small cottage industry that uses *P. tenax* for paper making and a local market for woven crafts. There is both a domestic and international market in ornamental cultivars for gardens, and one producer exports the variously coloured leaves to florists all over the world.

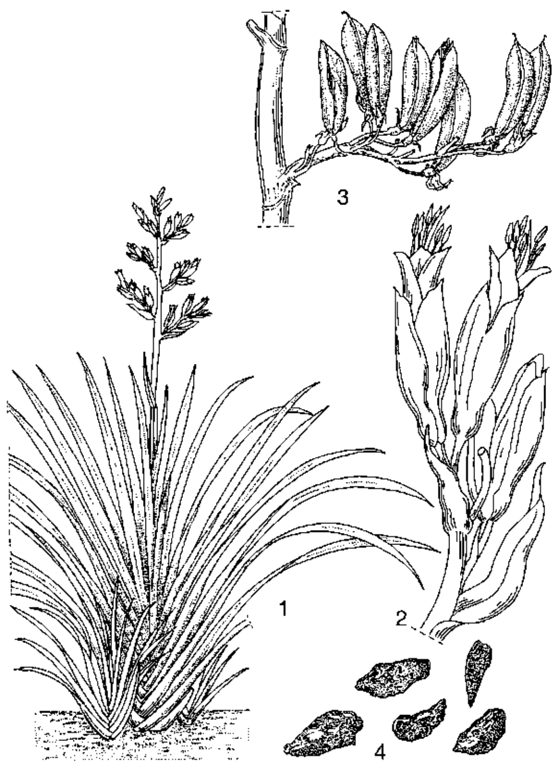
Fibre produced in St Helena and the Azores was exported to the United Kingdom, at least until the 1960s, whereas *P. tenax* grown in South America and Africa is used domestically. Recent statistics on *P. tenax* production or trade in these regions are not available.

Properties The properties of *P. tenax* fibre are somewhere between the hard fibres from sisal and abaca (*Musa textilis* Née) and the soft fibres from hemp (*Cannabis sativa* L.), jute and flax (*Linum usitatissimum* L.). *P. tenax* fibres are highly variable in dimensions and physical properties. Each fibre strand is a composite structure of ultimate fibres of uneven thickness. The ultimate fibre cells are (2–)5–10(–20) mm long and have a diameter of (5–)14–16(–25) μm. The fibre surface is smooth. In cross-section the ultimate fibres are round or oval and have a narrow lumen. The fibre (10% moisture) contains about 45% cellulose, 30% hemicelluloses, 11% lignin, 0.7% pectin, 2.2% water-solubles and 0.7% fat and wax. The colour of the extracted fibre ranges from white to pale reddish-brown. *P. tenax* fibre has a high tenacity combined with a low extension at break. When dry, the fibres have tenacities similar to those of textile grade synthetic fibres, but when wet they are weaker. A recent study of 11 traditional weaving cultivars of *P. tenax* showed marked differences between the content, strength and extension characteristics of their respective fibres. The fibre has been pulped using the soda process, with pulp yields of 60–70%, and the pulp is suitable for writing and wrapping paper and rayon.

The rhizome contains the purgative anthraquinones chrysophanol and emodin. Cucurbitacins with antibacterial and anticancer activity have been isolated from the leaves, and the antifungal compound musizin from the roots. The seed oil is rich in linoleic acid.

Adulterations and substitutes *P. tenax* can be replaced by sisal, abaca and jute, and is mixed with both jute and sisal in the production of sacks. The main competitor of *P. tenax* (apart from synthetic fibres) is sisal. *P. tenax* has some advantages over sisal: the leaves have a higher percentage of fibre, it is easier to grow and harvest and it can grow in regions where it is impossible to cultivate sisal. However, the fibre cannot be cleaned as efficiently using present technology, the cost of production is higher, and the fibre is less strong.

Description An evergreen perennial, stemless plant, 2–5 m tall, growing in tufts, with sword-shaped leaves that grow in the form of a fan from the ends of a fleshy, creeping and branched rhizome about 5 cm in diameter. Leaves more or less erect, 1–4 m × 5–12 cm, growing in two opposite rows, strongly keeled at base, lower third or half of the leaf closely folded across its midrib so that the upper surface of the leaf lies on the inner side of the fold, yellowish-green to blue-green (underside usually blue-green), sometimes bronze or variegated, with a narrow margin coloured in shades of orange, red, brown or black, marked by numerous fine, close, longitudinal striations and strengthened by tough bast fibres. Inflorescence a panicle, up to 5 m tall, growing from the centre of the fan; peduncle 2–3 cm in diameter, usually erect, dark, terete and glabrous, with a series of alternate, sheathing, deciduous bracts of progres-



Phormium tenax J.R. Forster & G. Forster – 1, habit flowering plant; 2, part of inflorescence; 3, part of infructescence; 4, seeds.

sively smaller size, the lower ones empty, the upper ones each subtending and entirely enclosing a comparatively short, alternately branched, flowering lateral; pedicel 8–10 mm long, articulated just below the flower; flower bisexual, tubular (tepals fused at base, otherwise partly connate), up to 5 cm long, usually dark red; tepals 6, in 2 whorls, the inner slightly longer than the outer one, tips of inner tepals slightly recurved; stamens 6, inserted at the bases of the tepals, longer than the tepals, filaments filiform, glabrous, slightly flattened, anthers inserted above their base; pistil with superior, sessile, cylindrical, 3-locular ovary with numerous ovules, style filiform, stigma small, capitate stigma. Fruit an erect, 3-sided prismatic capsule, 6–10 cm long, loculicidally 3-valved, abruptly narrowed at the apex, 60–150-seeded. Seed flattened-ellipsoid, more or less twisted, 9–10 mm × 4–5 mm, glossy-black.

Growth and development *P. tenax* seeds germinate in about a month. A seedling soon develops a fan of leaves which thicken at its base. Its initial taproot is replaced by numerous shallow roots, closely resembling the root system of the mature plant. Within a year a seedling can develop up to eight small fans, each about 30 cm in height. A fan of leaves may be seen as the unit of the plant. Young leaves arise continually from the centre of the fan, while the older leaves on the outside die away. Each fan usually has about 8 or 10 leaves, though they can have as many as 20 or 30. As the plant increases in age, the rhizomes branch freely, usually away from the centre, forming a ring of new fans around the original old rhizome. Plants take 6–8 years to flower. In New Zealand, flowers are produced in the early summer, between November and January, though the extent of flowering throughout populations fluctuates over a 2–4-year cycle. The nectar-filled protandrous flowers are bird pollinated and preferentially out-crossed. The stalk itself is heavy and full of sap, though later it dries, becoming extremely light. From late summer, the capsules split and spill their seeds, which are adapted for wind and water dispersal. Once an inflorescence has developed, the fan from which it has risen dies in about a year.

Other botanical information The taxonomic position of *Phormium* J.R. Forster & G. Forster has always been disputed, with it being classified variously in the *Liliaceae, Agavaceae* and *Phormiaceae*. At present the most accepted position is in *Hemerocallidaceae*, together with 12 other genera. *Phormium* comprises 2 species. The other species, *P. cookianum*, is also native to New Zealand. It has thinner, more flaccid leaves, yellowish flowers and longer, pendulous, twisted fruits, up to 20 cm long. *P. tenax* can hybridize with *P. cookianum* and such hybrids have given rise to numerous garden cultivars with coloured leaves. Maori also distinguish many cultivars of *P. tenax*, based on leaf and fibre qualities. Some of these named cultivars were used for breeding in the days of the flax industry.

Ecology *P. tenax* grows throughout New Zealand from sea-level to about 1200 m altitude. Mature bushes are frost-hardy, though they may not withstand prolonged temperatures below freezing. Cultivation is possible in warmer regions, like St Helena, with temperatures ranging from 13–29°C, but *P. tenax* is not suited to tropical lowland. It grows in areas with a relatively low (500 mm) to high (3500 mm) annual rainfall. It is found on a wide range of soils, but thrives on rich, well-drained soils. Before land clearance and drainage, it was found in abundance on moist alluvial soils near rivers and swamps.

Propagation and planting Propagation of *P. tenax* for small-scale plantations is done by rhizome division. Plantations of clones are ideal because they combine high quality and uniformity. A single, mature clump can provide many dozens of fans with attached rhizome. The youngest shoot is left unless it is longer than 1 m. Propagation by seed is also possible, but seedlings do not come true-to-type, even when the parents are of the same clone.

In the 1930s seedling propagation was used (along with vegetative methods) on a government-owned development plantation to increase the area under cultivation. Up to 5000 seedlings can be obtained from one inflorescence. On the development plantation the land was cleared of heavy growth, ploughed, planted with rye-grass and white clover, and grazed by sheep for 2 years. Planting was carried out in the spring, using a specially adapted tractor. Fans were planted every 1.5 m, with 2.5 m between the rows. Sheep continued to graze the land as the plants became established.

Nowadays *P. tenax* is no longer grown in New Zealand as a commercial fibre crop though many weavers and Maori villages have small plantings of cultivars for weaving purposes.

Husbandry Weed control in *P. tenax* is essential for the first 2 years after planting. Provided weeds are kept under control, little extra care is needed. Maori weavers cut the emerging inflorescences so that the plant's energy goes into the leaves rather than flowers, and trim the bushes of dead and diseased leaves.

Diseases and pests The most serious disease of *P. tenax*, and one which contributed to the decline of its industry in the 1920s, is yellow-leaf disease. It is characterized by abnormal yellowing and dying of the leaves and stunted new growth. Underground, the roots die off and rhizome tissues collapse. Eventually the whole plant may die. The disease is caused by a phytoplasma, which is transmitted by the plant hopper *Oliarus atkinsoni*. The phytoplasma has been named phormium yellow leaf (PYL) phytoplasma, but recently it has been proposed that it be included in the taxon '*Candidatus* Phytoplasma australiense'. Effective means of control are not available, though systemic insecticides may control the vector. Various fungal infections (spots and moulds) can affect the appearance of *P. tenax* leaves and in severe cases make fibre extraction impossible. Diseased leaves should be removed and burnt and it is important to ensure that plants have adequate air circulation.
The most serious pests for traditional weavers are the caterpillar of the windower moth (*Orthoclydon praefactata*) and the notcher (*Tmetolophota steropastis*). The former chews narrow strips from the underside of the leaf, exposing the fibre which soon decays. The latter eats large U- or V- shaped notches from the edge of the leaf, rendering that part of the leaf useless for plaiting or fibre extraction. The caterpillars are nocturnal and hide by day in debris at the base of the plant. The best control method is to keep the area free of dead leaf material. Insecticides can be used, though it is often difficult to penetrate the leaf bases thoroughly, and it is probably not practical on a large scale.

Harvesting When grown from divisions, the first harvest of *P. tenax* usually takes place when the plants are 4–6 years old. New Zealand weavers prefer to harvest after the plants have flowered, because it is easier to strip the fibre from the leaves at this time. The outer leaves of a fan are cut at an angle from the base of the outside leaf, leaving the growing shoot and the two blades on either side. Cut in this way, the fan is available for further harvesting within a year. In the industry days the plants were slashed with a semi-circular tool like a reaping hook, straight across the bush about 15–20 cm up from where the leaves go into the crown of the rootstock. This did not unduly weaken the plant, which was able to produce another crop in 3.5 to 4 years. Traditional weavers are able to use less mature leaves than the miller, whose machines required leaves with good body and strength.

Yield On commercial *P. tenax* plantations, it took 8–10 t of green leaves to produce 1 t of fibre, depending on the variety. Using traditional techniques, the yield is much less, because comparatively little of the leaf is used. A well-established plantation yielded 75–100 t leaves/ha/harvest.

Handling after harvest The method of separating the fibres from the leaves of *P. tenax* is a central factor in the quality of the product. When hand-dressed using traditional techniques, the fibre is stripped from the upper surface of the leaf only, and scraped clean from surrounding tissue. The resulting product is much finer and softer than that extracted by machine. Machines, however, used the whole leaf and butt and could process much greater quantities of leaf material rapidly. The technology used to process *P. tenax* in New Zealand until most production ceased in the 1970s had changed little since the early days of the industry. Bundles of leaves were carried to the stripping mill by light railway or truck and graded into lengths. Fibre was extracted using a Booth-Macdonald stripping machine or decorticator and carried into a washing machine. Extraneous matter was washed away, and the fibre formed into hanks and hung on rails to drain. When nearly dry, the hanks were spread out on the ground or fences to bleach. The fibre was then fed through a scutching machine, whose revolving beaters removed the remaining dry matter and short or rough fibres. Fibre was made up into hanks, pressed into bales and graded according to its cleanliness, colour and strength.

Genetic resources *P. tenax* is common in New Zealand, although many of the large natural stands have been converted into farmland. Individual weavers grow traditional weaving cultivars, as they have done for generations. Landcare Research, a government-owned research institute in Lincoln, New Zealand, maintains a living collection of both traditional named weaving selections and cultivars bred for commercial use.

Breeding In New Zealand no breeding programmes for *P. tenax* suitable for fibre exist anymore. Horticulturists breed *P. tenax* for garden and landscaping use, selecting for size, form and leaf colour.

Prospects There are no immediate prospects for the re-establishment of a *P. tenax* fibre industry in New Zealand. It is unlikely that a commercial fibre industry could be established unless a method is developed to extract the fibre in a way that ensures a quality matching that of hand-dressed fibre. However, the local use of *P. tenax* as a medium in arts and crafts, both traditional and contemporary, is strong and continues to grow. In experimental plantings in the Cameron highlands in Malaysia in the 1950s *P. tenax* grew very well and good quality fibre was prepared from sample leaves. At the time, it was considered a useful crop for valley bottom highland soils too wet for tea (*Camellia sinensis* (L.) Kuntze). However, with other fibre plants more suited to a tropical climate and producing earlier than 4 years after planting, there seems little benefit in considering *P. tenax* as a fibre crop for South-East Asia.

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S. Scheele

Phragmites vallatoria (Pluk. ex L.) J.F. Veldkamp

Blumea 37: 233 (1992).

GRAMINEAE

$2n = 36, 38, 48$

Synonyms *Arundo vallatoria* Pluk. ex L. (1754), *A. karka* Retz. (1786), *Phragmites karka* (Retz.) Steudel (1840).

Vernacular names Reed (En). Roseau (Fr). Indonesia: perumpung (general), bayongbong (Sundanese), glagah asu (Javanese). Malaysia: tebuh salah, terupuk (Dusun). Papua New Guinea: tik-tik (Pidgin). Philippines: tambo (Tagalog, Bisaya, Bikol), tanubung (Bontoc), lupi (Bikol). Burma (Myanmar): kyu-phyu. Thailand: yaa khaem (Prachin Buri), yaa lang po (Trang). Vietnam: s[aaj]y n[us]i.

Origin and geographic distribution *P. vallatoria* has a very wide distribution and occurs in wetlands throughout the Old World tropics, from Senegal to Eritrea and Madagascar, and from Yemen through South and South-East Asia to the Philippines and Japan. It is also widespread in northern Australia, Papua New Guinea and Polynesia. *P. vallatoria* is sometimes considered a weed, e.g. in lakes in West Java and in irrigation tanks in Thailand.

Uses The culms of *P. vallatoria* are used as thatch and are made into wickerwork, for instance in Indonesia, the Philippines and Vietnam. In the Philippines and Indo-China bundled culms with panicles serve as brooms. The best grade brooms are made of culms with very young panicles. In the Philippines the culms are also used for whistles used during periods of mourning, and for making children's toys. In the Philippines leaves of *P. vallatoria* are used as fertilizer for ponds. In Asia and Africa young shoots are eaten, mainly in times of famine. Young shoots also make good fodder. *P. vallatoria* is planted in cleaning basins to treat mainly domestic waste water. It can be used for soil stabilization. In Assam (India) culm sections are worn in the ears of women and short sections are dyed violet and yellow and strung as beads.

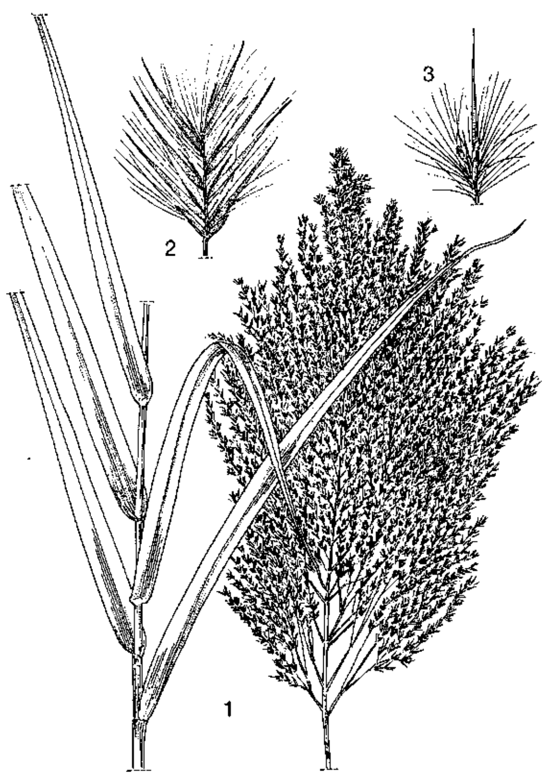
Production and international trade No production statistics for *P. vallatoria* exist. It is not traded internationally.

Properties Oven-dry reed (culm with inflorescences) of *P. vallatoria* contains about 55% cellulose (Cross and Bevan method), 27% lignin and 3% ash. Pulps suitable for writing and printing paper can be obtained from the reed with the soda or sulphate process, with a bleached pulp yield of about 40%. The fibres in the pulp are (0.5–)1.2 (–3.2) mm long and (6.6–)11.6(–19.8) μm wide. Because of the shortness of the fibres *P. vallatoria* pulps have to be mixed with long-fibre pulps to be used in commercial paper machines.

Pilot projects in Indonesia (Bandung) and India have shown that constructed wetlands planted with *P. vallatoria* are highly efficient in treating household sewage under tropical conditions. Under laboratory conditions it has been shown to absorb chromium efficiently from tannery effluents and sludge.

Adulterations and substitutes In the Philippines *Phragmites* brooms may be replaced by brooms made of *Thysanolaena latifolia* (Roxb. ex Hornem.) Honda (synonym: *Thysanolaena maxima* (Roxb.) Kuntze), which are more durable and expensive.

Description A robust, erect, strongly tufted, perennial grass (reed) up to 8 m tall, often with an extensive, creeping, branching rhizome or stolon up to 20 m long. Culm 2–8 m tall and 1.5 cm in diameter, very stout, often woody and bamboo-like with hollow internodes and glabrous nodes. Leaves sheathed on flowering culm; sheath glabrous or sparsely hairy and ciliate at the top; ligule very short, represented by a narrow, minutely ciliate rim; blade linear, 20–80 cm × 1–4 cm, base broad, margin smooth or rough, apex stiff and tapering-acute, glabrous above, scabrid beneath towards the apex, usually with 2–3 shallow depressions caused by pressure of mouths of older sheaths. Inflorescence a loose panicle, 20–75 cm long with a rather robust central axis and repeatedly branched, thin, rough, erect or nodding branches which are crowded in groups; pedicel 2–10 mm long; spikelets 3–7-flowered, 10–12 mm long, rachilla with numerous, thin, white-silvery hairs 4–8 mm long; lowermost floret sterile or male and persistent, succeeding florets bisexual and disarticulating below each fertile floret; glume boat-shaped, ovate-lanceolate, 3–4.5 mm long, 3(–5)-veined, acute, awnless, upper glume larger than lower one; lemma narrowly elliptic, 7–12 mm long; palea 2.5–3 mm long, scabrid on the veins; stamens 2 or 3; pistil with stipitate ovary, 2 styles with plumose stigmas exserted laterally near the base of the spikelet. Fruit a caryopsis, crowned by the stylar base.



Phragmites vallatoria (Pluk. ex L.) J.F. Veldkamp – 1, habit of leafy culm and inflorescence; 2, spikelet; 3, floret.

Growth and development The leaves of *P. vallatoria* have movable sheaths so that all leaves turn leeward in the wind. In Java *P. vallatoria* flowers throughout the year. It spreads by its creeping rhizomes (underground) or stolons (aboveground). In natural stands in Rajasthan (India) the standing aboveground dry biomass was 4.2–6.7 kg/m^2, and the underground biomass 0.8–1.2 kg/m^2.

Other botanical information *Phragmites* Adans. comprises 3 or 4 species of aquatic or semi-aquatic reeds which are distributed worldwide. They are all extremely closely related and can only be distinguished by minor, disputable characteristics. *P. vallatoria* is most similar to, and has often been confused with, *P. australis* (Cav.) Trin. ex Steudel (synonyms: *Phragmites communis* Trin., *Phragmites vulgaris* (Lamk) Crépin), which mostly occurs in temperate regions. *P. vallatoria* can be distinguished by its rough stiff-pointed leaves, its spikelets with an acute upper glume, and rather shorter and less dense rachilla hairs. In the literature *P. vallatoria* is better known by its synonym *P. karka*. Because of the similarity of *P. australis* and *P. vallatoria*, information on individual species cannot be trusted absolutely.

Ecology *P. vallatoria* is found in tropical and subtropical regions in marshy or seasonally flooded soils and moist locations, such as river banks. It occurs in fresh and brackish water. In Indonesia it occurs from sea-level up to 1700(–2200) m altitude. In shallow fresh water it is often the dominant species growing in association with *Alternanthera* spp., *Colocasia* spp., *Hydrilla verticillata* (L.f) Royle and *Nymphaea* spp., and with floating plants such as *Eichhornia crassipes* (Martius) Solms, *Salvinia molesta* D.S. Mitchell, *S. natans* (L.) All. and *Pistia stratiotes* L. In shallow waters

P. vallatoria can form extensive masses of vegetation which are important feeding and breeding grounds for fish. However, tree seeds from the surrounding forest may germinate in these reed masses leading to progressive expansion of the forest into the wetland. *P. vallatoria* plays an important role in the rehabilitation of tin tailings in Malaysia. Part of these tailings consist of former 'slime retention areas' and are characterized by very heavy clay soils. The first vegetation, in which *Nelumbo* and *Typha* spp. dominate, is followed by a shrub stage which is initiated by the establishment of *P. vallatoria*. *Cyclosorus*, *Emilia*, *Lycopodium*, *Nephrolepis* and *Pteris* spp. complement this community. If there are repeated deposits of fresh slime, all species except *P. vallatoria* are buried and the succession starts again. If undisturbed the *P. vallatoria* community gradually gives way to forest, initially characterized by *Bridelia*, *Ficus*, *Muntingia* and *Psidium* spp. *P. vallatoria* may become a weed in irrigation systems and rice fields.

Propagation and planting *P. vallatoria* can be propagated by division and by seed. A procedure has been developed for the large-scale micropropagation of *P. vallatoria* from axillary buds, with buds from the lower and middle culm giving better results than those from the upper third. Multiple shoot formation and root initiation occurred on Murashige and Skoog (MS) basal medium supplemented with 0.5 mg/l benzyladenine (BA), 0.5 mg/l kinetin and 2% sucrose. Shoots and roots elongated after transfer to half-strength MS basal medium with 2% sucrose but without any plant growth regulators. About 10 000 plants were produced from 3 buds within 9 months.

Husbandry *P. vallatoria* tolerates some grazing, but under heavy grazing it is replaced by less palatable species.

Yield No information is available on the yield of *P. vallatoria* in South-East Asia. A uniform stand of *P. vallatoria* in a constructed wetland system for wastewater treatment in central India produced about 12 kg/m^2 dry biomass within 1 year, of which about 11 kg/m^2 was aboveground.

Handling after harvest The culms of *P. vallatoria* may be split before being used for thatching. In Kudus (Java) the culms are flattened with a hammer, halved, dried and scraped before being used for very coarse wickerwork. In the Philippines brooms are made by tightly binding the culms to a central piece of bamboo or wood about 2 cm in diameter, with the panicles arranged in a fan-like manner.

Genetic resources A few germplasm accessions of *P. vallatoria* are included in collections of *Saccharum* L. in India.

Prospects Where large natural stands exist, *P. vallatoria* will probably remain a source of thatch and material for wickerwork. It is likely that it will become more important in the biological treatment of sewage and industrial effluents.

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L.P.A. Oyen

Raphia P. Beauv.

Fl. Oware 1: 75, t. 44–46 (1806).

PALMAE (ARECACEAE)

n = 14, 16; *R. farinifera*: $2n$ = 32; *R. hookeri*, *R. vinifera*: $2n$ = 28

Major species and synonyms

- *Raphia farinifera* (Gaertn.) Hylander, Lustgården 31–32: 88 (1952), synonyms: *R. pedunculata* P. Beauv. (1806), *R. ruffia* (Jacq.) Mart. (1838), *R. kirkii* Engl. ex Becc. (1910).
- *Raphia hookeri* G. Mann & H. Wendl., Trans. Linn. Soc. 24: 438 (1864), synonyms: *R. gigantea* A. Chev. (1932), *R. sassandrensis* A. Chev. (1932).
- *Raphia vinifera* P. Beauv., Fl. Oware 1: 77 (1806), synonym: *R. diasticha* Burret (1942).

Vernacular names General: raphia palm (En). Raphia (Fr).
- *R. farinifera*: Madagascar raphia palm, Bamenda raphia (En).
- *R. hookeri*: wine palm, Ivory Coast raphia palm, giant raphia palm (En).
- *R. vinifera*: bamboo palm, king bamboo palm (En). Palmier bambou (Fr).

Origin and geographic distribution *Raphia* comprises about 28 species, mostly African ones, with 1 species (*R. taedigera* Mart.) occurring in tropical America. *R. farinifera* is distributed throughout Central and East Africa and in Madagascar, where it is probably introduced, and has naturalized in the Lesser Antilles. In Africa it is also cultivated (Nigeria, Madagascar) and semi-cultivated. Outside Africa it is grown in India, Singapore and (rarely) in Java. *R. hookeri* is found from Gambia through the forest zone of West Africa to Cameroon, Gabon and Congo and possibly to Angola. It is occasionally cultivated or semi-cultivated. Outside Africa it is grown in India, Peninsular Malaysia and Singapore. *R. vinifera* occurs from Benin to Congo. It is grown in Nigeria, Cameroon, India and Singapore and possibly in Java.

Uses No information is available on the extent to which raphia palms are presently used in South-East Asia, but elsewhere they have a wide range of applications, which could be potentially considered for South-East Asia. Two valuable types of fibre are obtained from raphia palms: 'raffia' and 'piassava' (or 'bass'). The soft but strong raffia fibre is obtained by pulling off ribbon-like strips from the upper surface of the leaflets of young, unfolding leaves of *R. farinifera*, *R. hookeri* and *R. vinifera*. Raffia fibre is used in Africa to make articles such as mats, hats, baskets, bags, ropes, belts, hammocks, curtains and ceremonial costumes. It may also be woven into cloth. In Europe it is used as tying material in horticulture and for handicrafts. The strong piassava fibre ('African piassava' or 'African bass') is obtained from the vascular bundles of the petiole and leaf sheath, mainly from *R. hookeri*. It is used locally in Africa to make weather-resistant coarse ropes, belts for climbing oil palms, brushes, fish-traps, hats, baskets and screens. In Europe it serves for the production of brooms and brushes. Piassava fibre can be processed into exceptionally strong paper and other stem and leaf fibres are also considered potential sources of pulp and paper.

Raphia leaves, often split lengthwise, are used for thatching in Africa. They are also made into mats, baskets and other articles of wickerwork, and hut-walls and fences. Split midribs of *R. vinifera* are woven into floor-mats. The midribs and petioles of *Raphia* leaves ('raffia bamboo' or 'bamboo') are used for poles, rafters, ladders, furniture and cross-bearers in canoes. Split lengthwise they are made into screens. The trunks are applied in house construction.

Sap tapped from the stems of *R. farinifera* and *R. hookeri* ferments rapidly into palm wine. *R. vinifera* is not much used for this purpose, because its taste is not appreciated. The wine is distilled into a strong alcoholic liquor and can also be used as bakers' yeast. Oil is extracted from the boiled mesocarp pulp and the kernels of various raphia palms and utilized for food ('raphia butter') and non-food purposes (soap, stearin, fuel, lubricant, pomade). *Raphia* fruits are eaten boiled, and seeds are consumed boiled or roasted. The raw fruit of *R. hookeri* is poisonous and in crushed form it is used as fish-poison. The mesocarp of the fruit of *R. hookeri* is used in traditional medicine for its laxative and stomachic properties and as a liniment for pains. The terminal bud of all raphia palms is eaten as palm cabbage. Raphia wax is obtained from the lower surface of the leaves and serves as polish for floors and boats and for making candles.

Production and international trade Most of the raffia entering the international market is produced in Madagascar from *R. farinifera*. The main importing countries are the United States, France, Germany, Hong Kong and the United Kingdom. Recent production and trade statistics are not available. The main piassava-yielding raphia palm is *R. hookeri*. Its piassava has been exported from West Africa to temperate countries (mainly Europe) for the production of brooms and brushes since the end of the 19th Century, when the supply of South-American piassava from *Attalea funifera* Mart. ('Bahia piassava' or 'Bahia bass') and *Leopoldinia piassaba* Wallace ('Para piassava' or 'Monkey bass'), used in Europe for brooms since the middle of the 19th Century, could no longer meet demand. The trade reached its peak in the 1950s and 1960s, after which it declined following the advent of plastic brooms. The quality of African piassava for broom-making is such that it still enters the international market. The main types of African piassava fibre in trade are 'Sherbro', 'Sulima' and 'Calabar'. Sherbro and Sulima are obtained from the petiole, the former from *R. hookeri* and the latter from *R. palma-pinus* (Gaertn.) Hutch. (synonyms: *R. gaertneri* Becc., *R. gracilis* Becc.), often with an admixture of *R. hookeri* fibres, whereas Calabar is extracted from the leaf sheath of *R. hookeri*. The leaf sheaths of *R. palma-pinus* are rather short and do not yield high-quality fibre.

Properties Raffia fibre is well suited to horticultural purposes, because it is supple and durable and it does not have sharp edges which might damage tender plant parts. It is easily dyed, making it suitable for the production of fancy articles. *R. hookeri* yields high-quality raffia with a high tenacity. This is due to the hypodermic layer of the leaflets of *R. hookeri* consisting of thick fibres which are arranged in a continuous ribbon-like layer. In *R. vinifera* and *R. sudanica* A. Chev. the fibres are not arranged in a ribbon-like layer, but discontinuously, which accounts for the lesser tenacity of their raffia fibre.

Piassava fibre is water resistant, hard-wearing, and has the right balance between stiffness and elasticity to give a firm stroke to a broom and sufficient spring action to make the broom self-cleaning. The best piassava fibre is cylindrical with a firm wall and soft core and a diameter of 1–1.5 mm. It is obtained from the sides ('wings') of the petiole, whereas fibre from the upper and lower surface is of only reasonable quality. Fibres near the central flattened ridge are woody and brittle. The central core of the petiole gives a soft fibre ('straw' or 'piassava tow') which may be used as adulterant or as a substitute for coir. The best quality Calabar fibre is obtained from the sides of the leaf sheath, i.e. not near the suture and not near the midrib. Fibre obtained from the midrib of the leaf sheath is softer and more pliable making it suitable for plaiting ropes. Calabar piassava is stiffer than Sherbro and Sulima and tends to be black, whereas Sherbro and Sulima are pale at harvest, but turn darker during retting. Mature leaves yield higher quality piassava fibre than young leaves.

Both the stem and petiole of *R. hookeri* are suitable as raw material for the paper industry. Stem fibres are mostly thick walled and on average 2.4 mm long and (17–)30(–46) μm wide. The fibres of the petioles are on average 1.7 mm long and (10–)18(–27 μm) wide. Many fibres have scalloped walls. The pitted vessel elements of the stem are few in number but very large, up to 5 mm long and 350 μm wide, whereas those of the petioles are generally smaller. Pulp from *R. hookeri* also contains rounded, thick-walled parenchyma cells and spherical silica bodies. Dry stems contain about 74% fibre, 25% parenchyma, and 1% vessel elements.

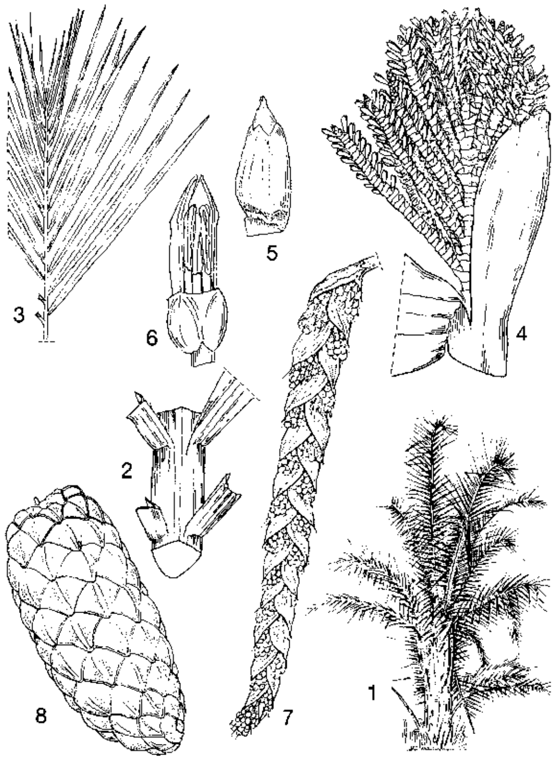
Palm wine obtained from *R. hookeri* is attractively milky-white in colour, but is weaker and less popular than that from oil palm (*Elaeis guineensis* Jacq.). The fresh sap tastes like ginger beer. The alcohol content of the palm wine increases from less than 2% to about 5% during the first 8 days of tapping, remaining constant thereafter.

The major fatty acids in mesocarp oil and seed oil of raphia palms are palmitic acid, oleic acid and linoleic acid. Raphia oil resembles that of oil palm in colour, taste, odour and chemical composition, except that it contains more linoleic acid, giving it a higher unsaturated acid content. The raw fruit of *R. hookeri* contains toxic and anti-nutritional factors, such as hydrocyanic acid, tannins, oxalates and phytic acid, but cooking reduces the level of these. In bioassays the aqueous and butanol fractions of the methanolic extract of *R. hookeri* mesocarp showed cytotoxicity against brine shrimp, and the butanol fraction also against mosquito larvae and 5-day old tadpoles.

Adulterations and substitutes In South-East Asia *Corypha utan* Lamk plays a role very similar to that of *Raphia* in Africa, yielding various types of fibres (including petiole fibre and a kind of raffia fibre from the leaflets), thatch and palm wine. Other palms, such as *Borassus flabellifer* L. and *Nypa fruticans* Wurmb, also yield material for weaving, thatch and palm wine in South-East Asia. In the market of raw material for brooms and brushes, *Raphia* competes with *Attalea funifera* and *Leopoldinia piassaba* and with synthetic material.

Description Solitary or clustered, armed, monoecious, acaulescent or erect palms. Stem subterranean to erect, massive, internodes short and often with spine-like roots, usually partly obscured by the long persistent leaf bases. Leaves large, sheathing, reduplicately pinnate, withering before being shed; sheath unarmed, splitting opposite the petiole, with or without a conspicuous ligule, disintegrating into thin sheets or sometimes partly into black fibres that clothe the stem; petiole short to very long, unarmed, usually deeply channelled adaxially only at the base, rounded distally; rachis unarmed, angled adaxially, rounded abaxially; leaflets numerous, linear, single fold, regularly arranged or grouped and fanned within the groups to give the leaf a plumose appearance, often whitish-waxy beneath, armed with short spines along the margins and the midrib. Inflorescence produced simultaneously in the axils of the most distal few leaves, either interfoliar and pendulous, or aggregated into a massive, erect, suprafoliar, compound inflorescence; peduncle short; first bract (prophyll) tubular, 2-keeled, closely sheathing to inflated; peduncular bracts several, about 6, inflated basally with triangular limbs; rachis much longer than the peduncle, repeatedly branched, each first order branch with faintly 4-ranked bracts each with an axillary rachilla; rachilla with distichous, tubular bracts each one subtending a unisexual flower, upper part of the rachilla bearing male flowers, basal part bearing female flowers; male flower with tubular 3-lobed calyx, a tubular corolla with 3 free petal lobes, stamens 6–20 or more, usually partly connate by the fleshy filaments, small pistillode sometimes present; female flower with calyx and corolla as in male one, usually a staminodial ring with sterile anthers, a pistil with 3 free or connate terminal stigmas, a 3-loculed-ovary covered with vertical rows of reflexed fimbriate scales. Fruit usually a 1-seeded drupe or berry, tipped with the stigmatic remains and covered with the enlarged scales arranged in vertical rows, each normally with a depressed vertical central line; mesocarp thick, oily; wall of endocarp spongy. Seed with a thick, dry testa and endosperm penetrated by rather large ruminations. Germination adjacent-ligular; seedling leaf pinnate.

– *R. farinifera*. A clustering palm, up to 25 m tall with stout trunk up to 10 m tall and 1 m in diameter, covered with persistent leaf sheaths. Leaves erect, about 12 in the crown, slightly spreading, up to 20 m long; petiole rounded in cross-section, sheath and petiole about 1.5 m long; rachis stout, several m long, reddish; leaflets up to 150 on each side of the rachis, inserted in 2 planes, stiff, linear, the median about 1 m × 3–8 cm, basal and terminal ones smaller, white-waxy at underside, margins and upperside midrib with yellowish spines. Inflorescence pendulous, up to 3 m × 35 cm, branched to 2 orders; primary inflorescence bract about 30 cm × 20 cm, tubular, partially enclosing the first and second order branches; peduncular bract 18 cm × 8 cm, tubular for 11 cm; second order prophylls 9 cm long; first order branches with 13–32 rachillae; rachilla 6–13 cm × 5–8 mm; male flowers: calyx tube 4.5–5 mm tall, lobes very small, corolla tube 2–3 mm long, lobes narrowly ovate, 6–6.6 mm × 2–2.5 mm, stamens 6, inserted at the mouth of the tube, filaments slightly connate, 2–3 mm long, pistillode absent; female flowers: calyx 5–6.5 mm tall, corolla tube 1–1.3 mm long, lobes narrowly triangular, about 3 mm × 1.5 mm, staminodes absent, ovary 5.5 mm × 2.7 mm. Fruit very variable at maturity, ovoid to ellipsoid, 5–10 cm × 4–5.5 cm, base conical, apex rounded and with a beak 5 mm long, scales in 12–13 rows, largest scales 15 mm × 18 mm, brown. Seed ovoid to ellipsoid, 3–6 cm × 3–4 cm, endosperm sparsely to densely ruminate.



Raphia farinifera (Gaertn.) Hylander – 1, habit; 2, mid-section of leaf; 3, leaf apex; 4, inflorescence branch; 5, female flower; 6, male flower (one petal removed); 7, infructescence branch; 8, fruit.

– *R. hookeri*. A palm with trunk up to 10 m tall and 30 cm in diameter, usually single, not forming a clump, but occasionally with 1–4 suckers; upper part of the trunk clad with blackish fibres (persistent withered leaf-bases). Leaves arranged spirally, pinnate, up to 12 m long, erect, dark green and shining above, waxy and glaucous below; sheath 3–4 m long; petiole 3–4 m long; leaflets 1–1.5 m × 4–5 cm, about 200 on each side of the rachis, terminal segments gradually narrowing to a fine point and having spines on the upper side of the midrib and on margins. Inflorescence axillary, pendulous, 2.5 m or more long, branched to 2 orders, compressed-cylindrical, with crowded branches; branches bearing many curved ultimate branchlets in 4 rows but mostly compressed into a plane; branchlets 15–23 cm long, rigid; branches and branchlets with short-tubular, truncate bracts at base; flowers unisexual; male flowers 1.5–2.5 cm long, with 1 bracteole slightly longer than calyx, thick, with blunt lobes, corolla much longer than calyx, curved, with segments thickened near the tip, stamens (15–)18–22(–24), with erect, linear anthers; female flowers larger than male ones, with 2 bracteoles, calyx as in male flowers, corolla about as long as calyx, with acuminate segments thickened near tip, staminodes 12–15, ovary superior, 3-celled, stigma sessile, recurved, subulate. Fruit a 1-seeded berry, inversely conical or ellipsoid, 6–12 cm × 4–5 cm, with stout beak 1–1.5 cm long, more or less obliquely tipped, covered with scales in (11–)12(–15) vertical rows; scales convex, slightly less broad than long, narrowly furrowed, reddish-brown or pale yellowish-brown with darker point, obtuse at the base, almost entire. Seed cylindrical, 6–7.5 cm × 3–3.5 cm, irregularly grooved; albumen narrowly ruminate. Seedling with hypogeal germination.

- *R. vinifera*. A palm with stout trunk up to 5 m long and a crown of arching leaves up to 13 m long. Leaves bright green, shining above, rather glaucous and waxy below; rachis stout, light brown to orange; terminal leaflets linear with spiny margins and a ragged or blunt tip; midveins spiny above with fine brown spines at intervals of 1–2 cm. Inflorescence pendulous; partial inflorescences (branches) 30–60 cm long; bracts of peduncle and branch-bases ring-like, short; rachillae in 4 ranks, 10–15 cm long, slender, curved, laterally compressed, tapering; male flowers curved, 8 mm long, bracteole sharply bicarinate behind, encloses the calyx, calyx almost cup-shaped, roundly 3-lobed, chaffy at the margin, corolla nearly 3 times the length of calyx, splits into 3 segments almost to the base, stamens usually (6–)9, filaments thick, completely free or connate for half their length; female flowers with outer bracteole slightly longer than calyx, calyx cup-shaped, tridentate, corolla one-third longer than calyx, divided halfway into 3 pointed segments, staminodial ring fused to the corolla with 9 deltoid sterile anthers. Fruit cylindrical-ellipsoid, 6.5–9 cm × 3.5–4 cm wide, ending abruptly in a small sharp beak 3–5 mm long; scales in 9 rows, rhomboid, about 2 cm × 2 cm, rather flat or slightly concave towards the point of the scale, brown. Seed ovoid to ellipsoid, slightly narrower at one end than the other; endosperm deeply ruminate.

Growth and development *Raphia* is monocarpic: the palms flower and fruit only once, followed by death. Inflorescences are produced more or less simultaneously in the axils of the most distal leaves. Tapping for wine may damage the developing inflorescence, making flowering impossible and accelerating death. Germination of *R. hookeri* seeds requires 20–40 days. When young its main stem forms a few suckers. The time from planting to flowering in *R. hookeri* is 3–7 years, whereas *R. vinifera* requires about 8 years. *R. hookeri* is protogynous and cross-pollinated, mainly by wind. The fruits reach maturity at 1–4 years after the onset of flowering and the palm dies 3–4 years after fruit fall. *R. farinifera* in Madagascar takes about 20–25 years from seed to flowering and 5–6 years from flowering to ripe fruit, with all fruits maturing in the same year.

Other botanical information *Raphia* is an isolated genus, comprising approximately 28 species, with no obvious close relatives. It is classified within the *Palmae* in the subfamily *Calamoideae*, tribe *Calameae*, subtribe *Raphiinae*. *Raphia* is mostly described as having several inflorescences in the axils of the topmost leaves. Alternatively it is sometimes described as forming one massive terminal raceme branched from the base. *Raphia* leaves may be as long as 25 m and are the largest known among flowering plants. In most *Raphia* spp. several varieties and forms have been distinguished on the basis of local differences, but these subclassifications are without much practical value.

Ecology Most raphia palms occur in swampy parts of lowland forest, where they may form dense, almost pure stands. In its natural distribution area *R. farinifera* is widespread in gallery forest and freshwater swamp-forest up to 2500 m altitude. It is common near villages at the edge of water courses. *R. hookeri* occurs in freshwater swamps and on river banks. It generally does not tolerate saline conditions and is said to prefer less wet conditions than *R. vinifera*. *R. vinifera* is also found in moist locations, especially on the edges of creeks.

Propagation and planting Raphia palms are generally propagated by seed. Seedlings may be collected from the wild and raised in a nursery before being planted out in the field. It has been claimed that *R. hookeri* seeds should be sown with the ventral side upwards, because the embryo is located on this side, but experiments have shown that seed orientation does not influence germination or seedling growth. In Africa managed stands of *R. hookeri* are mostly left to rejuvenate naturally by seed and in Nigeria and Benin selected trees are left untapped for this purpose. *R. vinifera* is also propagated by suckers. Propagation by tissue culture techniques may offer potential for *Raphia*.

Husbandry In West and Central Africa *R. hookeri* is exploited from natural stands, but it is also planted and tended on upland farms. Suckers are often removed by farmers to promote growth of the main stem. In some regions human activity (cutting of dicotyledonous trees, planting of *R. hookeri*) has turned natural swamp vegetation into 'rafiales', in which *R. hookeri* is the dominant species.

Diseases and pests Fruit rot, caused by *Thielaviopsis paradoxa* (synonym: *Chalara paradoxa*) affects *R. hookeri* and *R. vinifera* in Nigeria, causing dark brown rot of the mesocarp. It enters the fruit via wounds, sometimes killing the embryo and leading to loss of planting material. *R. hookeri* in Nigeria is affected by seedling blight, caused by *Glomerella cingulata*. Symptoms are transparent yellow circular spots appearing on the youngest fully expanded leaves, later becoming necrotic and coalescing. The infection spreads from the tip to the base of the leaflet and may lead to leaflet shedding. Severely infected seedlings may die. The aphid *Cerataphis palmae* may cause considerable damage to *R. hookeri* and *R. vinifera*, e.g. in Nigeria. No information is available on diseases and pests affecting raphia palms in South-East Asia.

Harvesting Because palm wine from *R. hookeri* is highly prized, African farmers are reluctant to diminish plant vigour by cutting green leaves from this palm to obtain piassava fibre. However, dying leaves can be harvested with little effect on wine yields. As it is easier to remove the leaf sheaths from a fallen trunk, palms are often felled after tapping to harvest the fibre.

Tapping of *R. hookeri* for palm wine starts when the first small leaf (2–3 m) subtending an inflorescence appears. A cavity is cut in the stem just below the growing point and the resulting sap is collected. *Raphia* can usually be tapped for 18–25 days before the tree dies. Unlike oil palm, *Raphia* palms are seldom felled before tapping. For maximum oil yields, the fruits should be harvested 36–42 months after pollination.

Yield No statistics on fibre yields of raphia palms are available. Palm wine yields of 870 l have been recorded from a single tree in a 2-month period from cutting to death, but average yields are about 100 l per palm.

Handling after harvest To obtain raffia fibre, the young leaflets are detached and while still fresh a small incision is made on their lower side, near the top. The raffia fibre is then quickly pulled away by hand or by running the leaflet across a knife. The strips, about 1–2 m long and 2–3 cm wide, are tied together at one end and dried in the sun. On drying they develop a creamy yellow colour. Sometimes they are split into fine strands.

Piassava fibre extraction is different for leaf sheaths than for petioles, as the tissue of older leaf sheaths is already moribund and has started to soften. The outer thicker and more brittle fibres can be stripped off the leaf sheaths or are removed by burning the trunk. Starting from the outer 'wings', the useful fibres are then sequentially stripped by hand. When fibre removal is difficult, usually in younger leaf sheaths, the tissue is beaten with a stick or the trunk is left exposed until the tissue has softened. The traditional practice of fibre extraction from the petiole, with its more solid tissue and hard epidermis, is to split the petiole along the longitudinal axis into 3 or 4 parts, which are then tied into bundles and retted in water. The retting period varies from a few weeks to 2–3 months. Retting influences the appearance of the fibres. Sherbro and Sulima piassava, somewhat pale at harvest, turn brownish during retting. Material retted in fresh running water tends to be pale brown, whereas that in stagnant swamp pools develops a reddish-brown tinge, which is more attractive and leads to higher prices. The extracted fibres still have a coating of decomposing background tissue which has to be removed, as the cleanliness of the fibre has a large impact on quality and market value. Cleaned fibres are dried in the sun for a few days. Further drying may occur under the eaves of houses or above fireplaces. High quality Sherbro and Sulima fibres show little variation in length, being about 1.5 m long. Though shorter fibres are acceptable, they should not be shorter than 25–30 cm. Calabar fibres are more variable in length and require sorting into bundles of uniform length.

Genetic resources and breeding No germplasm collections or breeding programmes of *Raphia* are known.

Prospects *R. farinifera*, *R. hookeri* and *R. vinifera* have been grown in South-East Asia since the 19th Century, but their importance has remained limited, notwithstanding their potential multiple use as a source of fibre, palm wine, thatch, construction material and oil for local use, and of raffia and piassava fibre for export. It is unlikely that the importance of raphia palms in South-East Asia will increase much, either for local use or for export: other palms fulfil the local roles that raphia palms have in Africa, whereas the global markets for raffia and piassava fibre are small and already saturated by production from African countries.

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H. Rustiami & M. Brink

Sansevieria Thunb.

Prodr. fl. cap. 29: 65 (1794).

DRACAENACEAE

$x = 20, 21$; *S. roxburghiana*, *S. trifasciata*: $2n = 40$

Major species and synonyms

- *Sansevieria roxburghiana* J.A. Schultes & J.H. Schultes, Syst. veg. 7, 1: 357 (1829), synonyms: *S. zeylanica* auct. non (L.) Willd. (1799), *Cordyline roxburghiana* (J.A. Schultes & J.H. Schultes) Merrill (1923).
- *Sansevieria trifasciata* Prain, Bengal. plants 2: 1054 (1903), synonyms: *S. guineensis* auct., *S. zeylanica* auct. non (L.) Willd. (1799).

Vernacular names General: bowstring hemp (En). Philippines: tigre (Tagalog, Bisaya), buntot tigre (Tagalog).
- *S. roxburghiana*: Indian bowstring hemp (En). Thailand: waan laai, waan lin hia (central), haang suea (Bangkok).
- *S. trifasciata*: African bowstring hemp, snake plant, mother-in-law's tongue (En). Chanvre d'Afrique (Fr). Indonesia: lidah buaya (Malay), letah bayawak (Sundanese), lidah mertua. Malaysia: lidah buaya. Thailand: waan hang suea (general), waan chakhe (northern), lin naakkharaat (Bangkok). Vietnam: h[oor] v[ix], l[uw][owx]i c[oj]p s[oj]c.

Origin and geographic distribution *Sansevieria* comprises about 100 species indigenous to tropical Africa and Asia. Several *Sansevieria* spp. have been introduced throughout the tropics as fibre plants or as ornamentals and have often naturalized. *S. roxburghiana* occurs wild and cultivated in India and is frequently grown as an ornamental elsewhere. *S. trifasciata* is native to tropical Africa and is widely grown as an ornamental, e.g. in Indo-China, Indonesia (Java) and Malaysia. It is cultivated as a fibre plant in tropical regions and has often escaped from cultivation. Both *S. roxburghiana* and *S. trifasciata* are reported to be cultivated for their fibre in the Philippines.

Uses Fibre from the leaves of *Sansevieria* is used locally for making string, rope, nets, mats, hats, backs for matting, hammocks and coarse fabrics, mainly in India and Africa. The name bowstring hemp stems from the longtime use of *Sansevieria* fibre for bows in Africa and India. *Sansevieria* fibre is also used for paper production. In South-East Asia *Sansevieria* fibre is locally used, but it is not always clear which species are involved. In the Philippines *Sansevieria* fibre is mixed with pineapple (*Ananas comosus* (L.) Merr.) fibre in weaving fabrics. In Vietnam *Sansevieria* fibre is sometimes used for making string. Good-quality *S. trifasciata* fibre was produced in Singapore and Malaysia in the early 20th Century, but interest was short-lived and commercial production never occurred.

In Singapore and Indo-China the warm juice of *S. trifasciata* leaves is dropped into the ear as a treatment for earache. In Indo-China the juice of fresh leaves is used to treat pharyngitis and hoarseness. In Perak (Malaysia) a warm decoction of the leaves is applied to itchy skin. In Java the sap of *S. trifasciata* has been used to promote hair-growth. In the Philippines roasted *Sansevieria* leaves serve as an emollient. The pulp remaining after mechanical fibre extraction from *S. trifasciata* leaves contains gelling substances which are used in India as a base for cosmetics and medicines. *Sansevieria* is grown worldwide as an ornamental plant.

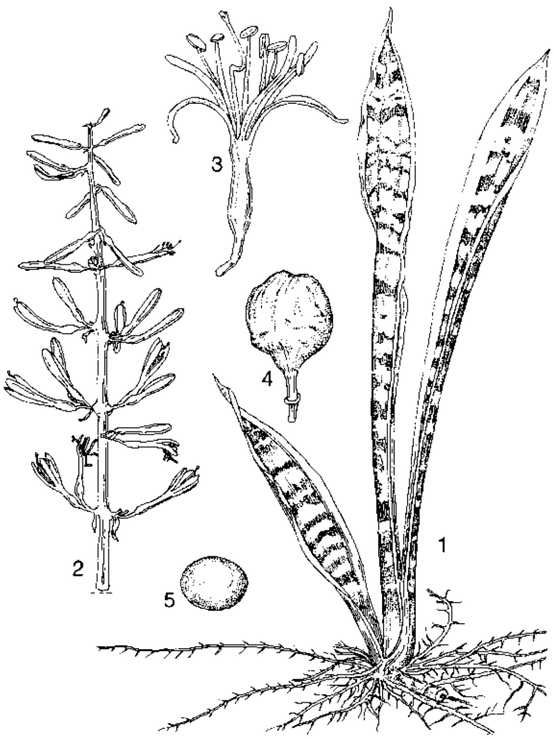
Production and international trade *Sansevieria* fibre is mainly used locally. At various times attempts have been made to develop commercial production, especially when there were shortages of other fibres such as sisal (*Agave sisalana* Perrine) and abaca (*Musa textilis* Née), but most of these have been unsuccessful. During and after the Second World War studies were made in the United States to examine the potential of various *Sansevieria* spp. to replace sisal and abaca as a source of marine fibre. *S. trifasciata* was considered the most suitable species, because of its leaf length, fibre content and tolerance to cold. No recent production and trade data for *Sansevieria* are available.

Properties In cross-section, *Sansevieria* leaves are divided into a peripheral region of green chlorenchyma tissue and a central region of water-storage tissue. Fibre bundles are present throughout the leaf but are largest and most prominent in the chlorenchyma. In general *Sansevieria* fibre strands are 45–180 cm long (depending on leaf length), creamy white, rather soft and lustrous, with good strength, elongation and resistance to salt water microorganisms, but species differ in fibre quality. The ultimate fibre cells are 1–7 mm long, with a diameter of 12–40 μm. Individual fibres are approximately cylindrical in shape, with rounded ends. In cross-section they are polygonal, with thin cell walls and a very large, oval to polygonal lumen. Most fibre cells have only a primary cell wall or a very thin secondary cell wall. *S. trifasciata* leaves from experimental stands in Florida yielded on average about 1.6% decorticated dry fibre. The leaves of *S. trifasciata* contain steroidal saponins and pregnane glycosides.

Adulterations and substitutes If produced commercially, *Sansevieria* fibre would have to compete mainly with sisal fibre, which is less fine but stronger and less brittle. Furthermore the leaves of many *Sansevieria* spp. are shorter than those of sisal and the fibre recovery is lower. *Sansevieria* fibre also faces competition from abaca and synthetic fibres.

Description Stemless, often xerophytic, perennial herbs with leaves in a rosette borne on a subterraneous rhizome. Leaves erect, flat or concave or terete, fleshy, fibrous, often variegated. Inflorescence a terminal, erect, branched raceme, with bisexual, often fragrant flowers fascicled in the axils of scarious bracts; pedicels articulate; perianth tubular with 6 narrow, equal, spreading or recurved lobes; stamens 6, inserted in the top of the perianth-tube, equalling the perianth or often much exserted, filaments filiform, anthers versatile; pistil with superior, sessile, broad-based, 3-locular ovary, (cells 1-ovuled), style long filiform, stigma slightly thickened. Fruit a 1–3 seeded berry.

- *S. roxburghiana*. Leaves 6–24 over the life cycle, those of juvenile plants and the outer ones of a tuft spreading, others usually ascending; blade stiff, linear-oblong, 20–60 cm × 1–2.5 cm, deeply concave channelled down the face, rounded or slightly keeled on the back, margins entire and with age becoming narrowly whitish, apex tapering to a soft point, green, with transverse darker green rather regular bars on both sides and with 6–11 longitudinal dark green lines on the undersurface and often 1–3 on the upper. Raceme spike-like, 30–75 cm long (peduncle included), lower part with 4–5 erect acuminate sheaths 1–2 cm long; flowers 3–5 in a cluster; pedicel up to 8 mm long, jointed near the middle; tube 6–7 mm long; lobes linear, 8–9 mm long, greenish tinged with purple; stamens about 7 mm long, anthers dorsifixed; ovary obovoid, 1.5 mm long, stigma simple, obscurely lobed. Berry globose, up to 6 mm in diameter.
- *S. trifasciata*. Rhizome sympodial, robust, yellowish-red. Leaves in each plant 2–6, much broader than thick, fleshy to rigidly coriaceous, dark green, with numerous very conspicuous, light or greyish-green, irregularly confined transverse bonds, in the normal form with a narrow dark green margin; large leaves linear-lanceolate, 40–175 cm × 2.5–9 cm, base channelled, margins entire, apex acute. Raceme erect, 40–75 cm long (peduncle included); flower-fascicles scattered or arranged group-wise; pedicel 6–8 mm long, articulated at about the middle; perianth 2.5–3 cm long, greenish-white, scented, divided just below the middle; lobes narrowly linear, broadening towards the greenish tip; stamens 7–8 mm long; style 15–18 mm long. Berry globose, 7–9 mm in diameter, or-



Sansevieria trifasciata Prain – 1, habit cv. Laurentii; 2, inflorescence; 3, flower; 4, fruit; 5, seed.

ange, 1–2-seeded. Seed globular-ellipsoid, 6–7 mm × 5 mm, cream-brown.

Growth and development From the planted *Sansevieria* rhizome or seed a juvenile rosette develops, which later produces upright leaves. If leaf cuttings are planted, the rosette stage is usually not produced, except when basal leaf parts are used. The number of leaves produced over the life cycle varies with the species, but generally ranges from 8–15. In Java *S. trifasciata* flowers year-round, with the flowers expanding and becoming fragrant towards the evening.

Sansevieria uses 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.

Other botanical information *Sansevieria* has been classified in the *Liliaceae*, the *Agavaceae*, and more recently, together with *Dracaena* L. in the *Dracaenaceae*, the latter option being supported by chloroplast DNA studies. Most probably, in the future *Sansevieria* will be united with *Dracaena* and consequently all *Sansevieria* names will have to be recombined in *Dracaena*.

In the literature, *S. trifasciata* and *S. roxburghiana* have often erroneously been called *S. zeylanica*. The true *S. zeylanica* (L.) Willd. ('Ceylon bowstring hemp') seems to be native to and cultivated only in Sri Lanka and it is assumed here that it does not occur in South-East Asia although some doubt remains. A thorough revision of the genus is badly needed.

S. trifasciata Prain 'Laurentii' (syn. *S. trifasciata* Prain var. *laurentii* (De Wildem.) N.E. Br., *S. zeylanica laurentii* hort.), with broadly yellow-margined leaves, is the leading *Sansevieria* cultivar in commercial horticulture. It is found worldwide as an ornamental potted plant and is occasionally cultivated as an ornamental in Java. Other ornamental cultivars of *S. trifasciata* include 'Bantel's Sensation', 'Craigii', 'Compacta' and the dwarf cultivars 'Hahnii', 'Silver Hahnii', 'Golden Hahnii', 'Hahnii Variegated' and 'Loop's Pride'.

Other *Sansevieria* species which are sometimes used for their fibre and which may occasionally be cultivated in South-East Asia include: *S. cylindrica* Bojer ex Hook., in tropical eastern and western Africa; *S. ehrenbergii* Schweinf. ex Baker, in tropical eastern Africa and Yemen; *S. hyacinthoides* (L.) Druce (syn. *S. guineensis* (L.) Willd.), in tropical and southern Africa; *S. liberica* hort. ex Gérome & Labroy, in tropical Africa; *S. longiflora* Sims, in tropical Africa and also cultivated in Jamaica, Trinidad and southern Florida; and *S. senegambica* Baker, in tropical West Africa. *S. hyacinthoides* has been commercially produced in Mexico, with exports to the United States.

Ecology Some *Sansevieria* species grow in arid regions with an annual rainfall of less than 250 mm, whereas others occur in evergreen tropical forest with an annual rainfall over 2000 mm. They are usually able to survive in adverse conditions, but for commercial production a warm, moist climate and well-drained, somewhat calcareous soils are recommended. Shading is sometimes recommended, but its favourable effect may be due more to its influence on soil moisture and nutrient status than to a direct effect on plants. In Java *S. trifasciata* is found up to 1000 m altitude.

Propagation and planting *Sansevieria* can be propagated by rhizome division, suckers or leaf cuttings. Propagation by seed is also possible, but some *Sansevieria* species rarely produce seed. *S. trifasciata*, however, readily produces seed. *S. roxburghiana* as well as *S. trifasciata* are easily propagated by leaf cuttings. In a Philippine study with *S. trifasciata* cv. 'Laurentii', rhizomes or suckers gave earlier rooting and better growth than leaf cuttings. Because the number of leaves produced per plant is low compared to e.g. sisal, *Sansevieria* has to be planted at closer spacing, e.g. 1 m × 0.5 m. Seeds should be sown at a depth of about 2.5 cm and rhizome parts should be planted at 5 cm depth.

In horticulture leaf cuttings are the preferred method of propagation for *Sansevieria*, because it takes longer to obtain many plants from rhizome division. Leaf cuttings may be as short as 5 cm, but the longer the leaf, the sturdier the offspring and therefore 20–25 cm long cuttings are recommended. Cuttings form roots in about a month, and about 3 months after planting rhizomes develop, which produce upright leaves. Longer leaf cuttings will usually produce more than one offshoot. It is sometimes recommended that complete leaves be used, from which the offshoots may be severed and the leaf left to produce more offshoots. Cut leaves may be left unplanted for several months, after which they are still able to form offshoots. Leaf cuttings must be placed with the basal portion in the ground, because roots will not form if the tip is put in the ground. Cuttings from the leaf tips give the best results. Variegated plants often revert to a green colour when propagated from leaf cuttings.

In vitro micropropagation of *Sansevieria* is also feasible, making it possible to obtain a large number of plants in a short time from a small amount of plant material. Plant regeneration has been achieved from leaf explants of *S. trifasciata* and its cv. 'Laurentii'.

Husbandry *Sansevieria* is easy to cultivate. Weeding may be done until crop establishment, after which weed growth is effectively suppressed by the crop. *Sansevieria* is said to respond well to fertilizers and mulching, but no quantitative recommendations are available.

Diseases and pests No information exists on diseases and pests affecting *Sansevieria* in South-East Asia. *S. roxburghiana* in India is reported to be susceptible to the fungus *Sclerotium rolfsii*.

Harvesting *Sansevieria* is usually ready for harvest after 18–30 months, and the regrowth may be harvested at intervals of about 24 months. The leaves are cut manually.

Yield With 1 harvest every 2 years, the average annual dry fibre yield of *S. trifasciata* in Florida (United States) was estimated to be about 2 t/ha and that of the hybrid 'Florida H-13' (*S. trifasciata* × *S. deserti* N.E. Br.) up to 3.1 t/ha. No information exists on *Sansevieria* yields in South-East Asia.

Handling after harvest *Sansevieria* fibres are removed by hand or by mechanical means. In hand-processing, the fresh or retted leaves are scraped to remove all extraneous matter from the fibre. Using raspadors 75–90% of the fibre in the leaves has been recovered as clean dry fibre suitable for marine cordage. In a Philippine study various methods of extraction of *S. trifasciata* fibre were compared: machine decortication with a Mayon decorticator, retting for 2 weeks, and the 'sipit' method, in which the leaves are gently pounded, pressed between a bamboo split ('sipit'), and the fibres pulled through the sipit to remove the pulp, after which they are washed thoroughly and dried in the shade. There was no difference in the length of the fibre strands obtained by the different methods, but the fibre recovery was highest with the retting method, slightly lower with machine decortication and much lower with the sipit method. The tensile strength of fibre obtained from machine decortication or sipit method was three times as high as that of fibre obtained by retting. In India the fibre of *S. roxburghiana* ('murva fibre') is extracted by scraping fresh or retted leaves.

Genetic resources About 50 *Sansevieria* accessions are kept at the United States Department of Agriculture (USDA) Subtropical Horticultural Research Unit in Miami, Florida (United States).

Breeding Breeding programmes were carried out in the 1950s in the United States to develop *Sansevieria* types suitable for fibre production in Florida. Fertile hybrids were obtained from interspecific crosses between diploid species (*S. aethiopica* Thunb., *S. deserti*, *S. ehrenbergii*, *S. parva* N.E. Br. and *S. trifasciata*), whereas sterile hybrids evolved from crosses between *S. trifasciata* and the tetraploid *S. cylindrica*. The programme resulted in the release of the hybrid 'Florida H-13' (*S. trifasciata* × *S. deserti*) for fibre production. At present no breeding programmes of *S. roxburghiana* and *S. trifasciata* as fibre plants are known to exist.

Prospects *Sansevieria* is a useful local source of fibre, but the prospects for commercial fibre production are bleak, in view of the competition from sisal, abaca and synthetic products. *Sansevieria* will remain important for ornamental purposes, especially *S. trifasciata* with its many cultivars.

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T.N. Praptosuwiryo

Schoenoplectus (Rchb.) Palla

Bot. Jahrb. Syst. 10: 298 (1888).

CYPERACEAE

x = unknown; *S. lacustris*: $2n$ = 38, 40, 42; *S. litoralis*: n = 39, 42; *S. mucronatus*: n = 21, 22; $2n$ = 42, 44

Major species and synonyms

- *Schoenoplectus lacustris* (L.) Palla, Verh. K.K. Zool.-Bot. Ges. Wien 38 (Sitzungsber.): 49 (1888), synonyms: *Scirpus lacustris* L. (1753), *S. validus* Vahl (1806), *Schoenoplectus tabernaemontani* (Gmel.) Palla (1888), *S. validus* (Vahl) T. Koyama (1978).
- *Schoenoplectus litoralis* (Schrad.) Palla, Verh. K.K. Zool.-Bot. Ges. Wien 38 (Sitzungsber.): 49 (1888), synonyms: *Scirpus litoralis* Schrad. (1806), *S. subulatus* Vahl (1806), *Schoenoplectus subulatus* (Vahl) Lye (1971). Note: the epithet '*litoralis*' is sometimes written '*littoralis*'.
- *Schoenoplectus mucronatus* (L.) Palla, Verh. K.K. Zool.-Bot. Ges. Wien 38 (Sitzungsber.): 49 (1888), synonyms: *Scirpus mucronatus* L. (1753), *S. triangulatus* Roxb. (1820), *S. sundanus* Miq. (1856).

Vernacular names General: bulrush, sedge (En). Vietnam: chi c[os]i d[uf]i.

- *S. lacustris*: great bulrush, clubrush (En). Jonquine, jonc de chaisiers, scirpe des lacs (Fr). Philippines: tiker (Ilokano).
- *S. litoralis*: Indonesia: endong, penjalinan (Javanese).
- *S. mucronatus*: bog bulrush (En). Indonesia: rumput kerecut (western Sumatra), mendongan (Javanese), jajaruman (Sundanese). Malaysia: rumput kerechut, rumput kumbar. Philippines: bibiran (Tagalog), parapipit (Ilokano), pulutapit (Bontoc). Thailand: kok klom (central), kra chu-ut (peninsular), yaa salaep (northern). Vietnam: c[os]i d[uf]i.

Origin and geographic distribution *Schoenoplectus* is a large genus with worldwide distribution, comprising more than 60 species, of which about 10 occur in South-East Asia. *S. lacustris* occurs worldwide in temperate and tropical areas, in South-East Asia particularly in areas bordering the Pacific. *S. litoralis* is distributed from the Mediterranean region and Africa through southern Asia to Australia. In South-East Asia it is rare, but it occurs in Indonesia (Java, Madura, Kangean, Lesser Sunda Islands), the Philippines (Luzon) and north-eastern New Guinea. *S. mucronatus* originates from Asia and is distributed in the warmer parts of the Old World, from southern Europe through South and South-East Asia to Japan and Australia; it is rare in tropical Africa. It is naturalized in North America. It is found through much of South-East Asia, but has not yet been recorded from the Moluccas. It is cultivated in western Sumatra (Padang uplands) as a source of weaving material.

Uses The stems of *S. lacustris* serve for mat-making in the Philippines and India; elsewhere they are or have been used for basketwork, chair seating, thatching, paper production and as a source of cellulose. Stems of *S. litoralis* are used for making mats in West Java. In Ghana they serve for stuffing mattresses, and in Oman for thatching. The stems of *S. mucronatus* are utilized in South-East Asia for the production of sitting-mats, sacks and bags. In Papua New Guinea (Tari) the stems are made into skirts. In the past the stems of *S. mucronatus* were commonly used as string or rope, e.g. in Indonesia and Malaysia, but they have been replaced by synthetic products.

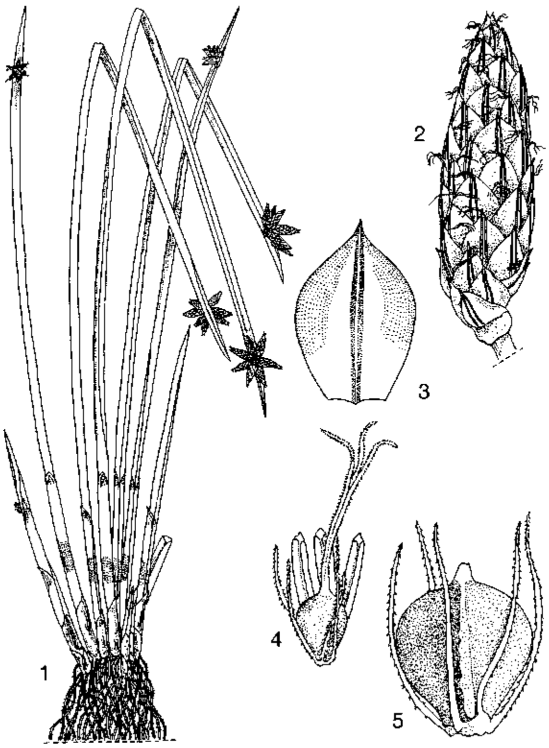
In India the rhizomes of *S. lacustris* are eaten raw or ground into flour to make bread. Medicinally, the stems are credited with astringent and diuretic properties. *S. lacustris* is also used as fodder and as an ornamental. It is planted to filter and clean polluted or eutrophic water. In Europe (the Netherlands, Germany) *S. lacustris* is sometimes planted for land reclamation along seashores. The stems of *S. litoralis* are used as fodder in Oman when other sources are scarce. Its rhizomes are eaten cooked as a vegetable and stems are roasted, peeled and the sections consumed, or the outer skin is removed and the pith (white interior) eaten raw or boiled.

Production and international trade No production or trade figures of *Schoenoplectus* are available. In some South-East Asian areas, *Schoenoplectus* is traditionally important for the local economy.

Properties Mats made of *S. lacustris* stems are not considered very durable. *S. lacustris* belongs, along with *Phragmites australis* (Cav.) Trin. ex Steudel and *Typha latifolia* L., to the main species planted for biological purification of polluted water and removal of nutrients from eutrophic water. In beds planted with these species, organic materials and inorganic nutrients are absorbed, colloidal substances precipitate, and bacteria and other pathogens are significantly reduced. Mechanisms involved are sedimentation, mechanical filtration, nutrient uptake by these plants, and the creation of attachment sites on the plants for aerobic and anaerobic microorganisms purifying the water. Under laboratory conditions *S. lacustris* has been shown to efficiently absorb chromium from tannery effluents and sludge.

Description Annuals or rhizomatous perennial herbs. Stems terete or trigonal, solid, rarely transversely septate. Leaves reduced to bladeless sheaths surrounding the stem bases, rarely with short blades. Inflorescence pseudolateral and compact umbel-like, or anthelate with terminal spikelet or cluster overtopped by lateral ones, or with single spikelets; involucral bract solitary, foliar, often also stem-like and continuous with the stem, sheathing; spikelets solitary or clustered, usually many-flowered; rachilla not winged; glumes spirally arranged, keeled, mucronate, lower ones empty, upper ones not developing; flowers bisexual; hypogynous bristles or scales absent or when present persistent; stamens 1 or 3; pistil with style continuous with ovary, at apex splitting into 2 or 3 stigmatic branches. Fruit a nut-like achene, biconvex or trigonous, smooth, undulate or ridged.

- *S. lacustris*. A perennial herb with stout, horizontally creeping rhizome up to 1.5 cm thick. Stem stout, erect, growing in a row along the rhizome, subterete, 0.5–2 m × 0.5–2 cm, soft and easily compressed, glaucous-green. Sheaths 3–5, lower ones soon disintegrated into reticulate fibres, upper ones 10–30 cm long, rarely with up to 10 cm long blade. Inflorescence pseudolateral, compound, 5–15 cm long, consisting of many spikelets; involucral bract erect, 2–5 cm long, shorter than inflorescence; primary rays stiff, up to 5 cm long, secondary rays up to 2 cm long; spikelet solitary or in clusters of 2–3, ovoid, 5–10 mm × 4–5 mm, many-flowered, dark brown; glumes scarious, ovate with prominent midrib, 3–4 mm × 2–2.5 mm; hypogynous bristles 5–6, slightly longer than the fruit, retrorsely scabrous; stamens 3 with 2 mm long linear anthers; style at top branching into 2 stigmas. Fruit plano-convex with low rounded back, obovoid, 2 mm × 1.5 mm, grey-black.
- *S. litoralis*. A loosely tufted perennial herb with rhizome, runners ending in a tuber. Stem stout, terete, only obtusely trigonal just below inflorescence, 0.5–1.5 m × 3–10 mm, smooth, grey-green, clothed at base with bladeless sheaths. Sheath cylindrical, 4–20 cm long, septate-nodulose, grey-brown; blade setaceous, 5–10 mm long, recurved. Inflorescence a pseudolateral, simple umbel-like corymb, 2–8 cm long, with 3–7 unequal ascending rays up to 5 cm long, terminated by 1–3 spikelets; bract as long as inflorescence; bracteoles scale-like; spikelet solitary, ellipsoid-ovoid, 7–15 mm × 3–4 mm, many-flowered, red-brown; glumes membranous, slightly boat-shaped with slender keel, 3–4 mm × 2 mm; hypogynous scales 3–4, ligulate-spatulate, plumosely fimbriate with multicellular, backward directed hairs on upper part, slightly longer than fruit; stamens 3 with linear anthers 2 mm long; pistil with style slightly longer than achene, branching into 2 stigmas. Fruit broadly obovoid, biconvex, 2 mm × 1.3–1.7 mm, shiny brown-black.
- *S. mucronatus*. A tufted perennial with short rhizome. Stem erect, sharply trigonal, 25–120 cm × 2–9 mm, sides concave, dark green, striate when dry, at base tightly clothed with 1–3 sheaths. Sheath membraneous, the lowest often scale-like, upper one 3-angled cylindrical, 7–20 cm long, brown. Inflorescence pseudolateral, hemispherical, head-like, up to 4 cm in diameter, with 1–10(–25) spikelets; bract similar to stem, 1–10 cm long, narrowed at apex to a blunt pointed tip, at first erect and a continuation of the stem, finally often bent down; spikelet sessile, ovoid-ellipsoid, 6–20 mm × 3–6 mm, pale brown, many-flowered; glumes boat-shaped, ovate-circular, 3–4 mm × 2–3 mm, many-veined and with pale green prominent midrib, margin minutely ciliolate; hypogynous bristles 5–6, hard, unequal, longer than the fruit, bearing backwardly directed short fine spines, red-brown; stamens 3 with 1–2 mm long anthers; pistil with straight slender style 2.5 mm long,



Schoenoplectus mucronatus (L.) Palla ex Kerner – 1, flowering plant; 2, spikelet; 3, dorsal view of opened glume; 4, flower; 5, fruit with bristles.

branching into 2–3 stigmas. Fruit compressed ob-3-pyramidal but dorsal angle indistinct, about 2 mm long and wide, sides flat to slightly convex, glossy black-brown.

Growth and development The fruits of *S. lacustris* can float only for a short period (mostly less than 1 hour) and dispersal over large distances probably depends on transport by seed-consuming birds.

In Java *S. litoralis* and *S. mucronatus* flower year-round.

Other botanical information The taxonomy of *Cyperaceae* is difficult, often confusing and has not yet been clarified. In the past *Schoenoplectus* was a section of the very large (200–300 species) and heterogeneous genus *Scirpus* L. At present attempts are being made to split *Scirpus* s.l. into smaller, more homogeneous genera and *Schoenoplectus* is one of those, although authors differ in opinion about its delimitation (60–80 species). In South-East Asia it comprises about 10 species, but authors also disagree here on delimitations of many species.

S. lacustris comprises 3 subspecies: subsp. *lacustris*, distributed in temperate and tropical Europe and Asia (including South-East Asia), Africa, Australia, Polynesia, North and Central America in fresh water only; subsp. *tabernaemontani* (Gmel.) A. & D. Live, distributed in temperate Europe and Asia (cultivated as a fibre crop in Korea and widely as a pond border ornamental) in brackish and in fresh water; and subsp. *validus* (Vahl) T. Koyama (synonym: *Scirpus validus* Vahl), distributed in countries bordering the Pacific Ocean, growing on wet or flooded soils, particularly useful for its edible rhizomes and its culms that are used for matting and thatching in the Philippines.

S. litoralis is similar in appearance to *S. lacustris*, but usually has a less compound inflorescence and can be easily recognized by the flat, plumose, hypogynous scales. Plants from the Mediterranean, Middle East, China and Mongolia have stems which are triangular throughout and are sometimes classified in subsp. *litoralis*; according to this classification the South-East Asian plants (as described here) belong to subsp. *subulatus* (Vahl) T. Koyama (synonym: var. *subulatus* (Vahl) Chiov.).

Some other *Schoenoplectus* species, occurring in South-East Asia but without recorded use as a fibre plant there, might be potential fibre sources as well: *S. articulatus* (L.) Palla (Mediterranean, Africa, throughout South and South-East Asia to South-East China and northern Australia) serves for thatching in India, where it is also used medicinally as a purgative. *S. juncoides* (Roxb.) Palla (Madagascar, from India to northern Australia) is used in South-East Asia as a forage with a high feeding value and in China it is applied medicinally to release heat, to clear the eyes and to stop coughing. It is also a weed in agricultural fields. *S. lateriflorus* (J.F. Gmel.) Lye (from India to Australia) is a weed in fallow rice fields in south-East Asia, where it is grazed by cattle and it serves as a green manure; in Taiwan its stem fibres are used to make hats. *S. wallichii* (Nees) T. Koyama (from India throughout South-East Asia to China and Japan) is used medicinally in China to alleviate cystitis.

Ecology Most *Schoenoplectus* species prefer open, wet locations, such as swamps, pools, ditches, rice fields, lake shores and the banks of streams. *S. lacustris* is found in open marshes, open sandy foreshores and freshwater swamps, at altitudes up to 1900 m. *S. litoralis* occurs, sometimes abundantly, in brackish swampy locations and saline pools near the sea. It is also found at higher altitudes, e.g. at Tarogong (Java, 800 m altitude) in water originating from hot springs, and along Batur Lake (Bali, 1000 m altitude). *S. mucronatus* is found at altitudes of up to about 2100 m in open, wet localities, swamps, ditches, pools, lake margins and sometimes in inundated rice fields. It is often dominant or co-dominant with *Leersia hexandra* Swartz. In Sumatra (Padang uplands) *S. mucronatus* is planted in swampy rice fields and other continuously moist terrains. In Java *S. mucronatus* is considered a weed of minor importance in rice fields, where it can be controlled by hand, by deep-ploughing before seed formation, or with herbicides.

Propagation and planting Most *Schoenoplectus* species can be propagated by seed and by division of clumps. The germination of 1-year-old *S. lacustris* seeds is improved by stratification (storage in demineralized water at 4°C) or bleach scarification (pre-soaking of the seeds in sodium hypochlorite). In western Sumatra planting material of *S. mucronatus* is obtained by division of old clumps into pieces containing 10–15 stems, which are planted out at a distance of 1 m × 1 m. Before planting, the soil is ploughed or hoed until it is mud.

Harvesting In western Sumatra *S. mucronatus* stems are harvested 3–4 months after planting, when the flowers have turned brown.

Handling after harvest In western Sumatra harvested stems of *S. mucronatus* are sorted, dried (1–2 days in full sun and then several days indoors) and flattened with a piece of bamboo until they become lustrous.

Genetic resources and breeding No germplasm collections or breeding programmes of *Schoenoplectus* are known to exist.

Prospects *Schoenoplectus* will remain important as a local source of weaving material, providing an additional source of income for rural people. It also has prospects as an ornamental for pond banks. On a global scale *S. lacustris* certainly has potential as a component of effective plant filter systems for the biological purification of water.

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P.C.M. Jansen & M. Brink

Scirpodendron ghaeri (Gaertn.) Merr.

Philipp. J. Sci., Bot. 9: 268 (1914).

CYPERACEAE

$2n$ = unknown

Synonyms *Chionanthus ghaeri* Gaertn. (1788), *Pandanus caricosus* Spreng (1826), *Scirpodendron costatum* (Thw.) Kurz (1869).

Vernacular names Indonesia: rumbai (Bangka), pies (Lampung), pandan ayer (Moluccas). Malaysia: selensing, selingsing. Philippines: gaás (Bikol), bilis (Subanon), barongis (Bagobo).

Origin and geographic distribution *Scirpodendron ghaeri* is distributed from Sri Lanka through peninsular Thailand, the Nicobar Islands (Great Nicobar) and Malesia to Australia (northern Queensland), the New Hebrides and Polynesia. In Malesia it is found in Peninsular Malaysia, Sumatra (including Bangka, Simeuluë and the Mentawai Islands), Java (West and Central), Borneo, Sulawesi, the Moluccas, the Philippines and New Guinea. It is sometimes cultivated in South Sumatra.

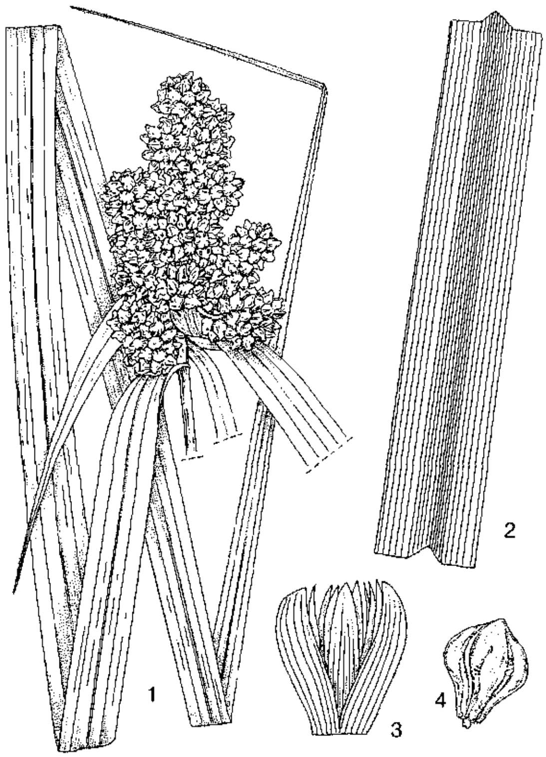
Uses In Indonesia (Sumatra, the Moluccas) the leaves of *S. ghaeri* are made into mats (e.g. for sitting, sleeping, drying of rice), bags and various small products for domestic use. In the Philippines (Leyte) they serve in the production of hats. The leaves are sometimes used together with those of *Pandanus* spp. In Sri Lanka and Vanuatu the leaves are used for the production of mats, in Fiji for thatching. The fruits are eaten in Samoa.

Production and international trade No production statistics are available for *S. ghaeri*. Mats and bags made of *S. ghaeri* are traded locally in Indonesia.

Properties The leaves of *S. ghaeri* look like pandan leaves, but weaving material obtained from them is apparently of lesser quality and durability. Nevertheless, *S. ghaeri* is specifically cultivated for mat-making in South Sumatra. No detailed information is available on the morphological, chemical and physical properties of *S. ghaeri* leaves.

Adulterations and substitutes Other *Cyperaceae* and *Pandanus* spp. may be used for weaving instead of *S. ghaeri*.

Description Subaquatic, low but robust, rhizomatous, perennial herb, up to 60 cm tall (but leaves much longer), in habit resembling a small pandanus, often growing in large, dense clumps. Rhizome thick, woody, prostrate but obliquely ascending at neck, 6–12 cm × 1–2.5 cm, clothed with imbricating, acute scales and their fibrous remains and bearing several robust, dark brown roots 3–5 mm thick. Stem erect, triangular in cross-section with slightly concave sides, 30–60 cm × 5–10 mm, smooth, glabrous, without nodes, leafy at the base only. Leaves numerous, arranged in 3 vertical rows, sheathed; sheath up to about 18 cm long, open, dark brown; blade oblong-plicate, drooping in the upper part, 1–4 m × 2–5 cm, coriaceous, 3-veined, margins serrulate-scabrous, apex gradually narrowing into a filiform, 3-sided, scabrous tail 15–25 cm long. Inflorescence a terminal, paniculate cluster of spikes, branched in the lower half, the lower branches in clusters of 3, short, thick and obliquely spreading; panicle dense, cylindrical to ovoid, in fruit (5–)10–20 cm × 5–7 cm; lowest 3 bracts pseudo-whorled and leaflike, higher ones much smaller, reduced to scales in upper ones; spikes ovoid, 1–2 cm × 5–9 mm, in subsessile clusters, many-flowered; glumes ovate, 6–10 mm × 3–4 mm, many veined, subcoriaceous, spirally imbricate, each glume bearing an axillary, bisexual cyme; terminal flower of each spike with a terminal pistil (pistillate flower) surrounded by flat, spirally arranged scales each bearing an axillary stamen (staminate flower); lateral flowers strongly compressed, also with a terminal pistil but with the 2 outer scales opposite and boat shaped and the other scales flat with an axillary stamen; in the lower fertile glumes of the spike the arrangement of the flowers can be more complex; style continuous with the ovary, not thickened at base, ending in 2 or 3 stigmas; anthers linear, 3–4 mm long. Fruit drupaceous, rather variable, conical-ellipsoid, 1–1.5 cm × 1 cm, acute, with 5–10 more or less prominent and tuberculate longitudinal ribs, dusky brown, exocarp succulent becoming corky when dry, endocarp bony, black.



Scirpodendron ghaeri (Gaertn.) Merr. – 1, infructescence with leaflike bract; 2, part of a folded leaf; 3, lateral flower with boat-shaped scales; 4, fruit.

Growth and development The fruits of *S. ghaeri* readily float away when the water rises. They are also carried off by rats who eat the corky exterior.

Other botanical information Within the subfamily *Cyperoideae*, *Scirpodendron* Zipp. ex Kurz belongs to the tribe *Hypolytreae*, which also includes *Lepironia* L.C. Rich., *Mapania* Aublet and *Thoracostachyum* Kurz. *Scirpodendron* has long been considered a monotypic genus, with *S. ghaeri* as the only species. In 1997, however, a second species, *S. bogneri* S.S. Hooper, was described from Peninsular Malaysia where it occurs in blackwater streams in inland swamp forest. It is somewhat smaller than *S. ghaeri* and its inflorescence has a much softer appearance due to the almost confluent spikes; its glumes are thinner and the flower scales longer and more acute.

In 1788, Gaertner described fruits of *S. ghaeri* as *Chionanthus ghaeri*, but classified them in the family *Oleaceae*. In 1864, Thwaites described it as a new sedge species from Ceylon: *Hypolytrum costatum*. In 1869 Kurz transferred this name to *Scirpodendron* and for a long time the species was known as *S. costatum* (Thw.) Kurz. In 1895 Boerlage discovered that *Chionanthus ghaeri* and *Scirpodendron costatum* were synonymous, but the new combination based on the correct basionym of Gaertner was not published until 1914 by Merrill.

S. ghaeri has stomata which tend to be tetracytic and are more irregularly distributed than in most *Cyperaceae*. Another distinguishing character are the wedge-shaped silica bodies, which are shared with only a few other genera of the *Cyperaceae*, notably *Thoracostachyum*.

Ecology *S. ghaeri* occurs in freshwater tidal areas on clayish soils, in tidal swamp forests, transition forests behind mangroves and along river mouths, especially in locations where the water is waist deep during high tide or following heavy rainfall. In the Philippines it is sometimes found at the borders of lakes. It often forms pure stands which are impenetrable.

Propagation and planting In cultivation *S. ghaeri* is propagated by means of offsets.

Husbandry In Sumatra (Jambi and Palembang) *S. ghaeri* is cultivated in marshes, but usually without much maintenance.

Harvesting In Jambi the leaves of *S. ghaeri* are considered suitable for weaving when they are about 3.5 m long, at 5 years after planting. The leaves are harvested by cutting.

Handling after harvest In Palembang the prickly edges and midribs are removed and the remaining leaf halves are dried and divided into strips, which are then pulled over a piece of bamboo to make them smooth and supple. In Jambi the midribs are removed and the leaves are first split into strips before being dried in the sun for about 3 days.

Genetic resources and breeding In the Nicobar Islands *S. ghaeri* is considered a rare and endangered species. No germplasm collections or breeding programmes of *S. ghaeri* are known to exist.

Prospects Though *S. ghaeri* may be locally important, its overall role will remain limited because of the availability of species yielding higher quality material, such as *Pandanus* spp. Because of the artistic value of the articles made of *S. ghaeri* leaves, the tourist market may offer some potential.

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D. Darmakusuma & A.T. Karyawati

Tetrapanax papyriferus (Hook.) K. Koch

Wochenschr. Gärtnerei Pflanzenk. 2: 371 (1859).

ARALIACEAE

$2n = 48$

Synonyms *Aralia papyrifera* Hook. (1852), *Fatsia papyrifera* Benth. & Hook.f. ex F.B. Forbes & Hemsl. (1888).

Note: In the literature the following orthographic variants of the specific epithet can be found: *papyrifer*, *papyrifera* and *papyriferum*.

Vernacular names Ricepaper tree, ricepaper plant, Chinese ricepaper plant (En). Papier de riz, Aralie à papier (Fr). Indonesia: kayu kertas (general). Vietnam: th[oo]ng th[ar]o, th[oo]ng tho[as]t (m[ooj]c), s[aa]m gi[ar].

Origin and geographic distribution *T. papyriferus* is native to Taiwan and perhaps southern China. In Taiwan and China it is cultivated as a source of ricepaper. It has been widely introduced elsewhere as an ornamental, especially in Asia, and is sometimes naturalized, e.g. in northern Vietnam. In some countries it has even become a troublesome weed. It is grown in the Cibodas Mountain Garden in West Java and it has naturalized in the surroundings.

Uses The pith of *T. papyriferus* yields ricepaper, which is used for making artificial flowers and as a surface for paintings. The use of ricepaper was first recorded by a Chinese author in 1634 and it was introduced into Europe in 1805. Throughout the history of its production most of the ricepaper produced has been used in the manufacture of artificial flowers, in China and Taiwan, as well as elsewhere, e.g. in the United States. It is very suitable for this purpose because it is easy to work, takes dye readily, and yields a product with a natural appearance. Ricepaper has been utilized in China as a surface for water colours since the early 19th Century, especially to portray Chinese products and Chinese life. In the second half of the 20th Century water colourings on ricepaper were often used in the preparation of Christmas cards. Nowadays ricepaper primarily serves for making artificial flowers and occasionally for greetings cards and paintings. Of several other uses recorded in the past, it is unclear whether they still exist. The Chinese employed the pith for surgical dressings and it has been imported into Malaysia for this purpose. In Taiwan ricepaper has been used as lens-paper and in the preparation of pictures for postcards, calenders, ornamental fans and menus. The scraps and trimmings have served locally for packing glassware and as a stuffing. Waste material has been used by children in the construction of animals, model buildings, etc.

In Vietnam the pith is administered as a galactagogue and in mixtures against bronchitis. In Chinese medicine it is used as a galactagogue and for cough and lung problems; it is considered a diuretic, deobstruent, sedative, febrifuge, anthelmintic, antidotal and laxative, and it is also prescribed against diabetes and leucorrhoea. Juice obtained by boiling the wood is considered a cure for uraemia and is used as a tonic after childbirth.

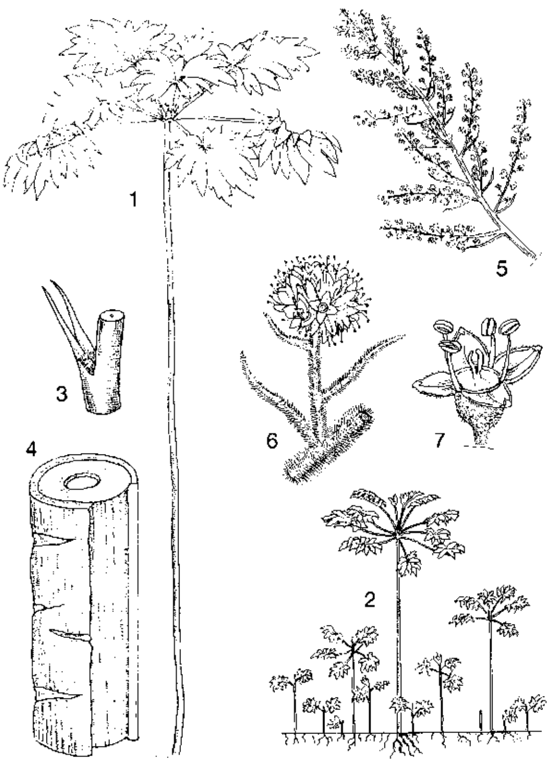
T. papyriferus is widely grown as an ornamental in the tropics and subtropics. In cooler climates it is grown as a greenhouse crop.

Production and international trade In the 1960s most of the ricepaper prepared from *T. papyriferus* in Taiwan was exported to the United States, where it was sold as 'wood fibre' and used for the preparation of artificial flowers. In the late 1990s ricepaper was no longer produced in Taiwan because of the high labour cost and some producers had moved to China.

Properties The pith of young *T. papyriferus* plants is snow-white, becoming creamy-coloured or brownish with age. It has a diameter up to 5 cm and attains its greatest diameter in the upper part of the main trunk. Fresh pith contains about 60% moisture. When dry it has a density of about 30 mg/cm^3. Pith up to three years old is solid, after that diaphragm-like septations occur at the core. Top-quality ricepaper has a soft-velvety feel and appearance. When dry, ricepaper is somewhat brittle; when dampened, it can be folded and stretched somewhat; and when wet it can be formed into almost any shape which it will retain after drying. Ricepaper becomes increasingly brittle and fragile with age.

The leaves and roots of *T. papyriferus* contain triterpenoid glycosides (papyriosides) and their aglycones (papyriogenins), several of which have shown anti-inflammatory and antihepatotoxic activity. Fresh leaves collected in Japan contained 0.014% essential oil, the major components being the sesquiterpenes β-caryophyllene (10.5–14.2%), trans-β-farnesene (7.0–8.0%), β-selinene (7.1–7.4%), δ-cadinene (4.1–5.0%) and trans-nerolidol (3.4–5.9%) and the monoterpenes α-pinene (4.9–13.3%), β-pinene (4.2–10.1%) and α-terpineol (3.0–4.5%).

Description An evergreen, unarmed, suckering shrub or small tree, up to 7 m tall, with successive stems arising as underground branches, eventually forming a clump, young parts with a greyish loose floss. Stems usually unbranched, up to 10 cm in diameter, bark rough, pith up to 5 cm thick, white. Leaves simple but arranged palm-like at the top of the stems; sheath at the top passing into 2 long, acute stipules; petiole 40–70 cm long, white to red hairy; blade circular in outline, 30–80 cm in diameter, 5–12 palmatilobed (sometimes palmatifid), the central segments usually forming 2 secondary lobes, the lobes oblong to ovate, with serrate margins and acuminate apex, glabrous above (at least when fully developed) and densely brownish tomentose with stellate hairs below. Inflorescence terminal, paniculate (3 times compound), 40 cm or longer, woolly with white stellate hairs; primary branches 3–4, radiating, with basal bracts and bearing numerous secondary branches each subtended by a bract up to 2 cm long; secondary branches each with 10–15 many-flowered globular umbels about 12 mm in diameter on peduncles up to 12 mm long which are subtended by 12 mm long linear bracts. Flowers bisexual, yellow-green-white; pedicel 4 mm long, not articulated; calyx wholly fused with the ovary and reduced



Tetrapanax papyriferus (Hook.) K. Koch – 1, habit tree; 2, habit clonal growth; 3, stipules; 4, stem part; 5, branch of inflorescence; 6, ultimate branchlet with umbel; 7, flower.

to an almost obsolete rim 1 mm tall on its top; petals 4–5, triangular, 2 mm long, tomentose outside, sometimes remaining together and falling as a calyptra; stamens 4–5 with 3 mm long filaments; disk slightly convex; pistil with 2-celled inferior ovary and 2 free filiform styles about 4 mm long, each with a terminal stigma. Fruit drupaceous, subglobose, 3–4 mm across, fleshy, 2-seeded. Seeds laterally compressed.

Growth and development *T. papyriferus* grows rapidly, increasing about 60–90 cm in height per year, until it reaches full stature in its fourth or fifth year. Many suckers develop at the base of the trunk, particularly after flowering. In West Java flowering specimens have never been found and here *T. papyriferus* spreads exclusively by subterranean runners.

Other botanical information *Tetrapanax* K. Koch is a genus with only one species. Several cultivars have been described. The ornamental 'Variegata' has cream to white variegated leaves against a background of bright to dark green.

Ecology In Taiwan *T. papyriferus* occurs naturally in thickets at 300–2000 m altitude, where the climate is warm-temperate to subtropical. The rainfall is abundant but very unevenly distributed, with the period of maximum rainfall coinciding with the warmer months, when moisture requirements are highest. In Java naturalized *T. papyriferus* is found in brushwood at about 1400 m altitude. Attempts to grow the plant in Singapore had limited success. When subjected to a light frost *T. papyriferus* may lose its leaves but survive; it is not winter hardy in temperate regions, however. *T. papyriferus* can grow on clay or gravelly soil but it prefers loams with a high organic matter content.

Propagation and planting In Taiwan *T. papyriferus* can be propagated by seed, but the germination percentage is low and vegetative propagation with suckers is more convenient. They are separated when about 30 cm tall and transplanted into the field.

Harvesting To harvest the pith, *T. papyriferus* is cut down when the main stems are 2–3 years old and 1.5–2 m tall, and the leaves and small twigs are removed. The stems may be soaked in running water for several days to loosen the pith and make its removal easy, but this is not always done. The main stems and larger branches are cut into pieces of 30–45 cm length. A round wooden or bamboo plug about the size of the pith diameter is then inserted in one end of the stem and driven against the ground or a solid object to force out the pith.

Handling after harvest Newly harvested pith of *T. papyriferus* must be dried promptly to prevent staining and loss of lustre. This is done by exposing it to the sun for several days. In Taiwan the pith is placed in a hollow section of a bamboo culm to dry straight, and several small pieces may be placed in one culm to force them together during drying. The best grade pith is of medium to large diameter, with small interior cavities, a thin, smooth and bright surface, light weight and pure white interior.

In traditional preparation of ricepaper for the manufacture of artificial flowers, the pith is divided into 7.5 cm long pieces. These are carefully unrolled with a sharp knife on a slicing board, normally made of brick, resulting in thin, narrow ribbons which are later cut into sheets of about 7.5 cm × 7.5 cm. In unrolling it is crucial to apply even pressure on the pith to achieve an even thickness of the ribbons. Thicker ricepaper is used as a surface for paintings and thinner paper for artificial flowers. Sometimes larger sheets of ricepaper to be used for water-colour paintings are made from longer pith segments, most commonly 11–18 cm long. The paper is separated into two or three grades, with first grade sheets being pure white and without any perforation. Sheets that are not pure white, have brown spots or have a few small perforations are considered second grade, whereas those with large or more perforations or irregular edges are third grade. First-grade paper is exported, whereas lower grades may be used locally for making artificial flowers. Nowadays most ricepaper is made by machine, though some manual production still occurs in China.

Genetic resources and breeding No germplasm collections or breeding programmes of *T. papyriferus* are known to exist.

Prospects *T. papyriferus* is easy to grow and has some prospects as a source of ricepaper for niche markets and as a medicinal plant. However, in South-East Asia it can only be cultivated in cooler climates at higher altitudes, and it is doubtful whether South-East ricepaper production can compete with Chinese production in the international market.

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U.A. Dasuki

Thespesia lampas (Cav.) Dalzell & A. Gibson

Bombay fl.: 19 (1861).

MALVACEAE

$2n = 26, 28$

Synonyms *Hibiscus lampas* Cav. (1787), *H. callosus* Blume (1825), *Azanza lampas* (Cav.) Alefeld (1861).

Vernacular names Polompom (Fr). Indonesia: kapas utan (Indonesian), kapasan, kemiren (Javanese). Philippines: marakapas (Tinggian), bulak-bulakan (Tagalog), kapas-kapas (Ilokano). Thailand: pho paa (central), po ieo (Chiang Mai), khwaai kwaang (Chumphon).

Origin and geographic distribution *T. lampas* is found in tropical East Africa, South and South-East Asia and Australia. In South and South-East Asia it occurs from India, Nepal and Sri Lanka through Burma (Myanmar), Thailand, Indo-China, southern China and Indonesia to the Philippines and New Guinea, but it is not found growing wild in Peninsular Malaysia. *T. lampas* is widely grown in the tropics as an ornamental, e.g. in India and Peninsular Malaysia.

Uses Bast fibre from *T. lampas* is used locally for rough cordage, e.g. in Indonesia, the Philippines and Laos. In the Caroline Islands it serves for making fishing nets. In India the stems are utilized as toothbrushes. The fibre is spinnable and seems suitable for the production of coarse sacks and bags. Utilization for clothing has also been suggested.

The roots and fruits are used medicinally in India to treat gonorrhoea and syphilis. The flowers are marketed in India as a medicine for dermatological problems. The tough and pliant timber is used in India for making drums and frames.

Production and international trade No production statistics are available for *T. lampas*. It is used locally and does not enter international trade.

Properties The fibre of *T. lampas* resembles that of jute (*Corchorus* spp.) and sunn hemp (*Crotalaria juncea* L.) in appearance and properties. The ultimate fibre cells are (0.9–)1.9(–4.7) mm long, with a diameter of (12–)16–20(–21) μm. The fibre is shiny, but its colour and luster vary with extraction method and the duration and nature of subsequent chemical treatment. Fibre from stems grown in the shade is longer than that from plants grown in the sun, but the latter is stronger. The fibre of *T. lampas* seems more susceptible to moulds than other crude bast fibres, such as those of *Abroma augusta* (L.) L.f. and *Sida acuta* Burm.f. The tensile strength of rope made from *T. lampas* is low: 268 kg per cm^2 when dry and somewhat higher (8%) when wetted, but both results were erratic. In studies in Indo-China in the 1940s, the fibre of *T. lampas*, separated by retting for 15 days, contained 60% cellulose, 17% pentosans, 13% lignin and 1% ash.

The flowers contain a yellow dye, which has given good results on wool. The principal colouring compound is quercetin. The seed (9% moisture) contains 25% protein and 9–17% oil. The main constituents of seed oil are palmitic acid 18%, oleic acid 15% and linoleic acid 64%. The seed oil also contains toxic cyclopropenoid fatty acids: sterculic acid 2.1% and malvalic acid 0.6%. The gossypol content of dried plant material is high: roots 2.8%, stems 0.2%, leaves 1.0%, flower buds 2.0% and seeds 1.7%.

The 1000-seed weight is 20–25 g.

Description An erect, slightly branched shrub or small tree, 0.5–3 m tall, densely tomentose with minute stellate hairs, glabrescent. Leaves spirally arranged; petiole 0.5–16 cm long; blade 2–22 cm × 1–25 cm, at base 5–7-veined, on base of midrib beneath with a 3–7 mm long linear nectary, entire, in lower leaves large, orbicular, base cordate, apex deeply 3–5-lobed with acuminate lobes, in upper leaves smaller, broadly ovate to oblong, often not lobed, above thinly, below densely covered with stellate hairs. Flowers solitary, axillary, or by reduction of upper leaves in long stalked racemes of 1–5 flowers; pedicel 10–35 mm long in solitary flowers, 4–8 mm in racemes, jointed above the middle; hypanthium obconical, 2.5–6 mm × 5–7 mm; epicalyx segments 4–6, free, subulate, 4–10 mm long, caducous; calyx cupular, 7–9 mm × 7–9 mm, coriaceous, ending in 5 subtriangular lobes or teeth 1–3 mm long, slightly accrescent and spreading in fruit; corolla campanulate, light yellow with a dark red-purple centre, petals 5, obovate, 6–7 cm × 5–6 cm, lower part fleshy and connate; stamens numerous, filaments united in a staminal column up to 2 cm long and dentate at apex, free part of filaments 3 mm long, anthers 1 mm long; pistil with 5-loculed ovary, style unbranched, 18 mm long, stigma clavate, 3 mm long. Fruit a globose to ovoid capsule, 2–3 cm × 2 cm, slightly pentagonous, stellately hairy, black, usually dehiscing with 5 valves, 8–14 seeds per locule. Seed angular-obovoid, 4–5 mm × 2.5 mm, glabrous, papillose, often with a ring of brown hairs around the hilum, glossy black.

Thespesia lampas (Cav.) Dalzell & A. Gibson – 1, habit flowering branch; 2, fruit; 3, seed.

Growth and development Seedling growth of *T. lampas* is slow. In Laos seedlings are about 15 cm and 90 cm tall at 2 and 6 months after germination, respectively. In Java *T. lampas* flowers from March to July, in Indo-China and the Philippines from September to January. Regrowth after coppicing occurs easily. This makes *T. lampas* rather persistent and gives it some advantage over annual fibre crops which have to be sown each year. Natural populations in Laos are subjected to bush fires in February, which destroy old stems, but also cause bursting of the seed coat of deposited seeds, thus leading to abundant germination after the first rains and rejuvenation of the population.

Other botanical information The genus *Thespesia* Sol. ex Correa contains about 15 species, distributed pantropically. In the Malesian region 7 species occur; 5 are endemic to New Guinea, whereas *T. populnea* (L.) Sol. ex Correa and *T. lampas* are widespread. The taxonomic position of *T. lampas* within *Malvaceae* is unclear and needs better investigation. It is closely related to section *Azanza* DC. in the genus *Hibiscus* L. *T. lampas* is highly variable in leaf form and hairiness, and many subdivisions have been proposed based on these characters. The differences, however, are continuous and fall within the normal pattern of variation in the species. Based on form and length of the calyx lobes, however, two varieties can be distinguished:

- var. *lampas*: calyx lobes subulate to triangular, 1–3 mm long, the usual situation, distribution same as the species;
- var. *longisepala* Borss.: calyx lobes long triangular or linear-acute, 8–10 mm long, occurring in Borneo and India.

A third variety, var. *thespesioides* (R. Br. ex Benth.) Fryxell (synonym *Fugosia thespesioides* R.Br. ex Benth.) has been recognized as a separate species, *T. thespesioides* (R. Br. ex Benth.) Fryxell. It differs by a 3–4-celled capsule, leaf apices acute to obtuse, calyx and capsule more densely hairy and its stellate hairs bearing more arms. It only occurs in Australia.

Ecology *T. lampas* is found in humid as well as seasonally dry regions with an average annual rainfall of 1500–1700 mm. It is a light-loving plant found in *Imperata* fields, teak forest or secondary forest. In Java it occurs especially in relatively dry areas at altitudes up to 300 m. In the Philippines it is found in open locations at low and medium altitudes. In Laos it grows spontaneously on alluvial soils near watercourses or ponds. It thrives on fertile clayey or loamy soils, but will grow on less favourable soils if sufficient moisture is available. In India it is found at altitudes up to 1200 m.

Propagation and planting *T. lampas* is easily grown from seed or cuttings. Germination is about 50% in 2 weeks. Seedlings can be transplanted when 30 cm tall. Cuttings should be rooted first in the nursery.

Husbandry In Laos T. lampas is mostly obtained from natural populations. It has been recommended that these populations be improved by coppicing the shrubs every year, renewing the populations from seed every 10–20 years, weeding, improving drainage and protecting seedlings from fire.

Diseases and pests In India fungi on *T. lampas* include *Hansfordia pulvinata* and *Pseudocercospora thespesiae*. In Indonesia several cotton (*Gossypium* spp.) pests are known to feed on wild *T. lampas*, such as pink bollworm (*Pectinophora gossypiella*, synonym: *Platyedra gossypiella*), spiny bollworm (*Earias fabia*) and *Amorphoidea pectoralis*. Insect pests recorded on *T. lampas* in India include sap-feeders (*Phenacoccus glomeratus*) and defoliators (e.g. the larvae of *Acontia intersepta* and *Sylepta derogata*).

Harvesting In Laos only young stems not too much damaged by bush-fires are harvested from natural *T. lampas* populations.

Yield No reliable and up-to-date yield data for *T. lampas* are available. Yields per hectare from natural populations in Laos are low; much higher yields are possible from improved natural populations or plantations.

Handling after harvest In Java the fibre is normally used without any processing, but in Indramayu (West Java) more elaborate processing is practised. Here the bast is removed from the stems immediately after harvesting, tied in bundles and submerged in water. Sometimes the bundles are wrapped in banana leaves. Retting of unwrapped bundles takes at least a month, whereas the retting process of wrapped bundles only takes 6–7 days. Too long retting leads to a reduction in strength and a darker colour. After retting the fibres are dried in the sun and the remaining impurities are removed with a knife. In Laos the fibres are extracted by retting the stems for 15–30 days in running water. The resulting fibre usually has a reddish colour, contains much extraneous matter and is unsuitable for industrial use. When improperly retted fibres are exposed to air they turn brown, as is also the case with jute fibres. Contact with boiling water has the same effect.

Genetic resources and breeding No germplasm collections or breeding programmes of *T. lampas* are known to exist.

Prospects At present *T. lampas* is merely a local source of rough cordage and it is not likely that it will increase in importance. However, fibre from *T. lampas* is very similar to that of jute and seems suitable for the production of sacks, so it could be used to produce substitutes for imported jute products.

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S.H. Widodo

Typha L.

Sp. pl.: 971 (1753); Gen. pl. ed. 5: 418 (1754).

TYPHACEAE

$x = 15$; *T. domingensis*: $2n = 30$; *T. orientalis*: $2n = 60$

Major species and synonyms

- *Typha domingensis* Pers., Syn. pl. 2: 532 (1807), synonyms: *T. angustata* Bory & Chaubard (1832), *T. angustifolia* auct. Fl. Malesianae (1951), non L. (1753).
- *Typha orientalis* C. Presl, Abh. Königl. Böhm. Ges. Wiss., ser. 5, 6: 599 (1851), synonym: *T. muelleri* Rohrb. (1869).

Vernacular names General: cattail, reedmace, bulrush (En). Massette (Fr). Indonesia: lembang (Jakarta), embet (Javanese), ampet (Madurese). Philippines: balañgot (Tagalog, Samar-Leyte Bisaya, Panay Bisaya), homai-homai (Bisaya), kaidked (Pangasinan). Thailand: kok chaang (central), thuup ruesee (Bangkok), yaa salaap luang (northern). Vietnam: (chi) c[or] n[ees]n, h[uw][ow]ng b[oof] (thao).

Origin and geographic distribution *Typha* comprises (8–)15(–20) species most of which are widely distributed throughout the temperate, subtropical and tropical zones of both hemispheres. As the taxonomy is still not clear and identification of the taxonomical units often difficult the mentioned areas of distribution of individual taxa are tentative. *T. domingensis* occurs in the subtropical and tropical zones north and south of the equator in both hemispheres. In Malesia it has been recorded from Java and Sumba. *T. orientalis* is widespread in the Philippines, Taiwan, Japan, New Guinea and Australia.

Uses It is unlikely that the closely related *Typha* species have been distinguished for practical purposes as their properties are so similar. For this reason general information is provided for the genus as a whole. Stems and leaves are woven into various products, such as mats, hats, bags, baskets, slippers and chair-seats. In the Philippines the stems and leaves are also used for tying, and they are sometimes twisted into coarse, weak ropes. The leaves serve for thatching. The floss (flower hairs) of the ripe female inflorescence has been used for stuffing. In the Philippines and Indo-China it has also been applied as a haemostatic to wounds and ulcers. In Papua New Guinea cattails are used as torches, and in Java the unripe spikes have been used as fuses. The stems and leaves are processed into paper, e.g. in China. Cattails have been found suitable for the production of textiles and fibreboard, but their use seems very limited in this respect.

The rhizomes, young shoots and pollen are eaten. In Vietnamese and Chinese traditional medicine, the pollen is considered to be diuretic and haemostatic, and the rhizome to be a diuretic, laxative, tonic and galactagogue. Cattails are sometimes grown as ornamentals, and the spikes are used for decoration. The stems have been made into sticks. *T. domingensis* and other *Typha* spp. are useful in aquatic plant systems for wastewater treatment.

Production and international trade *Typha* as a fibre plant is only collected from the wild. No production statistics are available.

Properties The stems and leaves of all cattails are tough and fibrous. The leaves are suitable for caulking, because they swell when wet. Paper made from cattails is fairly strong but difficult to bleach. The floss from female inflorescences has a high buoyancy and good insulating properties, both for heat and sound. No information is available on the chemical properties of *T. domingensis* and *T. orientalis*.

The seeds contain a drying oil similar in quality to linseed oil. Aqueous extracts of *T. domingensis* have shown phytotoxic properties, inhibiting the germination of lettuce and radish seeds and the growth of the water fern *Salvinia minima* Willd.

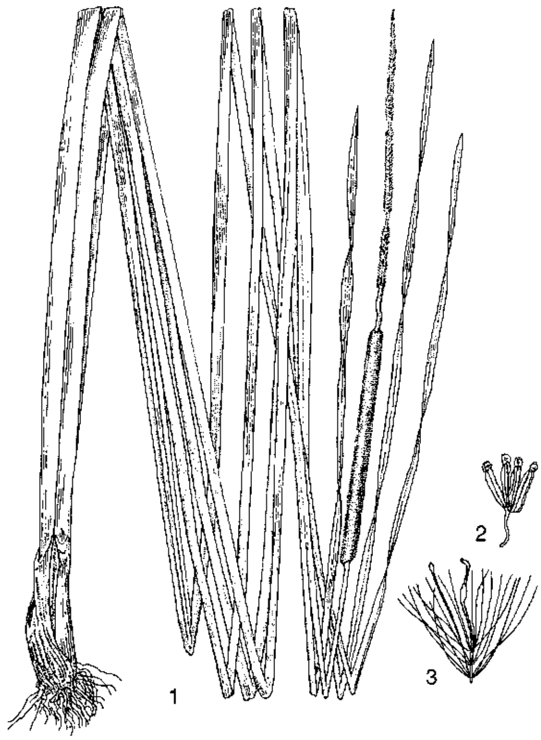
The 1000-seed weight is 0.02–0.03 g.

Adulterations and substitutes A range of *Cyperaceae* and *Pandanaceae* may be used for weaving instead of cattails.

Description Palustrine or aquatic, monoecious, perennial, glabrous herbs with long, creeping rhizomes and unbranched, solid, erect stems. Leaves in two series, partly subradical, partly cauline, sheathing, elongate-linear, rather thick and spongy; sheath excreting slime on its inner side. Inflorescence unisexual, cylindrical, spike-like, superposed; bract at base foliaceous, caducous; flowers numerous, small, closely packed. Male inflorescence situated above female one and flowering earlier; male flowers consisting of 2–3 flattened, hair-like, simple or branched bracts (or perianth-leaves) surrounding 2–5(–7) stamens; filaments connate, anthers basifixed. Female inflorescence 1, rarely 2, sometimes separated from the male inflorescence by a short interval; rachis densely covered by more or less cylindrical, wart-like, short excrescences bearing one to several fertile or sterile flowers with or without narrow, hair-like bracteoles widened into a short, flat, often dentate leaf blade which sometimes can be seen on the velvety surface of the inflorescence; fertile flowers consist of a fusiform ovary borne on a very thin stalk (gynophore) surrounded by a whorl of hairs at its base; style distinct, short and thin; stigma flattened, linear to spatulate; sterile female flowers either similar to fertile ones but with undeveloped ovary, or the pistil swollen and broadly club-shaped. Fruit a very small, 1-seeded follicle falling off before dehiscence together with its stalk. Seed striate.

- *T. domingensis*. Flowering stem up to 3 m tall. Leaves green or yellowish-green; sheath of upper leaves not auriculate or only in the uppermost 1 or 2 ones; blade up to 2 m × 0.5–1.5 cm. Male and female inflorescences separated by 2–5.5 cm. Male inflorescence 15–33 cm × 0.6–1 cm, pollen shed as single grains. Female inflorescence 12–40 cm × 0.5–2 cm, cinnamon-brown; floral bracts abundant, broadly spatulate, 4–8 cells wide; stigma narrowly linear, pointed and folded longitudinally.
- *T. orientalis*. Flowering stem up to 3 m tall. Leaves bluish or grey-green; sheath of uppermost 2–4 leaves distinctly auriculate; blade up to 2 m × 0.5–1.5 cm. Male and female inflorescences contiguous or 3.5–5 cm apart. Male inflorescence 10–30 cm × 0.7–1.4 cm; pollen shed as single grains. Female inflorescence 8–30 cm × 1–3 cm, chestnut-brown; floral bracts absent or few, narrowly spatulate, 3–4 cells wide; stigma narrowly lanceolate, often folded longitudinally.

Growth and development Cattail seeds readily germinate in open wet areas, but mortality is high and few seedlings reach the reproductive stage. The seedlings can survive either submerged in water or emerged. Once the plant is established, within a year after germination, rhizome growth starts and becomes the main mechanism maintaining a stand. Buds in 2 rows on each side of the rhizome apex may develop into new rhizomes or shoots.



Typha domingensis Pers. – 1, habit of flowering plant; 2, male flower; 3, female flower.

The pollen is transported by wind. On windy days cross-pollination may occur, but on calm days self-pollination is likely. Estimates of the number of seeds per inflorescence are up to about 340 000 for *T. orientalis* and 680 000 for *T. domingensis*. The number of seeds per m^2 has been estimated at 6 million and 17 million for *T. orientalis* and *T. domingensis*, respectively. The fruits are easily transported by wind, with the hairs serving as parachutes. Within minutes of contact with water the follicular tissues saturate and split open, and the seed is released. Seeds remain viable for a long period if conditions are unfavourable for germination. Cattails are perennials, with their rhizome enabling them to survive periods of cold and drought. Individual shoots do not live longer than 1 year. In Australia a maximum standing biomass of 1.3 kg dry matter per m^2 and a maximum underground biomass of 3.6 kg per m^2 have been recorded for *T. orientalis*.

Other botanical information The species concept within *Typha* is highly controversial and a review of the genus is badly needed. Interspecific hybridization occurs within *Typha*, adding to the confusion. The species are mainly distinguished by the presence or absence of a naked interval on the axis between the inflorescences, the presence or absence and shape of bracteoles and swollen pistils, the width and shape of the stigma and the relative length of the various parts of the female flowers which result in a characteristic surface pattern.

According to Flora Malesiana only 1 *Typha* species is present in Malesia, *T. angustifolia* L. in a very wide sense. However, most authors consider *T. angustifolia* as a species of temperate climates only. Typical *T. angustifolia* is 2–2.5 m tall, leaves flat, and male and female inflorescences clearly separated. In the female inflorescence the stigmas are apically widened, dark brown, shorter than the bracts which are narrow, brown and irregularly directed so that the surface pattern does not show any special order.

T. javanica Schnizl. is by some considered a synonym of *T. domingensis*, but more probably it is a separate species. In the latter view *T. domingensis* has female inflorescences on which surface only the extremely narrow-filiform bracts are visible, hiding the white hairs and the stigmas; *T. javanica* (widespread in Malesia, particularly in Indonesia) has female inflorescences on which surface between the narrowly filiform, cinnamon- to reddish-brown bracts islands of short-spatulate, incurved stigmas are visible.

From the literature it is not clear whether *T. elephantina* Roxb. from India also occurs in South-East Asia. The plants are up to 4 m tall. It has a very stout and long female inflorescence, 3–4 cm in diameter. Throughout the whole length of the inflorescence surface, between brown bracts islands of capitate, pale, apically truncate pistillodia are present.

T. latifolia L., a native of temperate regions of the northern hemisphere, could sometimes have been introduced in South-East Asia as it is in many other parts of the world (e.g. Australia). It is 2–2.5 m tall with about 2 cm wide leaves. The leaves are convex on the abaxial surface, in transverse section sickle-shaped due to the presence of a thick aerenchyme layer. The female inflorescence is very dark brown, bracts are lacking, stigmas are broadly ligulate.

Ecology Cattails grow in marshy locations, in shallow pools and along the margins of often stagnant, fresh or brackish water, along irrigation channels and in rice fields. They are known to grow at a water depth of up to 2 m. However, cattails vary in their tolerance to water depth, with e.g. *T. domingensis* tolerating deeper water than *T. latifolia*. In Malesia cattails occur up to about 1700 m altitude.

Cattails are often associated with disturbed, fertile environments. They grow on a variety of soil types, but are usually found on fine-textured organic muds and silts, which have a high nutrient content and water-retention capacity. They are considered moderately salt-tolerant, but growth is significantly reduced at salinities higher than 3–5 ppt. Permanent salinities of 7 ppt or higher exceed the tolerance limits of *T. domingensis*. The success of cattails in brackish environments seems to stem from their ability to grow rapidly when fresh water is available and to persist in a dormant state under saline conditions.

Cattails are often considered weeds. They are able to dominate vegetations, because their bulky rhizome and their tall, dense canopy give them a competitive advantage. The formation of monospecific stands is aided by a mat of dead cattail material, which prevents the establishment of other species, but which also may prevent growth of cattail seedlings. Cattails readily colonize disturbed areas where water is available, and they may block irrigation and drainage channels. They also increase water loss because of their high transpiration. In Australia both *T. domingensis* and *T. orientalis* are considered major aquatic weeds.

Propagation and planting Cattails are propagated by rhizome division or seed. *T. domingensis* seeds do not germinate without light.

Husbandry Cultivation of cattails is easy along the margins of natural or artificial pools. Where they are weeds, they may be controlled effectively by cutting or crushing below the water level or by spraying with glyphosate.

Yield Cattails are highly productive. In Australia an aerial dry matter production of 3.7 kg per m^2 per year has been recorded for *T. orientalis*. For *T. domingensis* in Cuba the aerial biomass production has been estimated at 1.3–1.5 kg dry matter per m^2 per year.

Handling after harvest In the Philippines cattail culms may be split before being woven. For pulping, the fibre can be chemically extracted from stems and leaves together by treatment with sodium hydroxide.

Genetic resources and breeding No germplasm collections or breeding programmes of cattails are known to exist.

Prospects The importance of cattails in South-East Asia will probably remain limited to local use as sources of weaving material. On a worldwide scale they have potential as components of aquatic plant systems for the treatment of wastewater.

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H. Riedl

Urena lobata L.

Sp. pl.: 692 (1753).
MALVACEAE
$2n = 28, 56$

Vernacular names Congo jute, aramina, urena (En). Grand cousin, cousin urène, cousin rouge (Fr). Brunei: anca-anca, jerupang. Indonesia: pulutan (Javanese), pungpulutan (Sundanese), pulut (Sumatra). Malaysia: pulut-pulut, pepulut, pulut lembu. Philippines: kulotan (Tagalog, Bisaya), kollokollot (Ilokano), molopolo (Pampango, Tagalog). Cambodia: daem chruk. Laos: nha ngum. Thailand: khamong dong (northern), po seng (peninsular), khee khrok (central). Vietnam: (c[aa]y) k[es] hoa d[af]o, b[as]i l[uw][ow]ng, k[es] d[aaf]u ng[uwj]a.

Origin and geographic distribution The origin of *U. lobata* is not certain, but it is probably of Asiatic or African origin. It is now widely distributed in a wild or naturalized state throughout the tropics and subtropics, including South-East Asia. *U. lobata* is grown as a fibre crop in mainland Africa, Madagascar, Brazil and India. It can be a troublesome weed, especially in pastures.

Uses The bast fibre from wild or cultivated *U. lobata* is widely used as a local source of cordage and coarse textiles and industrially as a substitute for jute (*Corchorus* spp.), e.g. for making sacks, carpets, cordage and upholstery. It is often used mixed with jute. In South-East Asia *U. lobata* serves for making string, twines, ropes etc., for instance in Malaysia, Cambodia and New Guinea. In northern Thailand it is a source of fibre for the hill tribes. In Indramayu (West Java) at the beginning of the 20th Century sacks and mats were made of fibre from wild *U. lobata*. The fibre of *U. lobata* can be made into strong paper and whole plant cuttings can be pulped as well.

The main medicinal applications of *U. lobata* in South-East Asia are the use of the juice of leaves or roots against bowel complaints, gonorrhoea and malaria, and leaf poultices on wounds, swellings and skin diseases. Young shoots and leaves are eaten as a vegetable. Animals eat the foliage. In Malaysia *U. lobata* is considered a magic plant, used in healing rites, for protection, and in wedding and rice ceremonies.

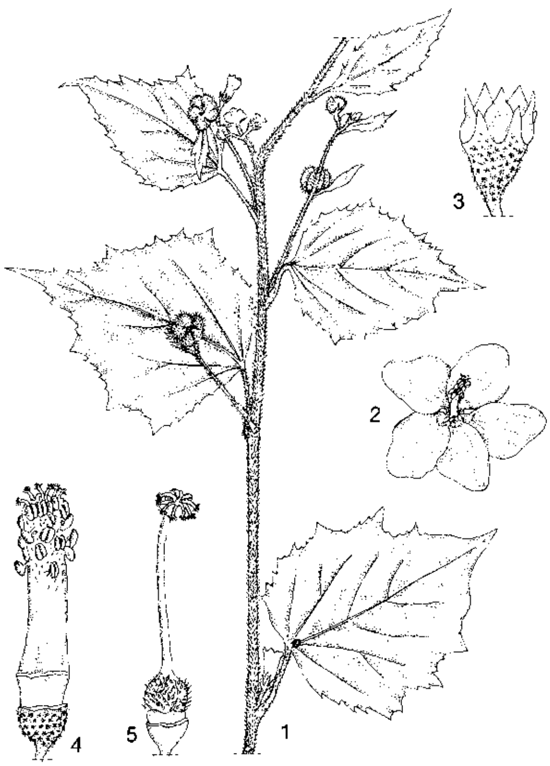
Production and international trade Recent production and trade statistics of *U. lobata* are not available. In the 1970s the world production was estimated at 38 000 t per year, with about 70% produced in Brazil.

Properties Fresh stems of *U. lobata* yield 5–5.5(–7)% retted bast fibre. The fibre is fine, soft, flexible and lustrous, with a creamy white or pale yellow colour. It resembles jute more than other jute substitutes, such as kenaf (*Hibiscus cannabinus* L.) and roselle (*H. sabdariffa* L.). It can be spun on jute machinery without any change to the machines and without the operators needing experience with *U. lobata*. The ultimate fibre cells are (0.8–)1.4–1.8(–5.9) mm long, with a diameter of (9–)12–19(–34) μm. Information on the fibre composition shows a wide variation in cellulose (63–87%) and lignin (7–12%) contents. Fibre from wild plants is usually only about 1 m long, whereas fibre from cultivated plants has an average length of about 2 m. In the Philippines rope made of *U. lobata* fibre is considered unsuitable for wet conditions, because of the lower wet strength and the fact that it deteriorates rapidly. Kraft pulping experiments with *U. lobata* bark and pith in South Africa gave pulp yields of 43–47%.

The seeds yield 7–18% oil, with linoleic acid, palmitic acid and oleic acid as major fatty acids, but also containing the cyclopropenoid fatty acids malvalic acid and sterculic acid. However, concentrations of the different compounds vary widely. The aerial parts contain the flavonol quercetin. A methanolic extract of *U. lobata* roots has shown antibacterial activity against a range of microorganisms.
The 1000-seed weight is 15–30 g.

Adulterations and substitutes *U. lobata* has to compete mainly with jute, kenaf and roselle. It is as fine and supple as jute, but not as strong. It has about the same colour and lustre as kenaf and roselle, and is finer, but less strong and durable.

Description A highly variable annual or perennial shrub; in its weedy forms low, spreading and branching, 0.5–2.5 m tall, cultivated forms erect, poorly branched, up to 4 m or taller; all aboveground parts more or less densely covered with minute stellate hairs, usually also with scattered, thin, purple tinged simple hairs. Taproot short (20–25(–40) cm) with lateral roots up to 2 m long.



Urena lobata L. – 1, flowering and fruiting branch; 2, flower; 3, epicalyx and calyx; 4, staminal column with pistil; 5, pistil.

Leaves alternate, simple, extremely variable in size and shape; stipules lanceolate to obovate, 2–4 mm long, acute, caducous; petiole 0.2–12 cm long; blade ranging from coarsely toothed lanceolate, orbicular or broadly ovate to shallowly or deeply palmately 3–7-lobed, 1–12 cm × 0.5–13 cm, base cordate to cuneate, margins serrate to crenate, apex rounded to acuminate, at base with 3–9 palmately arranged veins, surfaces densely stellate hairy, with 1–3 linear nectaries near the base of the main veins beneath. Inflorescence usually composed of solitary, axillary flowers, sometimes in clusters of 2–3, in the upper part flowers seemingly arranged in spikes or racemes because of the much reduced leaves. Flowers 5-merous, campanulate, 2–3 cm in diameter, pink with a purple centre; pedicel 1–7 mm long; epicalyx campanulate to tubular, 7–8 mm × 5–6 mm, closely enveloping the calyx and at base adnate to it, at apex with 5 long-triangular teeth 3–5 mm × 1–3 mm; calyx tubular to campanulate, 5–6 mm × 1.5–2 mm, at apex with 5 ovate to acuminate lobes 4–6 mm × 1.5–2 mm, at about one-third from the base of the slightly prominent calyx veins a nectary or a thickening only is present; petals obovate, 1.5 cm long, apex rounded; stamens arranged into a staminal column 10–14 mm long, usually curved, anthers in upper half, purple, pollen white; pistil with 5-carpelled ovary, style in the centre of the staminal column, at the apex divided into 10 arms each 1 mm long, stigmas 10, capitate, papillose, dark purple. Fruit a subglobular schizocarp, composed of 5 trigonous, indehiscent, 1-seeded mericarps, 4–5 mm long, covered with barbed bristles and a thick cover of stellate hairs. Seed reniform, 2.5–3.5 mm long, minutely hairy to glabrous, brown. Seedling with epigeal germination.

Growth and development Cleaned and scarified seed may germinate within 5–8 days, but germination of unhusked seed may take place over a period of 2.5 months. The growth rate during the first month is slow, but subsequent growth is fast. The time to flowering depends on photoperiod, with the time to flowering being delayed by long photoperiods and the minimum vegetative period varying with genotype. In Selangor (Peninsular Malaysia) flowering and seed set of *U. lobata* sown in May started at about 55 days and 105 days, respectively. In Java wild *U. lobata* flowers throughout the year. Flowering occurs over a prolonged period and one node may bear all stages from flower buds to ripe fruits simultaneously. The flowers open early in the morning and wither about noon. They are capable of self-pollination, but the large intraspecific variation suggests a rather high percentage of cross-pollination. The nectaries are frequently visited by ants, aphids and various *Hymenoptera*. Dispersal is aided by the fruits' barbed spines which stick to clothes and to the coats of animals.

Other botanical information The taxonomy of *Urena* L. has not yet been settled. Some consider *Urena* a monotypic genus with *U. lobata* as one polymorphic species, whereas others recognize more species. In this account the one-species approach has been followed. Within *U. lobata* s.l. 2 sharply distinct subspecies have been distinguished, based mainly on the form of the epicalyx:

- subsp. *lobata*, a stout plant with many ovate to lanceolate leaves, lower leaves shallowly lobed, and with a stiff, cupular epicalyx during fruiting, segments long-triangular, 4.5–5 mm × 2.5–3 mm, especially occurring above 400 m altitude; subdivided into var. *lobata* (syn. *U. tomentosa* Blume, *U. monopetala* Lour.), with the green parts more or less densely pubescent with matted wool, and var. *viminea* (Cav.) Gürke, with the green parts more or less densely pubescent with often slightly scabrous hairs;
- subsp. *sinuata* (L.) Borss. Waalk., with lower leaves angular to palmately lobed or more deeply incised, and a spreading or reflexed, flexible epicalyx during fruiting, segments linear to lanceolate, acute, 3–4 mm × 1–1.5 mm, especially occurring below 400 m altitude; subdivided into var. *sinuata* (syn. *U. sinuata* L., *U. procumbens* L.), with palmatifid to palmatipartite leaves, and var. *glauca* (Blume) Borss. Waalk. (syn. *U. scabriuscula* DC.), with angular to palmatilobate leaves.

Urena is morphologically very close to *Pavonia* Cav., which has mericarp bristles that are not barbed or with 3 hairy awns and leaves normally without nectaries. It is argued by several authors that the two genera should be merged.

Ecology For optimal growth and fibre production *U. lobata* needs a hot and humid climate with ample sunlight and rainfall, and a deep, fertile, well-drained soil. It prefers an average temperature of 21–27°C, a relative humidity of 73–85%, and a monthly rainfall of 160–210 mm during the growing season. Under less optimal conditions it may grow as a short, branched, wiry shrublet. *U. lobata* needs short days for flowering.

In South-East Asia *U. lobata* is common on roadsides and in waste places, fallow fields, plantations, secondary vegetation, teak-forests, and degraded peat-swamp forest, up to 2000 m altitude.

Propagation and planting *U. lobata* is propagated by seed. Germination can be slow or uneven because of dormancy due to the impermeability of the testa to water. It is considerably improved by scarification, for instance through removal of part of the testa or treatment with concentrated sulphuric acid. *U. lobata* is usually sown at the beginning of the rainy season in a well-prepared seedbed. Plants are closely spaced to prevent branching. Plant densities are usually around 300 000 plants/ha. Sowing may be done in rows (1–2 cm deep) or the seed may be broadcast.

In the wild state *U. lobata* is a perennial, but it is usually grown as an annual crop. In some areas it is grown as a perennial and ratooned. Because of the high nutrient uptake it is recommended that *U. lobata* be grown in rotation.

Husbandry Weeding of *U. lobata* is necessary in the early growth stages and is usually done twice; the crop may be thinned at the same time. *U. lobata* has a high nutrient demand. The nutrient uptake per hectare by a crop producing 40 t/ha green material has been estimated at 190 kg N, 24 kg P, 175 kg K and 148 kg Ca, of which 53%, 46%, 36% and 58%, respectively, is stored in the leaves. Therefore, returning the leaves to the soil helps to maintain soil fertility.

Diseases and pests *U. lobata* can be seriously damaged by several fungi that form stem lesions ('stem canker'). The most widespread of these fungi are *Botrytis cinerea* and *Macrophoma urenae*. Another disease is damping-off or seedling blight caused by *Fusarium* spp. In India *U. lobata* is attacked by *Corynespora callicioidea*, resulting in scattered, yellowish-red, irregular lesions on the leaves, with a black centre that develops into a hole. The fungal diseases can be controlled by treating seed with fungicides and by crop rotation. *U. lobata* is an alternate host for the okra mosaic virus.

U. lobata is attacked by some serious pests of cotton (*Gossypium* spp.), kenaf, roselle and ramie (*Boehmeria nivea* (L.) Gaudich.), such as cotton stainers (*Dysdercus* spp.) and leaf rollers (*Sylepta* spp.). *Dysdercus superstitiosus* can strongly reduce the viability of *U. lobata* seeds, but the fibre yield is unaffected. In Java (Indonesia) and India it is attacked by spiny bollworms (*Earias* spp.). In Thailand it is damaged by the leaf-sucker *Haedus vicarius*. Symptoms are white spots scattered over the upper surface of the leaves; severely infested leaves turn white, then pale yellow and fall off. *U. lobata* seems highly resistant to nematodes.

Harvesting To obtain the highest yield and the best quality of fibre *U. lobata* should be harvested when the plants are in full bloom. If harvested earlier, the fibre is finer but shorter and the yield is lower; if harvested later, the fibre is coarser, less white and shiny, and retting is more difficult. The plants are cut at about 20 cm above the ground, because the stem base is highly lignified and does not ret properly.

Yield Fibre yields of 0.5–1.5 t/ha are normally obtained from *U. lobata* in farmers' fields, whereas experimental yields of up to 3.6 t/ha have been recorded. Yields from wild stands are only about 0.3 t/ha. In India the cultivar JRU 415, spaced at 30 cm × 6 cm and fertilized with 60 kg N, 40 kg P and 60 kg K per ha, has yielded 2.85 t/ha. In experiments on newly cleared peat soils in Selangor (Peninsular Malaysia), with (suboptimal) fertilization of up to 110 kg N and 70 kg K per ha and a spacing of 30 cm × 15 cm with 2–3 seeds per hole, dry fibre yields of up to about 1 t/ha have been obtained. In Indonesia at the beginning of the 20th Century fibre yields of up to 1.2 t/ha were recorded.

Handling after harvest After harvest the plants of *U. lobata* are sometimes defoliated directly or after having been piled for 2–4 days to promote leaf shedding. Subsequently, the stems are tied in bundles with a diameter of 20–35 cm and retted in running or stagnant water for 8–20(–30) days, depending on water temperature and age of the stems. The bundles are suspended at least 10 cm below the water surface to prevent discolouration by sunlight, but above the bottom to prevent uneven retting or staining. The water should be clean and free of iron or other chemicals which can stain or change the colour of the fibre. After retting the fibre is stripped from the stem by hand, washed and dried in the sun. Sometimes the dry fibres are rubbed between the hands to increase lustre and suppleness and to remove any remaining extraneous matter. A raspador type of decorticator can also be used for fibre extraction. The fibres are graded according to quality, colour, length and strength, but grading systems vary among countries.

Genetic resources In view of its wide distribution, *U. lobata* does not seem threatened by genetic erosion. Small germplasm collections are kept at the International Jute Organization, Dhaka, Bangladesh, and the USDA (United States Department of Agriculture) Southern Regional Plant Introduction Station, Griffin, Georgia, United States.

Breeding The variability within *U. lobata* offers opportunities for selection. Cultivars with different growing period and fibre yield characteristics have been selected in various countries, such as 'JRU 415' in India.

Prospects *U. lobata* yields fibre of good quality, comparable to jute, suitable for making sacks and paper, but it is a smaller plant, giving lower yields per hectare. Therefore it seems attractive only where jute cannot easily be grown, e.g. in Malaysia. Until now the crop has not been commercially successful in South-East Asia, but its fibre qualities and its abundance (as a weed) could justify it as a potential domestic source of fibre.

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R.P. Escobin & S.H. Widodo

Wikstroemia Endl.

Prod. fl. Norfolk.: 47 (1833) ('*Wickstroemia*').

THYMELAEACEAE

$x = 9$; *W. indica*: $2n = 27$ (apomictic triploid), 28, 36, 52

Major species and synonyms

- *Wikstroemia indica* (L.) C.A. Meyer, Bull. Phys.-Math. Acad. Imp. Sci. St. Petersb. 1: 357 (1843), synonyms: *Daphne indica* L. (1753), *Wikstroemia viridiflora* Wallich ex Meisner (1841), *W. linearifolia* Elmer (1910).
- *Wikstroemia lanceolata* Merrill, Govt. Lab. Publ.

(Philip.) 29: 31 (1905), synonym: *W. angustissima* Merrill (1912).
- *Wikstroemia meyeniana* Warb., in Perkins, Fragm. fl. Philip.: 171 (1905), synonyms: *Daphne cannabina* auct. non Lour., Schauer (1843), *Wikstroemia longifolia* Lecomte (1915), *W. fenicis* Merrill (1918).
- *Wikstroemia ovata* C.A. Meyer, Bull. Phys.-Math. Acad. Imp. Sci. St. Petersb. 1: 357 (1843), synonyms: *Daphne indica* Blanco (1837), *D. foetida* Blanco (1837).

Vernacular names General: salago (En). Philippines: salago (Tagalog, Bisaya, Bikol).
- *W. indica*: small-leaf salago, tiebush (En). Indonesia: perapata, posi-posi (Sulawesi). Philippines: arandon (Ilokano), inyam (Panay Bisaya), salagong-liitan (Tagalog). Vietnam: (c[aa]y) gi[os], gi[os] m[os]c, gi[os] mi[eej]t.
- *W. lanceolata*: lance-leaf salago (En). Philippines: karanpinig (Negros), salagong-sibat (Tagalog), tuka (Ilokano).
- *W. meyeniana*: large-leaf salago (En). Philippines: sagu (Tagalog). Vietnam: (c[aa]y) t[os]c, gi[os] mi[ees]t, gi[os] qu[ee].
- *W. ovata*: round-leaf salago, oval-leaf salago (En). Brunei Darussalam: gelam hutan. Malaysia: pait-pait (Sabah). Philippines: arandon (Ilokano), dapnit, suka (Bontoc).

Origin and geographic distribution *Wikstroemia* comprises about 70 species and is widely distributed from East Asia at about 37°N southward through South-East Asia to Australia and across the Pacific to Hawaii. *W. indica* is widely distributed from India and Sri Lanka through South-East Asia to China and Taiwan, and to Australia, Fiji and the Cook Islands. In South-East Asia it occurs naturally in Thailand, Indo-China, Malaysia and the Philippines, whereas in Java (Indonesia) it has naturalized widely around the Botanical Gardens in Bogor and near Cipanas on Gunung Gede. *W. lanceolata* occurs in the Philippines (Palawan, Mindoro and Luzon) and Taiwan. *W. meyeniana* is found in Thailand, Cambodia, Vietnam and the Philippines. *W. ovata* grows in Borneo and throughout the Philippines.

Uses The inner bark of various *Wikstroemia* spp. yields a fibre which is an excellent raw material in the manufacture of high grade paper requiring strength and durability, such as paper currency, cheques and legal documents. It is also suitable for handmade paper. In mixtures with other fibres it can be used for paper of lesser quality. Salago fibre is also made into strong ropes and strings, e.g. in the Philippines and Vietnam. Other applications in the Philippines include fishing lines and nets, clotheslines, sacks, textile fabrics, mosquito nets, bags, wallets and hats. Applications elsewhere are in the production of Japanese sliding doors ('shoji'), kimonos and components for radios and microcomputers.

W. indica is used as firewood in Indo-China, where root decoctions are used to provoke vomiting in case of poisoning and crushed leaves are applied to treat furunculosis and phlegm. However, as the plants are rather poisonous, care should be taken when any part is used internally. In the Philippines, root decoctions of *W. lanceolata* are taken to treat amoebic dysentery, whereas *W. ovata* leaves are chewed and swallowed as a purgative, filings of the bark in water or wine are taken as a tonic, and fresh bark or branches are tied around the neck to relieve bronchial catarrh. Ground or pounded salago roots, leaves and stems are placed in porous containers to stupefy and catch fish.

Production and international trade In the Philippines salago is mainly harvested from the wild, the most commonly collected species being *W. indica* and *W. lanceolata*, but it is also grown commercially. Commercial production is mainly concentrated in Central Visayas. The annual quantity of baled salago fibre in the Philippines in 1990–1999 ranged from 800–950 t, of which 700–910 t came from Central Visayas. Annual exports of salago fibre in the same period ranged from 590–830 t, the countries of destination being China, Japan, South Korea, Taiwan and Thailand. Salago pulp was exported to Taiwan in 1998 (5 t) and 1999 (20 t). Most domestic consumption is by local producers of handmade paper. No statistics are available on salago production and trade in other countries.

Properties *Wikstroemia* bark yields a light-coloured, long, supple and strong bast fibre with a silky appearance. The ultimate fibre cells of *W. ovata* in the Philippines have been found to be (1.6–)2.9(–4.2) mm long, with a diameter of (3–)12(–21) μm, a lumen diameter of (1–)2(–4) μm and a cell wall thickness of 1–10 μm. In a comparative study in the Philippines, handsheets with a basic weight of 65 gsm made from *Wikstroemia* pulp (beaten to a freeness of 150–230 mL) had a tear index of 16.8 mN.m^2/g, a tensile index of 101 N.m/g and a folding endurance of 619. They were slightly inferior to handsheets made from abaca (*Musa textilis* Née) (18.5 mN.m^2/g, 106 N.m/g and 2127), but superior to those made from rice (*Oryza sativa* L.) straw and *Acacia mangium* Willd. wood

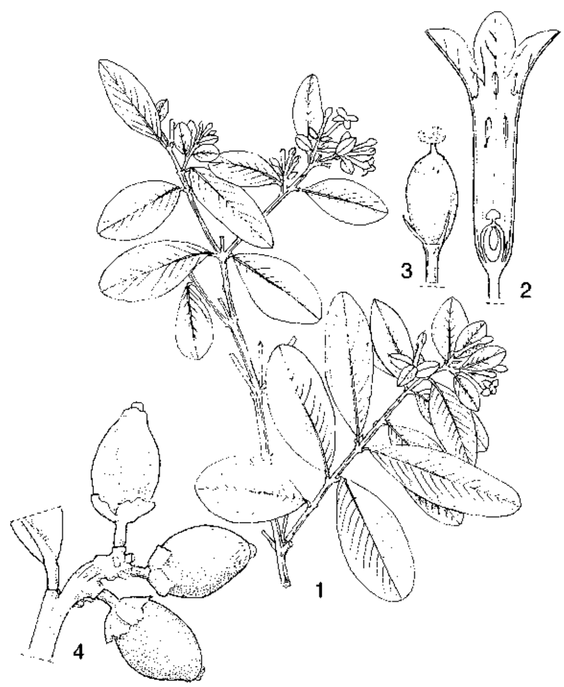
(3.7 and 6.9 mN.m²/g, 25 and 40 N.m/g, and 7 and 10, respectively).

All parts of *W. indica* are poisonous but fruits are more toxic than leaves and children have died from eating the fruits. The toxins are coumarin-like compounds which may cause internal haemorrhage and death to livestock. The dicoumarin daphnoretin, isolated from the stems of *W. indica*, has shown in vivo anti-tumour properties against Ehrlich ascites carcinoma in mice. Daphnoretin is a protein kinase C activator with suppressive effects on hepatitis B virus gene expression in human hepatoma cells and inducing respiratory burst. Tricin, kaempferol-3-O-β-D-glucopyranoside and (+)-nortrachelogenin (wikstromol) isolated from *W. indica* stems have antileukaemic properties. The lignan (+)-nortrachelogenin also has effects on the central nervous system, producing depression in rabbits. Daphnoretin, (+)-nortrachelogenin, genkwanol A, wikstrol A, wikstrol B and daphnodorin B isolated from *W. indica* roots showed antifungal activity, whereas (+)-nortrachelogenin, genkwanol A, wikstrol B and daphnodorin B were moderately active against human immunodeficiency virus type 1 (HIV-1) in vitro. Genkwanol A, wikstrol A and B and daphnodorin B showed moderate antimitotic activity. Wikstromin, a flavone glycoside isolated from the root bark of *W. indica*, showed diuretic action when intravenously injected in anaesthetized dogs. Despite the presence of anticarcinogenic compounds and reported anticancer activity of plant extracts, *W. indica* has also shown cancer-promoting effects in mice and rats and an activating effect on the Epstein-Barr virus.

Adulterations and substitutes As a raw material for currency paper and other specialty paper, *Wikstroemia* mainly has to compete with abaca, the dominant source, and hemp (*Cannabis sativa* L.).

Description Evergreen or deciduous shrubs or small trees. Leaves opposite or in whorls of 3, variable in texture and shape. Inflorescence terminal or axillary, in fascicles or solitary, arranged in or resembling a spike, raceme, umbel or head; flowers subsessile or with articulated pedicel, 4-merous, bisexual; floral tube corolla-like, usually with 4 spreading lobes; stamens 8, sessile or with filaments, in 2 distinct groups (inserted in tube, 4 upper, 4 lower), anthers basifixed; disk cup-shaped, deeply lobed or free and scale-like, crenate or dentate; pistil sessile, with 1-celled ovary, a short style and large subglobose stigma. Fruit drupaceous, pericarp fleshy or membranous, 1-seeded. Seed of same shape as fruit, black.

- *W. indica*. A shrub, up to 3 m tall, often dichotomously branched with black-brown branchlets, sometimes transversely fissured, scattered puberulous when young. Leaves subopposite, subcoriaceous, obovate to elliptic-oblong, 1–7 cm × 0.5–3 cm, shiny above. Inflorescence a 3–7-flowered raceme, subsessile, 3–6 mm long; pedicel up to 2 mm long, articulated below the middle; flowers about 1 cm long, green-yellow, lobes 2–3 mm long; stamens with very short filament, the 2 groups about 1 mm apart; disk consisting of 2 free linear scales 0.8 mm long; ovary 2 mm, style less than 0.5 mm long. Fruit ovoidal to broadly ellipsoidal, about 6 mm × 4 mm, red, sometimes at base surrounded by remnants of floral tube. Seed 3.5–5.5 mm long, black.
- *W. lanceolata*. A shrub, up to 4 m tall, young branches densely appressed pubescent. Leaves opposite, papery, lanceolate, 3–9 cm × 0.5–2.5 cm. Inflorescence umbelliform to shortly spicate, terminal, usually 3–5-flowered (rarely up to 20); peduncle 0–15 mm long, pedicel 1–1.5 mm, articulated at the middle or in upper half; flowers yellow-green, 6–15 mm long, lobes 1 mm long; disk consisting of 2 free linear scales. Fruit



Wikstroemia indica (L.) C.A. Meyer – 1, flowering branch; 2, longitudinal section through flower; 3, pistil with disk scales; 4, fruiting branch.

ovoidal, about 8 mm × 5 mm, red. Seed 6 mm long.

- *W. meyeniana*. A shrub, 1–3 m tall with sparsely pubescent to glabrous young branches. Leaves opposite, papery, oblong to lanceolate, 5–13 cm × 2–5 cm. Inflorescence umbelliform, 5–6(–10)-flowered; peduncle up to 3 cm, pedicel 1–2 mm long; flowers green-yellow, about 2 cm long, densely puberulous outside, lobes 2–3 mm long; stamens sessile or filament up to 0.5 mm long; disk consisting of 2 free oblong scales; ovary obovoidal, 2 mm long, style distinct, up to 1 mm long, stigma up to 0.5 mm in diameter. Fruit ovoidal, about 8 mm × 6 mm, red, surrounded at base by remnants of floral tube.
- *W. ovata*. A shrub, up to 5 m tall with glabrous to appressed-hirtellous branchlets. Leaves opposite, papery, ovate to oblong, 4–14 cm × 3–5 cm. Inflorescence terminal, short spicate or umbelliform, 7–20-flowered; pedicel articulated near the apex; flowers 1–2 cm long, green-yellow, lobes 2–4 mm long; disk consisting of 2 free oblong scales; ovary ellipsoidal, 2–3 mm long, style about 1 mm long, stigma capitate. Fruit subglobose to ellipsoidal, 8–10 mm × 6–8 mm.

Growth and development *Wikstroemia* seed usually germinates 7–15 days after sowing. The seedling grows slowly. In the Philippines plant height increases of 3–17 cm per month have been recorded in the first year after planting. Fruits are produced 6–9 months after planting and 30–35 days after flowering. The fruits ripen in about 20 days. *Wikstroemia* is probably insect-pollinated and the fruits are dispersed by birds or other animals. In Java *W. indica* flowers year-round. In Indo-China W. *meyeniana* flowers year-round and fruits from August to December. Apomixis has been found in *W. indica*. After cutting *Wikstroemia* new shoots will develop from the stump.

Other botanical information Within the *Thymelaeaceae*, *Wikstroemia* belongs to the subfamily *Thymelaeoideae* together with, among others, the fibre-yielding genera *Daphne* L., *Enkleia* Griff. and *Phaleria* Jack. In view of the minor differences between *Wikstroemia* and *Daphne* it has been suggested that the two be combined into a single genus, *Daphne*. All Malesian *Wikstroemia* species belong to the subgenus *Wikstroemia*. Specific delimitation in Malesian *Wikstroemia* is difficult. *W. indica* is highly variable in its vegetative parts but no well-defined infraspecific taxa can be distinguished.

The bark of *W. poilanei* Léandri is used for making cordage in Vietnam, whereas its root is credited with purgative properties. *W. ridleyi* Gamble is used in traditional medicine in Peninsular Malaysia: the pounded bark is applied to boils, and the leaves are considered aperient.

Ecology *Wikstroemia* occurs in primary and secondary forest at low and medium elevations, along roads and river banks, on marginal land, in coconut plantations and pasture land. Though it can grow in a range of rainfall conditions and in many soil types, the highest production is obtained on fertile, well-drained soils. *W. indica* grows in thickets and secondary vegetation, usually up to about 1300 m altitude, but sometimes as high as 2700 m altitude, for instance in Sulawesi (Indonesia) and New Guinea. It tolerates many soil types and occurs in various habitats, such as on sandy soils along the seashore, on limestone ridge tops, on granite peaks, along river banks and on open hillsides. *W. lanceolata* is commonly found on forested slopes up to 1300 m altitude. It is probably a short-day plant and it tolerates partial shading. *W. meyeniana* can be found over a wide range of ecological conditions, e.g. in humid primary forest, degraded formations and forest edges, and on many soil types, up to 1500 m altitude. *W. ovata* is found in thickets, primary and secondary forest up to 800 m altitude.

Propagation and planting *Wikstroemia* is normally propagated by seed, but vegetative propagation by stem cuttings is also possible. Ripe fruits are collected, macerated, and the seeds are separated from the pulp by hand, rinsed and then dried. Dried seeds can be stored temporarily or planted directly. In a Philippine study the germination percentage of seed stored for 5 months under ambient (27–30°C) and refrigerated (10–15°C) conditions was 40–50% and 80%, respectively. Planting is usually in a nursery in seedplots or in seedboxes containing 50% sand and 50% top soil. After germination the seedlings may be thinned out to a lower density and transplanted from seedboxes into plastic bags. Plants at least 20 cm tall can be planted out in the field 2–4 months later. The best time to plant salago in the field is at the start of the rainy season. The planting site should be cleared, all weeds removed and planting holes (20 cm × 20 cm × 20 cm) made 1 m × 1 m apart.

In vitro micropropagation of salago is possible. Node explants cultured in pure Murashige and Skoog (MS) medium formed leaves, and upon subculturing in MS medium with 0.5 or 1.0 g benzyladenine (BA) and 0.5 or 1.0 g naphthalene acetic acid (NAA) the node explants formed normally growing shoots.

Husbandry Weeding of *Wikstroemia* is necessary during early plant growth and dead seedlings may be replaced to maintain the plant density. No fertilizer recommendations are known to exist. Lateral sprouts develop one month after stem harvesting. Only 3–4 sprouts are maintained on small stumps while 5–7 sprouts are left in bigger stumps.

Diseases and pests The most common and destructive disease of *Wikstroemia* in the Philippines is stem rot caused by the fungus *Botryodiplodia theobromae*, which attacks all four *Wikstroemia* species treated here. It is characterized by wilting and drying of the leaves, followed by browning and drying of the stem and defoliation. The plant dies if the basal part of the stem is infected. Fungicides can protect plants from infection but cannot completely arrest the disease. Sanitation measures such as the removal and burning of diseased plant parts are recommended to limit the damage.
Aphids, locusts, mirid bugs, grasshoppers and mites attack salago plants and may be controlled using insecticides.

Harvesting For wild *Wikstroemia* plants, cutting depends on plant height and stem diameter. Salago gatherers in the Philippines usually fell the plant and strip off the bark with a knife, but sometimes the bark is stripped from unfelled plants. The bark is usually sold unprocessed to middlemen or buyers. Cultivated salago can be harvested 2 years after planting and the regrowth every 2 years thereafter. Cutting stems one month before the start of the rainy season has been recommended to ensure that the salago stumps survive and produce new shoots. The stems are cut diagonally 3–4 cm above ground level, after which all branches are removed. The stem and all branches with a diameter of at least 1 cm are cut into pieces 45 cm long and bundled together. Branches with a smaller diameter are used for other purposes, such as firewood.

Yield In the Philippines *Wikstroemia* reportedly yields up to 4–5 t/ha dry fibre at the first harvest with slightly higher yields at subsequent harvests, but these figures seem too high when compared to the yield of other perennial bast fibre crops, such as *Abroma augusta* (L.) L.f. and *Broussonetia papyrifera* (L.) L'Hér. ex Vent.

Handling after harvest *Wikstroemia* fibre is extracted either by the so-called 'hand-cleaned' (or 'direct') method or by the 'steam' (or 'boiling') method. The hand-cleaned method consists of directly peeling the bark off the stem, scraping the outer bark from the fibre and drying the fibre in the sun. In the steam method the stems and branches are steamed for about 2 hours in a container, without the stems touching the water, as this stains the fibre. After steaming the outer bark is removed from the stem by firmly gripping the stem with jute or plastic sacks in one hand and sliding it through the palm of the other hand. The fibre is then removed from the stem by scraping after which it is dried in the sun and bundled. The steam method is usually preferred because the fibre recovery is higher and the fibres can be stored for a longer time. The hand-cleaned method produces a white fibre which is susceptible to moulds and therefore cannot be stored for a long period. In the Philippines a grading system for salago fibre is available, consisting of 4 classes of hand-cleaned salago: SG-1 (salago superior), SG-2 (salago good), SG-3 (salago fair), SG-X (salago residual); and 4 classes of steamed salago: S-SG-1 (steamed salago superior), S-SG-2 (steamed salago good), S-SG-3 (steamed salago fair), S-SG-X (steamed salago residual). The exports of salago fibre from the Philippines in 1990–1999 mainly consisted of salago grade S-SG-3.

Genetic resources and breeding No germplasm collections or breeding programmes of *Wikstroemia* are known to exist.

Prospects Salago fibre remains in high demand in international markets, especially in Taiwan, Korea and Japan, which gives good prospects for *Wikstroemia* cultivation and fibre production in South-East Asia. To develop the salago industry, improved methods of bark harvesting, drying and storage should be promoted as well as better management techniques. New plantations must also be established because natural *Wikstroemia* populations have decreased due to continuous harvesting. In the Philippines support to the salago industry is provided by the Fiber Development Authority (FIDA) which conducts research to improve cultivation, processing and marketing. As well as good-quality fibre, *Wikstroemia* contains compounds that may have potential in drug manufacture. Pharmacological research has shown very interesting activities, such as antitumour, anti-HIV and antifungal properties, that deserve more attention.

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3 Minor fibre plants

Abelmoschus tetraphyllus (Roxb. ex Hornem.) R. Graham

MALVACEAE

Synonyms *Abelmoschus manihot* (L.) Medik. subsp. *tetraphyllus* (Roxb. ex Hornem.) Borss., *A. pungens* (Roxb.) Voigt, *Hibiscus tetraphyllus* Roxb. ex Hornem.

Vernacular names Philippines: annabo-a-dad-dakel (Ilokano). Thailand: po faai (northern), po kaeo (Phrae, Petchabun).

Distribution From Pakistan to northern Australia and southern China. Elsewhere it has been introduced and in some places it has naturalized (e.g. in Mexico). It is cultivated in India.

Uses White fibres from the bark are used for making ropes (the Philippines, India). Chewed seeds, applied to the site of the bite, are said to be effective against snake-poison (Mexico). Medicinal properties of leaves and roots have also been recorded.

Observations A shrub, 2–3 m tall. Stem erect, woody, branching, covered with prickly hairs. Leaves simple, alternate, very variable in shape, size and colour; stipules filiform or lanceolate, 5–12 mm long; petiole 3–25 cm long; blade linear, lanceolate, cordate, deeply lobed or parted with 3–7 segments. Flowers large, bell-shaped, 7–15 cm in diameter, axillary, solitary or in racemes; pedicel 1–5(–7) cm long; epicalyx segments 4–6(–8), free, ovate to oblong, 1–3 cm × 0.5–1 cm; calyx spathaceous, 2–3 cm long, splitting on one side, adnate to and falling with the corolla; corolla consisting of 5 large, obovate to orbicular petals, 3–8 cm in diameter, pale yellow with dark brown or reddish central spot; ovary superior, 5-celled; style surrounded by staminal column, 5-lobed; staminal column up to 3 cm long, white. Fruit an oblong-ovoid capsule, 3.5–6 cm × 2–2.5 cm, hairy, usually 5-angled and splitting into 5 segments, with numerous seeds. Seed spherical to reniform, 2–4 mm in diameter, black. *A. tetraphyllus* occurs up to 1600 m altitude, particularly in areas with seasonal rainfall. It is mainly found in secondary vegetation, waste places, clearings and fallowed land. *A. tetraphyllus* is considered by some as a subspecies of *A. manihot* (L.) Medik., comprising the wild forms of the species. *A. manihot* subsp. *manihot* comprises the cultivated forms which are used as a green vegetable, but which are better classified as a cultivar group.

Selected sources 19, 65, 66, 155, 95, 160, 189.

Abutilon theophrasti Medik.

MALVACEAE

Synonyms *Abutilon avicennae* Gaertner, *Sida abutilon* L.

Vernacular names China jute, Tientsin jute, Indian mallow (En). Velvetleaf (Am).

Distribution Probably native to the Mediterranean or to a wider area including temperate Asian and European countries. Cultivated and sometimes naturalized in Europe, Asia, America and Australia. In Malesia only recorded in Indonesia (Sumatra, Java, Sumbawa and Sulawesi).

Uses The bast fibre is made into sacks, coarse cloth, rugs, twine, rope, matting, slippers and fishing nets, either alone or blended with jute or kenaf. China jute is also used in paper making and for caulking. It does not seem to be used as a fibre plant in South-East Asia. The seeds are eaten, e.g. in China and Kashmir.

Observations An annual herb, up to about 1 m tall in Malesia, elsewhere up to 3–6 m tall. Leaves simple, often slightly 3-lobed, spirally arranged; stipules linear to filiform, about 8 mm long; petiole 0.5–30 cm long; blade orbicular, 1.5–18 cm in diameter, base deeply cordate, margin irregularly crenate to dentate, apex long-narrowly acuminate, 7–11-veined. Flowers solitary, axillary or by development of an accessory bud in few-flowered racemes; calyx campanulate, 5-fid, about 13 mm in diameter; corolla yellow, about 2 cm in diameter, petals widely obovate or orbicular; staminal column 2–3 mm long. Fruit a schizocarp, mericarps 10–16, 11 mm × 6 mm, at apex with 2 beaks.

Seed obliquely reniform, about 3.5 mm across, dark brown, puberulent. *A. theophrasti* is generally grown in areas with a mean temperature of 22–25°C during the growing season, and a monthly rainfall of 140–210 mm in this period. It requires moist alluvial soils or friable loams. The main production areas are at higher latitudes. In Malesia, China jute is found in areas with a distinct dry season or (in Sumatra) at high altitude. Premature flowering has been recorded in Taiwan at 23°N, and it is probably, like many other *Malvaceae*, a short-day plant. The main producers are China and the former Soviet Union. In China the plants are harvested at full flowering. The fibre is extracted by retting followed by hackling. The ultimate fibres are 2.5–4.5 mm long and about 18–19 μm wide. On a dry matter basis seeds in the United States contained 15.3% oil and 23.1% protein. The main fatty acids of the seed oil are linoleic acid (60.9%), palmitic acid (12.8%) and oleic acid (14.8%). China jute is an important weed of cotton, maize, sorghum and soya bean in the United States.

A. grandifolium (Willd.) Sweet (synonym: *Sida grandifolia* Willd.) is native to South America and cultivated in the tropics as an ornamental or fibre; it seems to be grown sometimes in Java (Indonesia) and Luzon (the Philippines), but it is not clear for which purpose. *A. indicum* (L.) Sweet is sometimes cultivated as a fibre plant, e.g. in India and East Africa; its primary use in South-East Asia is medicinal.

Selected sources 31, 42, 66, 94, 144, 164, 189, 191, 197.

Agave vivipara L.

AGAVACEAE

Synonyms *Agave angustifolia* Haw., *A. rumphii* Hassk., *A. zapupe* Trel.

Vernacular names Dwarf sisal, dwarf aloe. Indonesia: nanas domba (Javanese).

Distribution Originated in Mexico (Yucatán), but has widely naturalized in the tropics. In the Philippines, India, Mexico and Cuba cultivated as a fibre plant. Locally grown as an ornamental or for fencing in Java, where it also has naturalized.

Uses In Indonesia leaf fibres from wild plants or from planted hedges are sometimes made into rope. In Semarang (West Java, Indonesia) they have been extracted from the leaves on a rather large scale, by scraping with a knife or piece of bamboo, to be exported. In Malaysia, Indonesia, India and Madagascar *A. vivipara* is frequently grown as a hedge plant, e.g. along railway lines in India. In Mexico the leaves are used for the production of the alcoholic beverage 'mezcal'.

Observations A robust, perennial, monocarpic herb, 2.5–4 m tall when flowering, producing subterraneous, short stolons and suckers, and numerous, crowded leaves in a rosette; stem in older plants 25–50 cm long. Leaves numerous, almost straight, combined into a dense spreading crown, sessile; blade lanceolate with gradually narrowed base and apex, 40–80 cm × 5–10 cm, margin straight but with weak to moderately strong spines, apex ending in a 1–2 cm long spine, glaucous or grey-green, channelled but flat at top. Inflorescence a panicle, up to 3.5 m long (including 2.5 m long peduncle); branches widely patent, at apex repeatedly trichotomously branched; perianth tubular with 6 lobes, 4.5–5 cm long (including 1–2 cm long ovary); tube 0.5–1 cm long; lobes oblong-lanceolate, 2–2.5 cm long, green or brown, hardened apex with minute hairs, 3 outer lobes somewhat longer than 3 inner ones; stamens 6; pistil with inferior ovary, filiform style and obtusely 3-lobed stigma. After flowering bulbils are often produced on the inflorescence branches. Fruit a cylindrical capsule, 4 cm × 2.5 cm, longitudinally furrowed, shortly beaked, with numerous seeds. Seed dull black. The rate of leaf production of *A. vivipara* is very high and plants produce over 500 leaves during their life cycle. However, the leaves are short and spiny and the plant is not useful for commercial fibre production. The leaves contain 3–3.5(–5)% of a short and fine fibre. The leaves contain the steroidal sapogenins hecogenin, tigogenin, gitogenin and chlorogenin. *A. vivipara* is sexually fertile and has been used for crossing in sisal breeding. The hybrid '11648', obtained in East Africa by backcrossing a hybrid of *A. amaniensis* Trel. & Nowell and *A. vivipara* with *A. amaniensis*, has largely replaced *A. sisalana* Perrine in Tanzania. *A. vivipara* is presumably the ancestor of *A. fourcroydes* Lem., an important fibre plant grown in Central America and the Caribbean. *A. vivipara* var. *letonae* (Taylor ex Trel.) P.I. Forst. (synonym: *A. letonae* Taylor ex Trel.), known as 'Salvador henequen' used to be of considerable economic importance for fibre production in El Salvador and is also cultivated in Guatemala.

Selected sources 6, 20, 25, 31, 52, 60, 66, 69, 71, 75, 94, 104, 137, 139, 143, 159, 195, 196, 198.

Agelaea borneensis (Hook.f.) Merr.

CONNARACEAE

Synonyms *Agelaea everettii* Merr., *A. vestita* Hook.f., *Hemiandrina villosa* Schellenb.

Vernacular names Indonesia: akar sebasa itam, kayu poyoh (Sumatra), akar itam (Bangka). Malaysia: akar rusa-rusa, akar kachang-kachang, akar telur bujok (Peninsular). Philippines: kamagsa (Tagalog), balagum (Bisaya), ngaluk (Ibanag).

Distribution Peninsular Thailand, Peninsular Malaysia, Singapore, Sumatra, Bangka, western Java, Borneo and the Philippines; possibly also peninsular Burma (Myanmar).

Uses In Sumatra, Borneo and the Philippines the tough stems and branches are used for ropes; they are durable in water, and used in tying rafts and hoop-nets. *A. borneensis* stems have been holding and supporting the church bells in Tayabas, Quezon (the Philippines) for at least 200 years.

Observations A liana or scrambling shrub; stem up to 10 cm in diameter, young branches densely fulvous-tomentose. Leaves 3-foliolate, without stipules; leaflets up to 33 cm × 14 cm. Flowers in a lax axillary panicle, bisexual, (4–)5-merous, heterostylous, with (5–)10 stamens and 5 pistils. Fruit consisting of 1–5 follicles up to 2.5 cm long, smooth to tuberculate, densely pubescent, 1-seeded. Seed obovoid, basal half covered by a sarcotesta. *A. borneensis* occurs in primary and secondary rain forest up to 700 m altitude.

Selected sources 17, 19, 20, 45, 47, 49, 71, 115.

Agrostistachys sessilifolia (Kurz) Pax & K. Hoffm.

EUPHORBIACEAE

Vernacular names Malaysia: julong-julong, nulong, nyonyolong.

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo.

Uses The leaves are used for thatching and wrapping.

Observations A dioecious shrub, up to 6 m tall, with grey bark. Leaves alternate to distichous to spiral; stipules triangular, late caducous; petiole 2–5 mm long; blade linear to obovate, 25–55 cm × 7–9.5 cm, base emarginate to rounded, margin entire to crenulate, apex acuminate to cuspidate. Inflorescence a bracteate spike, axillary, single, up to 60 cm long; male flowers about 4 mm × 2 mm, sepals 2 or 3, petals 5, stamens 8–10 in 2 whorls; female flowers about 3 mm × 3 mm, sepals 5, petals 2–2.5 mm long. Fruit a crustaceous capsule, up to 1 cm in diameter. *A. sessilifolia* occurs in shaded areas in forests at altitudes up to 150 m. Flowering and fruiting is year-round. The fruits are eaten by birds. The distribution of the related species *A. borneensis* Becc. and *A. gaudichaudii* Müll. Arg. overlaps with that of *A. sessilifolia*. The same vernacular names apply to all three species and confusion of the species in the older literature is likely.

Selected sources 20, 153, 163.

Areca vestiaria Giseke

PALMAE

Synonyms *Areca langloisiana* Potztal, *Mischophloeus vestiaria* Merr., *Seaforthia vestiaria* Mart.

Vernacular names Indonesia: pinang merah, lanut (Sulawesi), eslait (Buru).

Distribution Native to Indonesia (North Sulawesi, the Moluccas). Cultivated in Indonesia and elsewhere as an ornamental.

Uses In Sulawesi and the Moluccas (Buru) the epidermis of young, unfolded leaves yield fine, white thread which is made into clothes and covers for pillows and mattresses. In Tondano (Sulawesi) the scraped stem of *A. vestiaria* is pounded into a fibrous mass which is used for making rope. The leaves are used to thatch temporary shelters.

Observations A non-tillering palm with stilt roots; stems clustered, up to 10 m tall, about 10 cm in diameter; crownshaft orange-red. Leaves pinnate, up to 2 m long; petiole short; leaflets obliquely truncate, praemorse, very broad, dark green. Inflorescence branched, arising below crownshaft; flowers unisexual, cream. Fruit orange-red, 2 cm × 1 cm. *A. vestiaria* occurs wild in rainforest at 300–1200 m altitude. It is very colourful at altitudes between 600 and 1200 m, but at lower altitudes the colour is less spectacular. In cultivation it requires shade and prefers soils with a high organic-matter content. To obtain thread, the fleshy parts of the leaves are scraped off and the epidermis is torn into strips which are dried in the sun, tied together and twisted into thread. The material may be bleached in the sun or dyed.

Selected sources 8, 41, 71, 80, 90, 91.

Artocarpus blancoi (Elmer) Merr.

MORACEAE

Synonyms *Artocarpus communis* J.R. Forster & G. Forster var. *blancoi* Elmer, *A. incisa* L.f. var. *blancoi* Elmer ex Merr.

Vernacular names Philippines: tipolo (general), antipolo (Tagalog).

Distribution Throughout the Philippines.

Uses The bast is made into weak ropes, which have, for instance, been used for yoking buffaloes. The wood is locally used for light constructions.

Observations A medium-sized, evergreen, dioecious tree, up to 15(–30) m tall, exuding white latex when wounded. Leaves arranged spirally; blade ovate-elliptical, 20–60 cm × 20–40 cm, base cuneate to rounded, margin entire or pinnatifid with 1–3(–4) pairs of lateral lobes, apex acute, almost glabrous above, pubescent throughout below, with about 12 pairs of secondary veins. Inflorescence capitate, solitary, axillary; numerous flowers densely packed together, embedded in the receptacle, the perianth enclosing a single stamen or ovary, mixed with abundant stalked interfloral bracts; male head cylindrical, 10–21 cm × 1–2 cm, on a 17–37 mm long peduncle; female head with bifid styles. Fruit an ellipsoid syncarp, up to 10 cm × 6.5 cm, yellow-brown, covered with flexuous, tapering, obtuse processes ('spines') 8–15 mm long, with rough, inflated hairs, with scattered interfloral bracts and with numerous non-fleshy fruiting perianths with free proximal region. Seed (pericarp) ellipsoid, 12 mm × 9 mm. *A. blancoi* occurs in lowland forest and thickets, in areas with a distinct dry season and an annual rainfall of 2000 mm or more. Rope made from the bast of old trees is reputedly stiff and durable, whereas that from young trees is more pliable. However, in Philippine studies in the 1910s, there was little difference in the tensile strength of dry rope made from old and young trees (367 and 356 kg per cm^2, respectively). Wet rope made from young bast had a tensile strength of 340 kg per cm^2; that of old bast was not tested in a wet state. The elongation at break was 11% and 15% for dry and wet rope from young bast, respectively; rope from old bast was not tested. The ultimate fibres of the wood are (1.5–)1.7(–1.8) mm long and 29 μm wide, with a lumen width of 20 μm and cell walls 4.5 μm thick. An extract of the bark has shown high antimicrobial activity against *Mycobacterium tuberculosis*.

Selected sources 11, 19, 86, 93; 99, 115, 186.

Artocarpus rubrovenius Warb.

MORACEAE

Vernacular names Philippines: kalulot (general), anubing (Tagalog), anabling (Bikol).

Distribution The Philippines (Luzon).

Uses The bark has been used for the manufacture of cloth and is recorded to have medicinal properties. The wood is used for light construction.

Observations A medium-sized, dioecious, evergreen tree up to 15(–30) m tall, with bark mottled grey and brown, exuding a white latex when wounded. Leaves distichous, stipules not amplexicaul; blade ovate to elliptical, 11–26 cm × 5–14 cm, base broadly rounded to cuneate, margin entire, apex long acuminate, glabrous, with 8–13 pairs of secondary veins. Inflorescence capitate, axillary, solitary or in pairs; numerous flowers densely packed together, embedded in the receptacle, the perianth enclosing a single stamen or ovary, mixed with abundant stalked interfloral bracts; male head obovoid to clavate, 1.5–4.5 cm × 1–2 cm on a 1.5–3 mm long peduncle; styles in female head simple. Fruit a subglobose or shallowly lobed syncarp, up to 3 cm in diameter, on a 0.5–1 cm long peduncle, brown, nearly smooth, short pubescent, with numerous persistent bracts. *A. rubrovenius* occurs in forest up to 350 m altitude.

Selected sources 19, 87, 99, 115.

Artocarpus tamaran Becc.

MORACEAE

Vernacular names Malaysia: timbangan (Sabah), tamaran, tembaran (Sarawak).

Distribution Endemic in Borneo.

Uses The bast is made into very good barkcloth. The timber is used and traded under the name of terap.

Observations A dioecious, evergreen tree up to 40 m tall, bole up to 100 cm in diameter, bark grey-brown, exuding white latex when wounded, buttresses up to 3 m tall. Leaves spirally arranged, simple, but leaves of juvenile trees deeply pinnately lobed and up to 1 m long; stipules amplexicaul, lanceolate, 3–18 cm long; blade ovate to elliptical, 20–35 cm × 11–17 cm, margins lobed, glabrous above, the main veins appressed sericeous below, with (15–)17–23 pairs of secondary veins. Inflorescence capitate, solitary, axillary; numerous flowers densely packed together, embedded in the receptacle, the perianth enclosing a single stamen or ovary, mixed with abundant stalked interfloral bracts; male head cylindrical, 7 cm × 1–1.5 cm on a 3–5 cm long peduncle; styles in female head simple and exserted. Fruit a cylindrical syncarp, up to 10 cm × 5 cm, on a 5–10 cm long peduncle, brown, covered by processes ('spines') of 2 lengths, the longer flexuous, filiform, solid, up to 1 cm long, the shorter conical, perforate, up to 3 mm long, both rough from short recurved hairs. Seed (pericarp) ellipsoidal, 6 mm × 4 mm. *A. tamaran* is found in mixed dipterocarp forest in lowland and hills, up to 600 m altitude.

Selected sources 20, 86, 99, 135, 139, 161.

Bauhinia bidentata Jack

LEGUMINOSAE

Synonyms *Bauhinia cornifolia* Baker.

Vernacular names Pride of Selangor (En). Malaysia: katup-katup, ketup-letup, dedaup. Thailand: chong-kho paa dok daeng (peninsular), lep krarok (Pattani), lep kwhwaai lek (Yala).

Distribution Nicobar Islands, southern Thailand, Malaysia and Indonesia (Sumatra).

Uses The long flexible stems are used for tying fences and are very durable. The use of the roots against toothache and of unspecified parts for nervous complaints is recorded from Malaysia. It is appreciated as an ornamental but difficult to propagate vegetatively and hence rare as a garden plant.

Observations A large-tendrilled liana with glabrescent young branches. Leaves alternate; stipules about 5 mm long, early caducous; petiole 1.5–2.5 cm long; blade orbicular, ovate or elliptical, up to 14.5 cm × 12 cm, base cordate to truncate, apex entire, emarginate or shallowly bifid, 4–9-veined. Inflorescence corymbose; flower buds ovoid, apiculate, hypanthium tubular; flowers bisexual; calyx splitting into 3(–4) reflexed lobes; petals 5, unequal, obovate, 15–22 mm long, claw short, yellow turning red; stamens 3, staminodes 2–7, much smaller than stamens; ovary 3–5 mm in diameter, stipe about 3 mm long. Fruit a legume, oblong, up to 10 cm long, glabrous, up to 5-seeded, dehiscent. Seed flat, about 1 cm in diameter. Based on the hairiness of filaments, flower buds and leaf-blade shape, *B. bidentata* has been subdivided into 7 varieties. Of these varieties 5 are restricted to lowlands, and 2 to altitudes of over 1000 m.

Selected sources 20, 47, 49.

Bauhinia fabrilis (de Wit) K. Larsen & S.S. Larsen

LEGUMINOSAE

Distribution Malaysia (Sabah).

Uses The stems are used for weaving fences and for tying floor materials.

Observations A large-tendrilled liana, young branches quadrangular. Leaves alternate; stipules 3 cm × 1 cm, early caducous; petiole 5–8 cm long; blade broadly ovate, 8–15 cm long, base deeply cordate, apex incised up to half of the blade length, 15–17-veined. Inflorescence corymbose when young, axis lengthening up to at least 15 cm; flower buds clavate, hypanthium tubular; flowers bisexual; calyx splitting into 5 sepals; petals 5, spatulate, about 2 cm long, claw 5–7 mm long, white to yellow; stamens 3, staminodes 2; ovary about 10 mm long, stipe 5–7 mm long. Fruit unknown. *B. fabrilis* is restricted to low altitude primary forest.

Selected sources 47.

Bauhinia integrifolia Roxb.

LEGUMINOSAE

Synonyms *Bauhinia cumingiana* (Benth.) Fern.-Vill., *B. flammifera* Ridley.

Vernacular names Malaysia: akar katup-katup, ketup-ketup, kekatup. Philippines: banot, agpoi (Tagalog), uplig (Ilokano). Thailand: ku-kuu kuu-do (Malay-Pattani), chongkho yaan (Trang), yothakaa (Bangkok).

Distribution Southern Thailand, Peninsular Malaysia, Sumatra, Borneo and the Philippines.

Uses The durable stems are used for tying and the strong bast is made into rope and bowstrings. Juice extracted from the leaves is used for stomach disorders in Johor (Peninsular Malaysia). A decoction of the roots is applied in the Philippines as a post-partum medicine and to treat coughs.

Observations A large-tendrilled liana with rusty-woolly, grooved young branches. Leaves alternate; stipules minute, early caducous; petiole 1–5 cm long; blade ovate to orbicular, 6.8–12.4 cm × 7.5–12.5 cm, base deeply cordate, apex entire, emarginate, shallowly or deeply bifid, 9–11-veined. Inflorescence a more or less dense panicle composed of corymbose racemes; flower buds globose, ovoid or ellipsoid, hypanthium tubular; flowers bisexual; calyx splitting into 2(–3) lobes; petals 5, obovate, 8–15 mm long, claw short, orange turning red; stamens 3, staminodes 2, minute; ovary subsessile, rusty-woolly. Fruit a legume, oblong, up to 20 cm × 5 cm, glabrescent, 5–8-seeded, dehiscent. Seed ovate-orbicular, about 2 cm in diameter. *B. integrifolia* is a common lowland species, found up to 1200 m altitude.

Selected sources 19, 20, 47, 49, 100, 115.

Bauhinia pottsii G. Don

LEGUMINOSAE

Synonyms *Bauhinia elongata* Korth.

Vernacular names Indonesia: sebari (Javanese), sobheuri (Kangean). Cambodia: choeung kôô (Koh Kong). Thailand: chongkho dam (Trang), chongkho (Trat & Ranong), chongkho khaao (Central).

Distribution Burma (Myanmar), southern and south-eastern Thailand, southern Cambodia, Peninsular Malaysia, Sumatra, Java and Borneo.

Uses The very tough bast is applied for tying. The leaves are used as cigarette paper.

Observations A shrub, tree or straggling tree with glabrescent young branches. Leaves alternate; stipules minute, early caducous; petiole 3–6 cm long; blade ovate to rotundate, 9–14 cm × 10–15 cm, base cordate, apex bifid up to half of the blade length, lobes rounded, 11–15-veined. Inflorescence a lateral or terminal raceme; flower buds elongate, 3–4 cm long, hypanthium tubular; flowers bisexual; calyx splitting into 2–5 segments; petals 5, 4–6 cm long; stamens 3, staminodes few; ovary 1–1.5 cm long, stipe 1–2 cm long. Fruit a strap-shaped legume, broadest towards apex, 4–6-seeded, dehiscent. Seed orbicular, up to 1.5 cm in diameter. Based mainly on length of the petal claw, petal colour and hairiness of leaf and ovary, 5 varieties are distinguished. *B. pottsii* occurs at lower altitudes, usually along forest margins, rivers, ditches and in swamps.

Selected sources 16, 47, 50, 71, 97.

Bauhinia scandens L.

LEGUMINOSAE

Synonyms *Lasiobema scandens* (L.) de Wit

Vernacular names Snake climber (En). Indonesia: areuy kupu-kupu (Sundanese), ping-keping (Madurese), daun lilin. Thailand: kradai wok (northern), chok-nui (Chaobon-Chaiyaphum), ma luem dam (Chiang Mai). Vietnam: a re an, re e cao (Thuân Hai), rönyan aro' (Jârai, Dac Lac).

Distribution From India through Burma (Myanmar), southern China, Indo-China and Thailand to Indonesia (Sumatra, Java, Madura, Sumba).

Uses The long stems are used as strong ropes. Juice extracted from the stem is applied to treat coughs in Java. Also young branches are chewed or taken as dried powder against coughs.

Observations A large, woody liana, up to 50 m long with glabrescent young branches, old branches flattened, undulated. Leaves alternate; stipules minute, early caducous; blade very variable, 5–12 cm × 6–10 cm, base cordate to truncate, apex entire, bilobed or consisting of 2 leaflets, 7-veined. Inflorescence a panicle composed of many-flowered, narrow racemes; flower buds globose, 1–2 mm in diameter, hypanthium very short turbinate; flowers bisexual; calyx cup-shaped with 5 teeth; petals 5, obovate, 2–3 mm long, claws very short, yellowish-white; stamens 3, staminodes 2, minute; ovary 1 mm long, stipe 1 mm long. Fruit a more or less elliptical legume, up to 4 cm × 2 cm, glabrous, 1–3-seeded, tardily dehiscent. Seed oblong, about 6 mm in diameter. *B. scandens* prefers a seasonal climate and is absent from the evergreen forest of Peninsular Malaysia. It seems most frequent on limestone. In Java it occurs up to about 800 m altitude.

Selected sources 6, 47, 50, 71.

Boehmeria macrophylla Hornem.

URTICACEAE

Synonyms *Boehmeria platyphylla* Buch.-Ham. ex D. Don, *B. pilosiuscula* (Blume) Hassk.

Vernacular names African jolanettle (En). Indonesia: celengan (Javanese), guntalian (Sundanese), nanasi utan (Manado). Thailand: chaa paan, paan (northern).

Distribution From tropical Africa through Asia to Australia and the Pacific. In South-East Asia: Indo-China, Peninsular Malaysia, Indonesia (Java, Sulawesi), the Philippines.

Uses In Indonesia and elsewhere (e.g. Pakistan) the bast is made into rope.

Observations A monoecious shrub, up to 3 m tall. Leaves simple, opposite; stipules lanceolate, 6–8 mm long; petiole 2.5–5(–15) cm long; blade ovate, 15–30 cm × 7–15 cm, base broadly cuneate, margin serrate, apex acuminate to attenuate, 4–5 pairs of lateral veins. Inflorescence a pendulous spike in upper leaf axils, 30(–50) cm long; male flowers mainly at the base of the spike, subsessile, 1–2 mm long; female flowers sessile, 1–3 mm long.

Fruit an ovoid, slightly compressed achene, 2–3 mm long. *B. macrophylla* is a highly variable species and a number of varieties have been distinguished. In the Philippines it is found in thickets and open locations at low and medium altitudes. To prepare rope from *B. macrophylla* in Indonesia, the outer bark is removed, the bast is taken from the wood, dried, and twisted into rope. In studies in Indo-China in the 1940s, the bark of *B. macrophylla* yielded about 13% fibre. Rough bark strips contained 15% moisture, 35% cellulose, 7% hemicelluloses, 12% lignin and 10% ash. After degumming the fibre contained 8% moisture, 61% cellulose, 5% hemicelluloses and 2% lignin.

Selected sources 6, 15, 21, 48, 55, 56, 59, 71, 102, 114, 124, 160, 197.

Byttneria maingayi Masters

STERCULIACEAE

Vernacular names Malaysia: akar kachubong, akar batu, akar perut gagak.

Distribution Peninsular Malaysia.

Uses The tough stems are used for tying fences, for which purpose they are very suitable.

Observations A stout, woody liana. Leaves alternate, simple; petiole about 2.8 cm long; blade elliptical to oblong, up to 20 cm × 9 cm, base rounded, apex shortly blunt-acuminate. Inflorescence an axillary, much-branched cyme; sepals 5, about 6 mm long, connate at base; petals 5, white, clawed, with 2 small side lobes and a long terminal appendage. Fruit a globose, spiny capsule, up to 3.2 cm in diameter, green with red ribs. *B. maingayi* is widespread in lowland forest margins. *B. curtisii* Oliver, a slender liana, less common than *B. maingayi*, may have similar uses.

Selected sources 20, 147.

Cayratia geniculata (Blume) Gagnep.

VITACEAE

Synonyms *Cissus geniculata* Blume, *C. rhodocarpa* (Blume) Gagnep., *Vitis geniculata* (Blume) Miq.

Vernacular names Indonesia: lakum (Malay), areuy ki barera (Sundanese), lunda (Javanese).

Distribution Sumatra, Java, Borneo and the Philippines.

Uses In Indonesia the stems, twisted together, are used as rough, strong rope. In Sumatra the fruit is boiled with vegetables to give them a slightly sour taste.

Observations A perennial liana, 2–10 m long; tendrils 1–3-times forked, sometimes ending in an adhesive disk. Leaves alternate, digitately 3-foliolate; leaflets 5–17 cm × 2.5–10 cm, margin dentate-crenate-serrate, glabrous or pubescent. Inflorescence an axillary, pendulous, leaf-opposed or seemingly terminal corymbiform cyme, glabrous or pubescent; peduncle long, articulate, furcate, upcurved at the apex, usually geniculate; flowers bisexual, 4-merous; calyx subtruncate; petals free, patent, or reflexed, 3–3.5 mm long, green with a pale base, glabrous on the back; disk cupular, adnate to the base of the ovary, thin-margined, bright yellow; ovary 2-celled, cells 2-ovuled, style terete, stigma small. Fruit a transversely ellipsoid berry, 15–26 mm in diameter, pale red, 2–4-seeded. Seed with a linear chalaza on the back and 1–2 deep cavities on the ventral side; albumen U or T-shaped on transverse section. *C. geniculata* occurs in brushwood and young forest up to 1500 m altitude. In Java it flowers throughout the year. *C. japonica* (Thunb.) Gagnep. is used in South-East Asia as a medicinal plant and for tying.

Selected sources 6, 71, 191.

Ceiba trischistandra (A. Gray) Bakh.

BOMBACACEAE

Synonyms *Eriodendron trischistandra* A. Gray.

Distribution Peru and Brazil. Occasionally cultivated elsewhere, e.g. in Java.

Uses The fruit yields a white fibre, which is of much lower quality than that of kapok (*Ceiba pentandra* (L.) Gaertn.).

Observations A tree, 10–20 m tall, with large buttresses and main branches in young trees erecto-patent. Leaves spirally arranged, palmately compound; petiole 10–15 cm long; leaflets 5–9, oblong-obovate, 6–12 cm × 2–5 cm, caudate. Flowers solitary or in clusters of 2–3, usually 5-merous, bisexual, regular, yellow-white; pedicel up to 4 cm long; calyx 3–4 cm long, densely rufous-pubescent; petals obovate, 5–6 cm long; staminal tube bearing apically 5 fascicles of 3 filaments each; style 6–8 cm long. Fruit a woody capsule, cylindrical-obovoid, 15–17 cm × 7–8 cm, pendulous, 5-valved, inside densely covered with white wool, many-seeded. Seed embedded in the wool (floss). *C. trischistandra* prefers a dry tropical climate, and growth in West Java is poor. In Central Java it flowers in May–July.

Selected sources 6, 66, 71, 190.

Chonemorpha fragrans (Moon) Alston

APOCYNACEAE

Synonyms *Chonemorpha macrophylla* (Roxb.) G. Don

Vernacular names Indonesia: bangi, plumbangan (Javanese), baneh (Madurese). Malaysia: akar gerit-gerit merah, akar gerip merah.

Distribution India, Sri Lanka, Burma (Myanmar), southern China, Thailand, Malaysia and Indonesia.

Uses The bark contains a high-quality fibre, which is durable in both fresh- and salt water and is made into fishing nets, e.g. in East Java. The stem yields latex from which rubber of varying quality can be obtained. *C. fragrans* is cultivated as an ornamental for the handsome sweet-scented flowers.

Observations A liana up to 30 m long, often clinging to trees. Leaves opposite; petiole up to 2 cm long; blade suborbicular to broadly ovate, 15–45 cm × 13–45 cm, base cordate, apex acute or rounded, cuspidate, lateral veins 10–12 pairs. Inflorescence a terminal cyme; calyx tubular, about 1 cm long, 5-toothed; corolla white, tube 3.5–4.5 cm long, dilated at base, limb up to 8 cm wide, lobes obliquely obovate, about 3.5 cm long, glabrous outside, throat villous. Fruit a pair of cylindrical to fusiform follicles, each up to 30 cm × 2 cm. Seed oblong, coma about 5 cm long. *C. fragrans* occurs in dense montane forest. In Sri Lanka it occurs at altitudes up to 800 m in primary forest but is more abundant in lowland secondary forest. Flowering is from March to May in Sri Lanka, and from May to July in southern China. In East Java the fibre of *C. fragrans* is obtained by exposing the stems to the sun, after which the bark is peeled off and the fibres are isolated from the bark. Collection of the latex is difficult because it coagulates rapidly. Chonemorphine, a steroidal alkaloid isolated from the roots of *C. fragrans*, has shown in vivo anti-amoebic properties.

Selected sources 6, 20, 22, 30, 39, 71, 109, 117, 154, 201.

Colona auriculata (Desf.) Craib

TILIACEAE

Synonyms *Columbia auriculata* (Desf.) Baill., *Diplophractum auriculatum* Desf.

Vernacular names Indonesia: nilau kucing (Palembang), dhalubang tali (Madurese), dalupang (Kangean). Cambodia: préal, prial venh ksè. Thailand: po phran (eastern, north-eastern), po thi (eastern), khi ma haeng (northern).

Distribution Indonesia (Madura and Kangean Archipelago), Thailand and Indo-China.

Uses The bast is made into good-quality rope. Timber is used for cabinet work in Thailand.

Observations A multi-stemmed shrub, up to 4 m tall. Stems drooping to all sides, long, rather thin, with a very tough bark. Leaves distichous; petiole 2–8 mm long, hairy; blade oblong to obovate-oblong, 4–28 cm × 1–7 cm, base unequal-sided cordate and broadly auriculate, margin doubly serrate, acute to caudate at the apex, densely villose at lower surface, 3-veined at base, secondary veins 3–7 pairs, scalariform and reticulate veins distinct and depressed on upper surface. Inflorescence axillary, in 1–3-flowered cymes, 2–3 cm long, sometimes collected into a racemiform terminal panicle, densely soft-hairy; pedicel 1–1.5 cm long; flowers bisexual; sepals 5, free, oblong-lanceolate, 8–10 mm long; petals 5, free, oblanceolate to spatulate, 5 mm × 1.5 mm, whitish, bearing a gland at base inside; receptacle columnar; stamens on apex of receptacle, numerous, free, glabrous; ovary ovoid, 3 mm × 2 mm, 5-celled, hairy; style filiform, stigma small, 5-dentate. Fruit subglobose, 1.5–2.5 cm in diameter, with 5 small, longitudinal, undulate wings or ridges, brown hairy, dry, hard, indehiscent, divided into many 1-seeded persistently connate mericarps. In Indonesia *C. auriculata* often grows gregariously, locally abundant, up to 300 m altitude on periodically strongly desiccating soils in alang-alang bush, brushwood and edges of or clearings in teak forest. In Thailand it occurs in swampy locations in old clearings and deciduous forest up to 200 m altitude. Flowering is from February to June in Indonesia, and from June to August in Indo-China. In Thailand flowering is from May to September and fruiting from May to December.

Selected sources 6, 49, 59, 71, 160.

Colona blancoi (Rolfe) Merr.

TILIACEAE

Synonyms *Columbia blancoi* Rolfe.

Vernacular names Philippines: anilau, mamaued (Tagalog), keddeng (Ilokano).

Distribution The Philippines (Luzon).

Uses The bast is made into weak rope, which is durable under wet conditions and therefore useful in the rainy season.

Observations A small tree, up to 10 m tall. Leaves ovate-oblong, 12–30 cm long, rounded or heart-shaped at the base, margins toothed, pointed at the apex, hairy. Inflorescence a terminal panicle of small cymes; flowers pink or yellow. Fruit an ovoid capsule, about 1 cm long, 2–4 winged. In Philippine studies in the 1910s, both dry and wet rope made from the bast of *C. blancoi* had a tensile strength of about 300 kg per cm^2. The elongation at break was 13% and 15% for dry and wet rope, respectively. The vernacular names 'mamaued' and 'keddeng' have also been mentioned for *C. serratifolia* Cav. and *C. mollis* (Warb.) Burret respectively. The vernacular name 'anilau' has also been mentioned for *Colona lanceolata* (Warb.) Burret and *C. serratifolia* Cav.

Selected sources 19, 20, 36, 93.

Colona lanceolata (Warb.) Burret

TILIACEAE

Synonyms *Columbia lanceolata* Warb.

Vernacular names Philippines: kadiin, baliuan (Pangasinan), anilau (Tagalog).

Distribution The Philippines (Luzon).

Uses The bark is made into rope.

Observations A tree, up to 25 m tall, stem diameter up to 40 cm. Leaves 8–15 cm long, base oblique, margins toothed, apex conspicuously pointed, hairy. Fruit 5-winged. *C. lanceolata* occurs in secondary forest in thickets at low altitudes. Its vernacular name 'anilau' has also been mentioned for *Colona blancoi* (Rolfe) Merr. and *C. serratifolia* Cav.

Selected sources 19.

Colona mollis (Warb.) Burret

TILIACEAE

Synonyms *Columbia mollis* Warb.

Vernacular names Philippines: keddeng (Ilokano).

Distribution The Philippines (Luzon).

Uses The bark is made into rope.

Observations A tree, up to 18 m tall, stem diameter up to 40 cm. Leaves alternate, 8–20 cm long, rounded and somewhat oblique at the base, with toothed margins, prominently pointed at the apex, hairy. Flowers in terminal panicles, pink or yellow. Fruit 2–3 winged. *C. mollis* is found in thickets and secondary forest at low altitudes. The vernacular name 'keddeng' has also been mentioned for *C. blancoi*.

Selected sources 19.

Colona winitii (Craib) Craib

TILIACEAE

Synonyms *Columbia winitii* Craib.

Vernacular names Thailand: po tin tao, yap (northern), po hu (eastern).

Distribution Thailand and Cambodia.

Uses The bark fibre is suitable for making string. The wood is used for cabinet work.

Observations A tree, up to 10 m tall. Leaves distichous; petiole 0.5–1 cm long, hairy; blade ovate to oblong, 12–25 cm × 5.5–11.5 cm, oblique and auriculate at the base, margin doubly serrate, 3-cuspidate-caudate at the apex, palmately 5–7-veined, secondary veins 3–5 pairs, scalariform and reticulate veins distinct on upper surface. Inflorescence a cyme, arranged in a terminal or axillary panicle, 5–15 cm long; flowers bisexual; sepals 5, free, oblong; petals 5, free, oblong, 5–10 mm × 2–2.5 mm, slightly narrowed to the base; stamens free, glabrous; ovary globose, with 3–4 longitudinal grooves, diameter about 2 mm, hairy. Fruit ovoid, 3–4 winged, 0.5–1 cm × 1.5–2 cm (wings included). *C. winitii* is found in mixed deciduous forest at 100–800 m altitude. In Thailand flowering is from June to September and fruiting from July to December.

Selected sources 49, 160.

Commersonia bartramia (L.) Merr.

STERCULIACEAE

Synonyms *Commersonia echinata* J.R. Forst., *C. platyphylla* Andr.

Vernacular names Indonesia: ki handeong (Sundanese), blencong (Javanese), andilo (Batak). Malaysia: durian tupai, mendarong gajah, rami hutan (Peninsular). Philippines: kakaag (Ilokano), anitap (Negrito), anilau-babae (Tagalog). Thailand: chong let, taa chai (Surat Thani), lang khao (peninsular).

Distribution From southern China through Indo-China, Peninsular Malaysia, Indonesia and the Philippines to the Central Pacific.

Uses In Indonesia and the Philippines the bast is made into general-purpose ropes. In Sumatra it is woven into mats. In the time of the Dutch East India Company fuses were spun from the bast. In New Britain (Papua New Guinea) the bast fibre is made into string for women's girdles, for headbands, and for tying. In Australia it was formerly used by indigenous people to make nets. The timber is not durable; it lasts up to 5 years under cover. *C. bartramia* is a good source of firewood. Because it spreads readily, grows fast and forms dense stands, it is useful for reforestation.

Observations A densely stellate-pubescent small tree, up to 15 m tall; trunk 15–25 cm in diameter; twigs often flexuous. Leaves arranged spirally, simple; stipule palmatilobed, caducous; petiole 0.5–1.5 cm long; blade herbaceous, suborbicular-ovate-oblong, 6–30 cm × 2.5–25 cm, base cordate to subtruncate, often oblique, margin serrate-dentate or lobed, apex acutely acuminate, palmately veined, sparsely stellate-pubescent to nearly glabrous above. Inflorescence an axillary, leaf-opposed or terminal corymbose cyme; flowers bisexual, 5-merous; sepals connate, ovate, 3–3.5 mm long, white, often inrolled; petals white, with widened concave base (cap); receptacle flat; staminal tube short, not adnate to the petal, crowned by 5 subsessile or stalked stamens (opposite the petals) alternating with 5 petaline staminodes; staminodes triangular-lanceolate, at first coherent, concealing the ovary, afterwards apically recurved, acute, white; filaments distinct, anthers subglobose, accumbent against base of petals, 2-celled; ovary 5-celled, ovules 2–6 in each cell; styles 5, short. Fruit a globose, woody capsule, 2–2.5 cm in diameter (including stellate-hairy bristles), dehiscent loculicidally, 5-valved, with 1–2 seeds in each cell. Seed exalate. *C. bartramia* is found in grasslands, brushwood, thickets and secondary forest, up to 1250 m altitude. In Malaysia it is widespread and found in disturbed locations in the lowland. In Java *C. bartramia* flowers throughout the year. Propagation is by seed. In studies in Indo-China in the 1940s, the fibre of *C. bartramia*, separated by retting for 36 days, contained 55% cellulose, 15% pentosans, 19% lignin and 3% ash. In Philippine studies in the 1910s, dry and wet rope made from the bast of *C. bartramia* had a mean tensile strength of 392 kg per cm^2 and 266 kg per cm^2, respectively, and an elongation at break of 14% and 13%, respectively.

Selected sources 6, 19, 20, 21, 71, 93, 111, 115, 138, 160, 194.

Corchorus aestuans L.

TILIACEAE

Synonyms *Corchorus acutangulus* Lamk.

Vernacular names Indonesia: bantji (Javanese), dengdek poik (Sundanese), gandja utan (Moluccas). Malaysia: rumput bayam rusa. Philippines: saluyot (Ilokano, Tagalog), salsaluyut (Ilokano), ubat-lagak (Sulu). Thailand: krachao naa (central), khat mon tua phu (northeastern). Vietnam: b[oos] d[aj]i, day d[aj]i.

Distribution A pantropical weed, thought by some to originate from the New World tropics in Latin America, by others from the Old World tropics in Africa and South and South-East Asia.

Uses The bast fibre can be made into thread and string, but the product is coarser and less durable than that made from *C. capsularis* L. (white jute). The leaves are used as a vegetable, e.g. in Indonesia, the Philippines and Vietnam. On cooking the leaves exude a large quantity of mucilage, making them very slimy. The medicinal uses in the Philippines are similar to those of *C. capsularis*: the leaves serve against headache, and the seeds, in the form of powder or in decoction, as a tonic, carminative and febrifuge.

Observations A variable, procumbent, ascending or erect, often much-branched herb, up to 1 m tall, sometimes becoming woody at base. Branches terete with sparse to dense indumentum of straight, stiff, ascending hairs and of curly hairs. Leaves ovate to elliptical, 2–9 cm × 1–4 cm, pubescent. Inflorescence a lateral, solitary, 1–3-flowered cyme at nodes; pedicel up to 2 mm long, erect in fruit; sepals 5, linear, 3–3.5 mm long; petals 5, 3–4 mm long, clawed; stamens 9–14; ovary 3–4-celled with 16–22 ovules per cell, style 1 mm long, stigma fimbriate. Fruit a 3–4-angular, cylindrical capsule, 13–30 mm × 3–7 mm, 6–8-winged, 3–4-valvate, at apex with 3–4 bifid horns 4–5 mm long, many-seeded. Seed rhomboid-cylindrical, 1.5 mm long, brown to black. In Java *C. aestuans* is found on pervious soils, often in sandy or grassy locations, e.g. wide beaches, up to 500 m altitude, in Peninsular Malaysia on open ground and rocks by the sea, and in Thailand in open locations, rice fields or shady limestone hills. In Java *C. aestuans* flowers year-round, in Thailand it flowers and fruits from September to December.

Selected sources 6, 19, 20, 39, 49, 64, 66, 71, 102, 108, 147, 160, 187.

Cordia aspera G. Forster

BORAGINACEAE

Synonyms *Cordia cumingiana* Vidal.

Vernacular names Philippines: anonang-lalaki (Tagalog), maratarong (Ilokano).

Distribution The Philippines, Borneo, Sulawesi, the Lesser Sunda Islands, the Moluccas, New Guinea, Taiwan, Australia, the Solomon Islands, Tonga, Fiji, New Caledonia and the Samoa Islands.

Uses In the Philippines bast strips are made into low-quality rope.

Observations A small tree or scrambling shrub, up to 7 m tall. Leaves simple, alternate; petiole 0.7–8 cm long; blade ovate, (2.5–)5–22 cm × 1.5–16 cm, base truncate or rounded, margin finely serrate, apex acuminate, rarely subobtuse, veins (3–)4–6. Inflorescence subcorymbose, lateral, subterminal or in fork of uppermost branches; peduncle up to 3.5 cm long; flowers numerous; pedicel less than 1 mm long; calyx with 10 distinct longitudinal ribs, 5-lobed, 3–3.5(–4) mm long, reddish tomentose; corolla 3 mm long, tube cylindrical, lobes revolute. Fruit drupaceous, ovoid, (5–)8 mm × (4–)5 mm, acute. In the Philippines *C. aspera* is found in thickets and secondary forest at low and medium altitudes. In Philippine studies in the 1910s, dry and wet rope made from the bast of *C. aspera* had a tensile strength of 388 kg per cm^2 and 364 kg per cm^2, respectively. The elongation at break of dry or wet rope was 16%.

Selected sources 19, 47, 93, 102, 103.

Cyperus alternifolius L.

CYPERACEAE

Synonyms *Cyperus flabelliformis* Rottb., *C. involucratus* Rottb.

Vernacular names Umbrella plant (En). Indonesia: papayungan (Sundanese), mansiang babunga (Sumatra). Thailand: kok rangka (Bangkok). Vietnam: th[ur]y tr[us]c.

Distribution Native from Arabia to South Africa and the Indian Ocean Islands. In South-East Asia and elsewhere in the tropics cultivated as a fibre plant (the Philippines, China, Hawaii, Argentina, the Canaries) or ornamental (Java). Sometimes escaped from cultivation, e.g. in Indonesia (Sumatra, Java), the Philippines, Australia, New Caledonia and Hawaii.

Uses The stems are used for mat-making in the Philippines. Pulping experiments have shown that the stems can be pulped with yields of 50% or more at 100°C and atmospheric pressure. The strength of unbeaten pulp was similar to that of beaten softwood pulps, but drainage was very slow. Reasonably strong paper was obtained by blending with unbeaten wood pulps. *C. alternifolius* is widely grown as an ornamental, also indoors in temperate climates. In Kenya it is also used as forage and, possibly because the plant contains alkaloids, in Africa decoctions are taken to cure digestive system disorders and fevers, and ash is applied to disinfect wounds.

Observations A perennial herb with a short woody rhizome; stem subdensely tufted, obtusely trigonous to terete, 50–170 cm × 5–10 mm. Inflorescence umbel-like, 15–30 cm in diameter; involucral bracts many, leafy, 20–50 cm × 5–15 mm, stiff; primary rays numerous, 7–10 cm long, each bearing 4–10 secondary rays up to 1.5 cm long; spikelets in clusters of 3–10, elliptical, 3–9 mm × 2–3 mm, densely 5–40-flowered; glumes ovate, 2 mm × 1.5 mm. Fruit a nut, 3-sided, 0.6–0.8 mm × 0.5 mm, brown. In South-East Asia *C. alternifolius* is found naturalized at altitudes up to 1200 m, in waste places, wet-rice fields and along river banks and ditches.

Two subspecies are sometimes distinguished:

- subsp. *alternifolius*. Native to Madagascar, Mauritius and the Mascarenes, not growing wild elsewhere; distinctive characteristics: stem with homogeneous chlorenchyma, involucral bracts glabrous, glumes lanceolate, fruits longer than 1 mm.
- subsp. *flabelliformis* (Rottb.) Kük. Native to tropical Africa and Arabia, widely cultivated and escaped; in South-East Asia only this subspecies occurs; distinctive characteristics: stem with heterogeneous chlorenchyma, involucral bracts scabrid, glumes broadly ovate, fruits shorter than 1 mm.

If these subspecies are elevated to species rank, which has sometimes been done, the correct names become *C. alternifolius* and *C. involucratus* Rottb. respectively, and the South-East Asian plants would be named *C. involucratus*. Here the one-species concept has been chosen.

Selected sources 6, 7, 39, 47, 66, 96, 96a, 158, 160, 161, 185, 187.

Cyperus digitatus Roxb.

CYPERACEAE

Synonyms *Cyperus auricomus* Sieber ex Spreng., *C. elatus* L. sensu Camus, *C. venustus* R. Br. sensu Nees.

Vernacular names Indonesia: rumput dekeng (Javanese), rumput bunga satuan, rumput musang (general). Malaysia: bunga sadaian rumput, rempara, rumput musiang (Peninsular). Thailand: kok dok daeng (Ayutthaya), kok rang kaa, yaa rangkaa (Bangkok).

Distribution Pantropical, including South-East Asia, but rare in Africa. Also occurring in subtropical America, southern China, Taiwan and Australia.

Uses The stems are woven into mats and baskets, e.g. in Indonesia. In Thailand they are made into roofs of poor quality. In Uganda leaves are used to treat coughs. In Sudan and Nigeria a special form of *C. digitatus* is used to prepare a perfume.

Observations A perennial herb with a very short, erect, woody rhizome and tufted or solitary, smooth, trigonous stems 50–200 cm × 3–7 mm. Leaves few, flat to plicate, up to as long as the stem. Inflorescence umbel-like, up to 40 cm in diameter; involucral bracts 3–8, longer than inflorescence; primary rays 6–10, unequal, up to 30 cm long, secondary rays 2–3 cm long; spikes digitately arranged, 3–6 cm × 1–3 cm; spikelets spicately arranged, 8–24(–44)-flowered, 0.5–2 cm long. Fruit a nut, up to 1 mm × 0.5 mm, yellow-brown. *C. digitatus* is found on river banks, in swamps, bogs, wet-rice fields and other open wet locations, up to 800 m altitude. In Java it flowers year-round. Natural propagation is by fruits which are dispersed by water and birds. In Indonesia *C. digitatus* is considered a weed of minor importance in rice and can be controlled by chemical means.

Selected sources 6, 20, 39, 47, 102, 108, 158, 160, 162.

Cyperus imbricatus Retz.

CYPERACEAE

Synonyms *Cyperus involucratus* Poir., *C. radiatus* Vahl, *C. verticillatus* Roxb.

Vernacular names Indonesia: adem-adem (Jakarta), lumbungan (Javanese), tintilo (Sulawesi). Philippines: alinang (Panay Bisaya), balabalangutan (Tagalog), balayang (Ilokano). Thailand: kok (Ayutthaya).

Distribution Pantropical. Widely found in South-East Asia.

Uses The stems are used for string in Java. Locally in the Philippines the outer portions of the leaves are stripped, dried in the shade and woven into mats and screens. In Peru the crushed rhizome is used as an aphrodisiac.

Observations A perennial herb with a very short rhizome and slender to robust, tufted, trigonous, smooth stems 50–150 cm × 8 mm. Leaves canaliculate, 5–15 mm wide. Inflorescence umbel-like, 20 cm long and wide; involucral bracts 3–5, up to 65 cm long; primary rays 6–8(–16), unequal, up to 15 cm long, secondary rays very short; spikes digitately arranged, very dense with usually 60–70 spikelets, 2–3 cm long; spikelets spicately arranged, 6–30-flowered, 4–6(–12) mm long. Fruit a trigonous nut, 0.6–0.8 mm × 0.4 mm, yellow-brown. *C. imbricatus* is found on river banks, in swamps, wet-rice fields and other open wet locations, mostly at low altitudes but rarely up to 900 m altitude. It is very polymorphic and many subdivisions into subspecies, varieties and forms have been described. In Java *C. imbricatus* flowers year-round. Natural propagation is by fruits which are dispersed by water and birds. In Indonesia it is considered a weed of minor importance in rice, where it can be controlled by chemical means.

Selected sources 6, 19, 20, 47, 71, 158, 160, 162.

Cyperus odoratus L.

CYPERACEAE

Synonyms *Cyperus ferax* Rich., *Torulinium ferax* (Rich.) Hamilt., *T. odoratum* (L.) Hooper.

Vernacular names Indonesia: rorisan (Sumatra). Philippines: biliran (Samar-Leyte Bisaya), pulak-galau (Subanon).

Distribution Widely distributed in warmer regions of the world. Occurring throughout South-East Asia but nowhere common.

Uses The stems are used in Sulawesi for the production of small mats. In East Africa they are also made into mats. In Brazil *C. odoratus* is used medicinally as an antispasmodic and stomachic. In Peru crushed rhizomes are taken as an aphrodisiac.

Observations An annual herb with fibrous roots and stout, trigonous, smooth stems 20–100 cm × 6 mm, growing solitarily or 2–3 together. Leaves subcoriaceous, flat, up to 12 mm wide. Inflorescence umbel-like, 5–25 cm in diameter; involucral bracts 6–8, up to 50 cm long; primary rays 7–12, up to 20 cm long; spikes with 20–30(–60) spikelets; spikelets spicately arranged, 4–20-flowered, 5–25 mm × 1 mm, at maturity breaking up into 1-fruit segments. Fruit a nut, trigonous-cylindrical, up to 2 mm × 0.7 mm, grey-brown-black. *C. odoratus* is widespread and very variable and thus has been described under numerous names. It is found in wet locations: marshes, wet-rice fields and along river banks, usually at low altitudes, but sometimes up to 2100 m. In Java it flowers year-round. Natural propagation is by fruits which are dispersed by water and birds. In Indonesia it is considered a weed of minor importance in rice, where it can be controlled manually.

Selected sources 6, 47, 158, 162, 197.

Cyperus pangorei Rottb.

CYPERACEAE

Synonyms *Cyperus tegetum* Roxb., *Papyrus pangorei* (Rottb.) Nees, *P. dehiscens* Nees.

Distribution India, Sri Lanka, Nepal, Burma (Myanmar) and China (Hainan). Formerly cultivated in Sulawesi (Indonesia) and Mauritius; it is not known whether it is still grown in Indonesia.

Uses The stems are made into mats and baskets, e.g. in Sulawesi (Indonesia), Burma (Myanmar), India, Sri Lanka and Mauritius. In India the stems, either entire or split into 2 or more strands, are used for weaving mats for floor covering and decoration.

Observations A perennial herb with a 3–7 mm thick rhizome and stems laxly tufted or row-arranged, trigonous, smooth, 70–200 cm × 3–7 mm. Leaves reduced to sheaths or some with blade up to 10 cm × 5 mm. Inflorescence umbel-like, 6–15 cm × 7–16 cm; involucral bracts 3–5, unequal, 17–30 cm × 5–8 mm; primary rays 5–7, unequal, up to 9 cm long, secondary rays about 5, up to 1.5 cm long; spikes 2–3 cm long bearing 5–14 spikelets 1–2 cm long. Fruit a nut, trigonous, 1.5 mm × 0.3 mm, brown. *C. pangorei* is found in open wet locations, marshes and on margins of water bodies. The stem of *C. pangorei* grown in India contained 65–69% holocellulose, 36–37% α-cellulose, 16–17% lignin, 2–26% pentosans, 5% fat and wax, 1% pectin and 10–11% ash.

Selected sources 13, 39, 63, 66, 108, 158, 197.

Daphne composita (L.f.) Gilg

THYMELAEACEAE

Synonyms *Daphne javanica* Thunb., *D. pendula* Sm., *Eriosolena composita* (L.f.) van Tiegh.

Vernacular names Indonesia: kakapasan (Sundanese), ki-salam (Javanese), kulei manis rimbo (Sumatra). Thailand: khem khao pa (northern), mueat soi (north-eastern). Vietnam: d[os] k[es]p.

Distribution India, Burma (Myanmar), southern China (Yunnan), Vietnam, Cambodia, Thailand, Peninsular Malaysia, Sumatra, West Java and Borneo.

Uses The bark is used as binding material, e.g. in Java. In central Vietnam the leaves and stems yield a decoction which, though toxic, is used medicinally.

Observations A shrub or small tree, up to 10 m tall, trunk up to 16 cm in diameter. Leaves spirally arranged, sometimes subopposite; petiole 3–5 mm long; blade elliptical-oblong to lanceolate, (3.5–)7–14(–20) cm × (1.5–)2–5 cm, base attenuate, apex acuminate, with 9–14 pairs of veins. Inflorescence axillary, solitary, very rarely 2 per axil; peduncle 2.5–6.5 cm long, (4–)7–12-flowered; flowers 10–15 mm long, sessile, fragrant; calyx lobes convolute, 2 longer and 2 shorter, lanceolate or ovate-oblong, rarely oblong, 2–4 mm × 1 mm; corolla tube cylindrical, white or light yellow; stamens 8, sessile or sub-sessile, anthers linear 1–1.5 mm long; ovary ellipsoid, densely hairy. Fruit an ellipsoid or ovoid drupe, 10–15 mm × 5 mm, black or red. Seed with crustaceous testa. *D. composita* is found in the undergrowth of rainforest at (900–)1200–2000 m altitude. In West Java it flowers throughout the year, in Indo-China from December to February.

Selected sources 6, 20, 47, 49, 50, 71.

Debregeasia longifolia (Burm.f.) Wedd.

URTICACEAE

Synonyms *Debregeasia velutina* Gaudich., *Urtica longifolia* Burm.f.

Vernacular names Indonesia: mencokan (Javanese), ki tongo (Sundanese), lang-alang (Madurese). Thailand: khai plaa (Loei), blaen-kee (Maeo-Chiang Mai).

Distribution From Indonesia to India and Japan.

Uses The bark yields a useful, strong, water-resistant fibre, which is locally used for cordage. The fruit clusters are sweet and edible and are used for making wine.

Observations A shrub or small tree, 1.5–7 m tall; stem slender, 2–4 mm in diameter, sometimes zigzag from node to node. Leaves alternate, simple; stipules 0.5–1 cm long; petiole 4–6 cm long; blade narrowly to broadly ovate or elliptical and (2–)3–5 times as long as wide, to narrowly elliptical or lanceolate up to 10 times as long as wide, often slightly asymmetrical, 4–24 cm × 1.5–6 cm, base tapering to narrowly rounded or slightly cuneate, margin serrate, apex acute or acuminate, with (4–)5–6(–9) pairs of lateral veins. Inflorescence axillary, branched, with densely clustered flowers, up to 1.5 cm long, usually unisexual, rarely arranged with male clusters in lower axils and female clusters towards the apex and intermediate ones in between; male flower clusters 3–5 mm in diameter; female flower clusters 1.5–2.5 mm in diameter; male flowers with 4–5-parted perianth, tepals oblong, about 1.5 mm long; female flowers with 4-parted or lobed perianth, stigma linear, persistent, minute. Fruit an obliquely ovoid or orbicular, laterally slightly compressed achene, up to 0.8 mm long. *D. longifolia* is found in moist locations, especially in forests, on river banks and on well-watered mountain sides at 200–2500 m altitude.

The use of another *Debregeasia* as a fibre plant has been recorded for Indonesia: *D. saeneb* (Forssk.) Hepper & Wood (synonyms: *D. hypoleuca* Wedd., *D. salicifolia* (Roxb. ex D. Don) Rendle). However, its distribution is limited to India, Pakistan, Afghanistan and tropical Africa, and it does not occur in Indonesia. The bark fibre is used in India and Pakistan to make rope and fishing lines. Uses recorded for this species from Indonesia should be attributed to *D. longifolia*. In New Guinea the bark fibre of an unidentified *Debregeasia* species is made into string for women's garments, net bags, fishing nets, ropes and for tying in house construction.

Selected sources 6, 20, 30, 71, 124, 138, 197, 199, 200.

Dendrocnide microstigma (Gaudich. ex Wedd.) Chew

URTICACEAE

Synonyms *Laportea microstigma* Gaudich. ex Wedd.

Vernacular names Indonesia: kemaduh, lateng (Javanese), kelating (Minahassa).

Distribution Indonesia (Java, northern Sulawesi).

Uses The bast is made into rope. The soft wood of this and other *Dendrocnide* species is only suitable for firewood.

Observations A monoecious or dioecious tree, 10–15 m tall; trunk 30–85 cm in diameter, branched from the base. Leaves spirally arranged, simple; stipules connate into an axillary scale; petiole 2.5–5.5 cm long; blade oblong-lanceolate, 16–28 cm × 5–8 cm, base subcordate, obtuse or acute, apex acuminate, with 12–22 pairs of lateral veins. Inflorescence an axillary, unisexual panicle, 10–15 cm long; male flowers with 4–5-parted perianth, tepals oblong, about 1.5 mm long; female flowers with 4-parted or lobed perianth, stigma linear, persistent, minute. Fruit an obliquely ovoid or orbicular, laterally strongly compressed achene, 1.7–2 mm long. *D. microstigma* is found in low-altitude forest. *D. stimulans* (L.f.) Chew (synonym: *Laportea stimulans* (L.f.) Miq.) has been recorded as a source of bark for cordage, but it seems to have more importance as a medicinal plant.

Selected sources 6, 71, 191.

Dichapetalum timoriense (DC.) Boerl.

DICHAPETALACEAE

Synonyms *Dichapetalum robinsonii* Merr., *D. sericeum* Merr., *D. submaritimum* Elmer.

Vernacular names Indonesia: derangdang areuy (Sundanese), popoler kusu (Ambon), buwah mulo (Aru Islands). Malaysia: akar kachang-kachang, akar pah kudah, tugor pontianak akar (Peninsular). Philippines: alibotbot (Panay Bisaya), dekdek (Ilokano), ariskis (Tagbanua).

Distribution Throughout Malesia (except the main island of Sumatra), the Bismarck Archipelago and the Solomon Islands.

Uses In the Moluccas the stems are split after removing the bark, and the splits are used for tying hoop-nets. Young leaves are eaten as a vegetable, raw or cooked, and cooked fruits are consumed with fish.

Observations A shrub with scandent or creeping stems up to 5 cm in diameter. Leaves alternate, simple, ovate to obovate, 7–18 cm × 3–10 cm, entire, pubescent below, shortly petiolate; stipules subulate. Inflorescence axillary, repeatedly dichotomously branched, densely tomentose, many-flowered; flowers bisexual or unisexual, 2.5–4 mm long, 5-merous; sepals almost free, ovate; petals free, spatulate, incised; stamens 5; ovary superior, densely woolly pubescent, styles 2–3, connate. Fruit a globular to ovoid drupe 1.5–2.5 cm in diameter, densely fulvous velvety pubescent, 1–3-seeded. *D. timoriense* occurs in primary and secondary forest, often at the edges, up to 1800 m altitude.

Selected sources 6, 47, 71, 115.

Eleocharis acutangula (Roxb.) Schult.

CYPERACEAE

Synonyms *Eleocharis fistulosa* Schult., *Scirpus acutangulus* Roxb., *S. fistulosus* Poir.

Vernacular names Indonesia: purun (Kalimantan), purun tikus (Sumatra), bhan-talobhanan (Madura).

Distribution Pantropical but uncommon. In Malesia found scattered in Peninsular Malaysia, Indonesia (throughout), the Philippines (Luzon, Mindanao) and New Guinea.

Uses The stems are used in western Borneo for making bags, in eastern Sumatra for making cigarette boxes and sacks. In Brazil they also provide material for weaving.

Observations A perennial herb, 30–70 cm tall, with short rhizome and long stolons. Stem erect, tufted, triquetrous, 3–4 mm wide, not transversely septate. Leaves reduced to bladeless tubular sheaths. Inflorescence a terminal, ebracteate, single spikelet; spikelet cylindrical, 2–3.5 cm × 3–4 mm, many-flowered, dusky green; glumes rather loosely imbricate, not keeled, many-veined, the lowest 1–2 usually empty; flowers bisexual with perianth of 6–7 bristles, stamens 2–3, pistil with 3-fid style. Fruit a yellow-brown nut, unequally biconvex, obovate, 1.5–2 mm × 1.2–1.5 mm, with a short neck and with about 15 vertical rows of shallow pits on each side. *E. acutangula* is found in open wet locations, such as swamps and rice fields, up to 800 m altitude. In Indonesia it is a weed of minor importance in rice, where it can be controlled manually. In Java it flowers from March to October. Natural propagation is by fruits which are dispersed by water.

Selected sources 6, 39, 47, 71, 102, 108, 158, 162.

Eleocharis ochrostachys Steud.

CYPERACEAE

Synonyms *Eleocharis subulata* Boeck., *E. variegata* (Poir.) Presl var. *laxiflora* (Thwaites) Clarke, *Scirpus laxiflorus* Thwaites.

Vernacular names Indonesia: purun, purun tikus (general), ngunu bobo (Halmahera). Malaysia: rumput sikat.

Distribution From India and Sri Lanka throughout South-East Asia to Taiwan, the Ryukyu Islands and Melanesia. In Malesia often occurring very locally; not yet reported from the Lesser Sunda Islands.

Uses In central and eastern Sumatra and western Borneo the stems are woven into bags.

Observations A perennial herb, 35–80 cm tall, with short rhizome and long stolons. Stem erect, tufted, terete or obscurely angular, 1–5 mm wide, not transversely septate. Leaves reduced to bladeless, tubular sheaths. Inflorescence a terminal, ebracteate, single spikelet; spikelet cylindrical, 0.5–2 cm × 3–4 mm, few- to several-flowered, pale green; glumes firm, loosely imbricate, many-veined, the lowest 1–2 usually empty; flowers bisexual with perianth of 5–7 bristles; stamens 2–3; pistil with 2-3-fid style. Fruit a pale brown nut, unequally biconvex, obovate, 1.5–2 mm × 1–1.5 mm, with an annular prominence at the apex and with 15–20 vertical lines on each side and prominent ribbed margins. *E. ochrostachys* is found at altitudes up to 1400 m in open wet locations, swamps, lake-margins and floating islands, sometimes dominant. In Indonesia it is a weed of minor importance in rice, where it can be controlled manually. Natural propagation is by fruits, which are dispersed by water.

Selected sources 6, 20, 39, 47, 102, 158, 162.

Eleocharis sphacelata R. Br.

CYPERACEAE

Vernacular names Papua New Guinea: kur (Enga language).

Distribution North-eastern New Guinea, Australia, Tasmania and New Zealand.

Uses In Papua New Guinea the stems are used by women for making skirts, for which purpose *E. sphacelata* is sometimes cultivated. The aerial parts are grazed by domestic animals and can be used as fodder.

Observations A perennial herb, up to 2 m tall, with very stout, woody, shortly creeping rhizome up to 1 cm thick but never producing tubers. Stems in a close linear series, up to 12 mm thick. Leaves reduced to bladeless, tubular sheaths. Inflorescence a terminal, ebracteate, single spikelet; spikelet cylindrical, up to 6 cm × 9 mm, many-flowered; glumes densely packed, many-veined, the lowest 1–2 usually empty; flowers bisexual with perianth of 8–10 bristles, stamens 2–3, pistil with 2–3-fid style. Fruit a pale brown nut, obovate to orbicular, 2–2.5 mm × 2 mm, with ribbed margins and a prominent longitudinal furrow. *E. sphacelata* is found in swamps at 2200–2900 m altitude. Because of a high potential for internal pressurization and low internal resistance, internal gas transport in *E. sphacelata* is easier than in some other wetland plants, such as *Cyperus involucratus* Rottb., allowing it to grow in deeper water. *E. sphacelata* much resembles *E. dulcis* (Burm.f.) Trinius ex Henschel (Chinese water chestnut) but it never forms tubers, its spikelets are broader and its fruits are slightly larger. It is so close to *E. dulcis* that it could be considered a subspecies.

Selected sources 18, 47, 158.

Eleocharis spiralis (Rottb.) Roem. & Schult.

CYPERACEAE

Synonyms *Scirpus spiralis* Rottb.

Vernacular names Indonesia: boroslanang (Javanese, Indramayu).

Distribution From tropical Africa through Madagascar, Mauritius, Sri Lanka, southern India and South-East Asia to southern China, tropical Australia and New Caledonia. In Malesia apparently very rare, occurring in Peninsular Malaysia, West and Central Java, Madura, Borneo, the Philippines and New Guinea.

Uses The stems are used for making mats in West Java (Indramayu).

Observations A perennial herb, 25–60 cm tall, with short rhizome and creeping stolons. Stem erect, tufted, robust, triquetrous at least in the upper part, 2–4 mm wide, not transversely septate. Leaves reduced to bladeless, tubular sheaths which have a 4 mm long point at the apex. Inflorescence a terminal, ebracteate, single spikelet; spikelet cylindrical, 1.5–3.5 cm × 3–5 mm, densely many-flowered, yellowish; glumes firm, strikingly spirally arranged and closely packed, many-veined, the lowest 1–2 usually empty; flowers bisexual with perianth of 4–6 bristles, stamens 3, pistil with 2–3-fid style. Fruit a pale brown nut, turgidly biconvex, obovate, 1.5–1.7 mm × 1.7 mm, without ribbed margins or annular prominence at the apex, with about 20 vertical, not pitted lines on each side. *E. spiralis* is found in open wet locations, pools and swamps, often on clayish soils, at low altitudes and almost restricted to brackish or salt localities. It sometimes forms extensive, almost pure stands. In Java it flowers from March to September. *E. spiralis* is very near to *E. mutata* (L.) Roem. & Schult. from Central and South America and Africa and they are considered as one species by some.

Selected sources 6, 39, 47, 158.

Eleutherococcus trifoliatus (L.) S.Y. Hu

ARALIACEAE

Synonyms *Acanthopanax trifoliatus* (L.) Voss, *Zanthoxylum trifoliatum* L.

Vernacular names Philippines: sibsibit (Bontoc). Thailand: phak paem (Northern). Vietnam: ng[ux] gia b[if] gai, ng[ux] gia b[if] gi[ar] ba l[as].

Distribution From the Himalayas through southern China to the Philippines (northern Luzon), Taiwan and Japan. Cultivated as a medicinal plant in Vietnam and as a vegetable in southern China.

Uses In northern Luzon (the Philippines) the stems are used for binding and for fencing. In Vietnam *E. trifoliatus* is applied medicinally as a substitute for ginseng (*Panax ginseng* C.A. Mey.). Decoctions of root bark and stem bark are used against rheumatism, lumbago, ostealgia and impotence.

Observations A spiny, scandent shrub, 1–8 m tall. Leaves alternate, palmate; stipules absent; petiole up to 5 cm long; leaflets (1–)3(–5), blade broadly ovate to subrotund, up to 3.5 cm × 2.3 cm, base cuneate, margin serrate, apex acute. Inflorescence a terminal panicle of umbels; flower whitish or yellow-greenish; calyx a rim, 5-teethed; petals 5, about 2 mm long. Fruit a subglobose drupe, about 5 mm in diameter, black when ripe. *E. trifoliatus* occurs in montane forest and thickets at altitudes of 1100–1400 m. The main components of the essential oil obtained from stems and leaves of *E. trifoliatus* from Vietnam were alpha-pinene (23.9%), sabinene (14.9%), terpinen-4-ol (9.0%), beta-pinene (7.7%) and rho-cymene (5.8%). Steroid derivatives and triterpenoid carboxylic acids have been extracted from stems and leaves. Aqueous extracts and their n-butanol fraction have shown antimutagenic action. Nevadensin, isolated from the leaves, has shown expectorant and antitussive activity.

Selected sources 15, 44, 47, 66, 79, 102, 113, 123, 160, 187.

Erycibe tomentosa Blume

CONVOLVULACEAE

Synonyms *Erycibe princii* Wall. ex Choisy.

Vernacular names Indonesia: akar akar kait (Bangka), tuba tuba (Kalimantan). Malaysia: akar perut kijang, jambul siul (Peninsular).

Distribution Peninsular Malaysia, Sumatra, West Java, Madura, Kangean Islands, Borneo and the Philippines (Leyte).

Uses The slender stems are used for tying.

Observations A climber, up to 25 m long or shrub, up to 3 m tall. Leaves spirally arranged, simple, entire; petiole 3–6 mm long; blade ovate to elliptical or oblong, up to 18 cm × 8.5 cm, 5–8-veined, base slightly cordate, apex usually distinctly acuminate. Inflorescence cymose, axillary, near apex of branch terminal, 3–15(–25)-flowered; corolla white, 7–9 mm in diameter, tube 2.5–3 mm long. Fruit an ellipsoid to ovoid berry, 12 mm × 7 mm, orange to red, black when mature. *E. tomentosa* occurs in scrub and forest up to an 1200 m altitude. The stems of the related species *E. expansa* Wall. ex G. Don, are used by fishermen in Peninsular Malaysia to make ropes.

Selected sources 20, 47.

Eulaliopsis binata (Retz.) C.E. Hubbard

GRAMINEAE

Synonyms *Andropogon binatus* Retz., *Ischaemum angustifolium* (Trin.) Hackel.

Vernacular names Sabai grass, berveza grass, baib grass (En). Philippines: kaboot (Ilokano, Ibanag), pueng (Bontoc), sangumati (Bukidnon).

Distribution Afghanistan, Pakistan, northern India, Nepal, Burma (Myanmar), Indo-China, southern China, Taiwan, Thailand and the Philippines.

Uses The culms are made into rope, mats and string, e.g. in the Philippines and India. They are considered durable and useful for making grass slippers. In India and China *E. binata* is also used on a fairly large scale for the production of paper pulp; the pulp is suitable to make high-quality printing and writing papers. *E. binata* is planted to prevent erosion, e.g. in sisal and tree plantations, and for land rehabilitation. It serves as a fodder, but is probably of inferior quality.

Observations A perennial, tufted grass with culms up to 1 m tall, swollen and densely woolly-hairy at base. Leaves subulate, up to 30 cm × 3 mm; ligule a ring of hairs. Inflorescence a raceme, digitately arranged; spikelets paired, one sessile and one pedicelled, about 5 mm long, densely covered with soft, golden hairs, 2-flowered; upper lemma with long awn. *E. binata* occurs in grassland up to 1400 m altitude. It thrives on well-drained sandy loams with an annual rainfall of 750–1500 mm. Propagation is best by rootstock division; seedlings raised in nurseries may also be used. The fibre cells are (0.5-)2.1(–4.9) mm long and (4–)9(–28) μm wide; they are thick-walled and have blunt or pointed ends. Pulping is performed under alkaline conditions, and the pulp is often mixed with short-fibred pulps from hardwoods or from agricultural waste material such as rice straw. In the early 1950s *E. binata* represented about 22% of the total fibrous material pulped in India, but in recent years its use for pulp production has decreased because of limited supply. Plantations have been established to increase production.

Selected sources 19, 30, 66, 84, 94, 115, 133, 143.

Euonymus benguetensis Merr.

CELASTRACEAE

Vernacular names Philippines: suka, tabkang (Igorot).

Distribution Indonesia (Sumatra) and the Philippines (Luzon).

Uses In the Philippines (Luzon) the bark is used to make cloth, e.g. blankets for the dead. The bark cut into strips is made into thread for weaving. The wood is used as firewood.

Observations A scandent or decumbent shrub. Leaves opposite; petiole 2–3 mm long; blade ovate to elliptical, 3–7.5 cm × 1.5–4 cm, base acute or cuneate, margin serrulate, crenulate or entire, apex acute to acuminate, with 3–5 pairs of veins. Inflorescence cymose, axillary, 3–10-flowered; flowers 4-merous, greenish-white or yellowish. Fruit globose, up to 13 mm in diameter, densely covered with spines. *E. benguetensis* occurs in montane rain forest at altitudes of 1200–2300 m.

Selected sources 15, 47, 115, 163.

Ficus altissima Blume

MORACEAE

Vernacular names Indonesia: waringin daun besar, waringin cempedak (Moluccas). Philippines: balete (Tagalog), nonok (Bisaya). Thailand:

kraang (Central), sai thong (Nakhon Si Thammarat), lung (Chiang Mai).

Distribution India (Sikkim eastwards), Burma (Myanmar), northern Thailand, Indo-China, southern China, Indonesia (Sumatra, Java, Sulawesi), the Philippines (Luzon, Mindoro, Mindanao).

Uses The aerial roots are used as rough cordage for binding, e.g. in Indonesia and India. A yellowish, handmade paper, similar to that made from the bast of paper mulberry (*Broussonetia papyrifera* (L.) L'Hér. ex Vent.), can be produced from the inner bark, by soaking it in water and then stretching it out carefully. In Indonesia the root bark is made into good-quality fuses. The stems yield low-quality firewood and the young leaves are occasionally eaten as a vegetable.

Observations A strangling fig tree, epiphytic when young, 20–50 m tall. Leaves coriaceous; stipules 4–5 cm long, short-hairy; petiole 3–8 cm long; blade broadly ovate to oblong, 13–25 cm × 4.5–16 cm, base obtuse or rounded, apex shortly acuminate, smooth, with 6–10 pairs of lateral veins. Fruit an axillary syconium, in pairs when young, 2.5–3 cm × 1.5–2 cm, orange or orange-red, with persistent basal bracts. In Java *F. altissima* is found in forest up to 1000 m altitude.

Selected sources 6, 20, 28, 30, 71, 115, 160.

Ficus callophylla Blume

MORACEAE

Synonyms *Ficus pachyphylla* Merr.

Vernacular names Philippines: balete (Tagalog), lunug (Panay Bisaya), pasakla (Ilokano). Thailand: sai (Trat).

Distribution Thailand, Indo-China, Malaysia, Indonesia, the Philippines and Hongkong.

Uses The bast fibres are made into durable and fairly strong rope.

Observations A strangling, monoecious tree, epiphytic when young, 20–40 m tall. Leaves subopposite; stipules lanceolate, 2.5–3 cm long; petiole 24.5 cm long; blade elliptical, 6.5–20 cm × 3–10 cm, base cuneate or obtuse, apex broadly rounded, smooth, with 8–10 pairs of lateral veins. Fruit a syconium, 1.2–1.5 cm × 11.5 cm, occurring in pairs, pale yellow with pink and red dots and lines, with persistent basal bracts. In the Philippines *F. callophylla* is a widely distributed forest species at low altitudes. In Philippine studies in the 1910s, dry and wet rope made from the bast of *F. callophylla* had a tensile strength of 464 kg per cm^2 and 544 kg per cm^2, respectively, and an elongation at break of 12% and 17%, respectively.

Selected sources 6, 19, 28, 93, 160, 194.

Ficus chartacea (Wall. ex Kurz) Wall. ex King

MORACEAE

Vernacular names Speckle-leafed fig (En). Malaysia: ara padi, rami hutan, buah sungai. Thailand: duea nok, maduea thet (Trat), maduea hom (Chanthaburi).

Distribution Burma (Myanmar), southern China, Indo-China, Thailand, Malaysia, Brunei and Indonesia (Sumatra).

Uses In Malaysia the tough bark is twisted into rough cordage.

Observations A shrub or small dioecious tree, up to 12 m tall. Leaves spirally arranged; stipules lanceolate, 0.3–1 cm long; petiole 1–3 cm long; blade elliptical, 7.5–15 cm × 2.5–6 cm, base symmetrical-cuneate, apex acute, with 4–6 pairs of lateral veins, glabrous, with cream-white or yellow dots on upper surface. Fruit a syconium, axillary or borne on twigs below the leaves, clustered or in pairs, globose, 6–8 mm in diameter, with 3 tiny basal bracts, when ripening yellow or orange-brown turning scarlet. In Malaysia *F. chartacea* is found from lowland to montane forest, especially in cleared areas. In Borneo it is recorded from lowland forest, often along streams.

Selected sources 20, 28, 29, 161, 194.

Ficus forstenii Miq.

MORACEAE

Synonyms *Ficus palawanensis* Merr.

Vernacular names Palawan balete (En). Philippines: agamid (Igorot, Ilokano), balete (Manobo, Tagalog), okob (Bagobo).

Distribution Peninsular Malaysia (Perak), Borneo, Sulawesi and the Philippines (including Palawan).

Uses The strong, durable and tough bast fibre is made into very strong rope. It is used for traps for wild hogs.

Observations A large, monoecious, strangling fig. Leaves alternate; stipules lanceolate, about 1.5 cm long, caducous; petiole 2–2.5 cm long; blade oblong, up to 21 cm × 11 cm, base rounded or subcordate, apex acute, glabrous, with 8–10 pairs of lateral veins. Fruit a sessile syconium, occurring in pairs, ovoid, about 1.5 cm in diameter, with persistent basal bracts, red. *F. forstenii* is found throughout its range in low-altitude forest. In Philippine studies in the 1910s, dry and wet rope made from the bast of *F. forstenii* had an elongation at break of 11–12% and 18–19%, respectively. Tensile strength measurements showed a very wide variation.

Selected sources 19, 28, 93, 161, 194.

Ficus fulva Reinw. ex Blume

MORACEAE

Synonyms *Ficus chrysocarpa* Reinw. ex Blume, *F. patens* Ridl.

Vernacular names Stinging fig (En). Indonesia: hamerang badak, kuyang (Sundanese), kebeg (Javanese). Malaysia: lengan, tempan (Sarawak).

Distribution Southern Thailand, the Nicobar Islands, Malaysia and Indonesia.

Uses The bast is made into rough string, notably used for tying sheaves of rice. The bark yields a wax of limited use.

Observations A small, dioecious, deciduous tree, 15(–18) m tall; trunk diameter up to 20(–25) cm. Leaves spirally arranged, entire or palmately lobed; stipules lanceolate, about 1 cm long; petiole 1.5–5 cm long; blade ovate, elliptical or obovate, 9–27 cm × 4.5–16 cm, base symmetrical, usually cuneate, apex shortly acute, densely velvety hairy below, sparsely hairy above, lateral veins 4–6 pairs. Fruit an axillary syconium, in pairs, ovoid to globose, 8–10 mm in diameter, velvety yellowish hairy, ripening yellow and then red, basal bracts persistent; fruit stalk up to 5 mm long. Plants from Java and Sumatra differ from those from elsewhere in the hairs being soft, not irritating and leaves being more often palmately lobed than entire. *F. fulva* is a common species throughout its range, in Malaysia especially so in secondary forest.

Selected sources 6, 20, 28, 29, 71, 161, 194.

Ficus minahassae (Teijsm. & de Vriese) Miq.

MORACEAE

Vernacular names Indonesia: mahangkusei, tambing-tambing, weren kuse (Minahassa). Malaysia: tapian dawit (Sabah). Philippines: alomit (Igorot), hagumit (Tagalog), sabfog (Bontoc).

Distribution Northern Borneo, Sulawesi, Talaud Islands (Indonesia) and the Philippines.

Uses The bast is made into ropes and was formerly made into barkcloth (Sulawesi). The leaves are used to treat rheumatic complaints. The fruits are edible.

Observations A small, dioecious, tree up to 15(–25) m tall, sometimes with stilt roots. Leaves spirally arranged; stipules ovate or lanceolate, 2–5 cm long; petiole 3.5–10 cm long; blade ovate, (9–)13–30 cm × (5–)7–20 cm, base rounded or cordate, apex acute or acuminate, rough hairy above, yellowish soft-hairy below, with 7–11 pairs of lateral veins. Fruit a syconium, obconical, 5–6 mm in diameter, with 3 persistent basal bracts, glabrous or finely pubescent, ripening red, in small clusters along leafless twigs hanging from trunk and larger branches. In the Philippines *F. minahassae* is found in primary forest at low and medium altitudes, mainly along streams.

Selected sources 19, 28, 71, 161.

Ficus odorata (Blanco) Merr.

MORACEAE

Vernacular names Philippines: isis (Panay Bisaya), agosos (Tagalog), aplas (Ifugao).

Distribution The Philippines; occasionally also cultivated elsewhere.

Uses Bast fibres are made into rope. Barkcloth is made from the bast. The leaves are used to clean kitchen utensils and for scouring and polishing wood. The wood serves for light or temporary construction.

Observations A dioecious tree, up to 20 m tall; trunk 10–20 cm in diameter. Leaf blade oblong, 15–25 cm × 6–10 cm, base strongly inequilateral, obliquely cordate, apex abruptly acute, hispidly pubescent. Fruit an axillary syconium, solitary or rarely paired, compressed-globose, 1.5–2.5 cm in diameter, with small basal bracts, tomentose, pale yellow when ripe, red-tinged where exposed to the sun. *F. odorata* occurs naturally in lowland rainforest. The bast fibres are non-ribbon-like, matted, dull, whitish, strong and durable. They are obtained by retting the stems in standing water for 3 weeks or more, after which they are beaten into sheets suitable for coarse clothing and other products. They are also twisted into rope. On drying the fibres become stiff and hard.

Selected sources 19, 28, 46, 115.

Flagellaria indica L.

FLAGELLARIACEAE

Vernacular names Indonesia: rotan dapit (eastern Sumatra), kokrok (Javanese), owar (Sundanese). Malaysia: rotan dini, rotan tikus. Philippines: anuad (Ilokano), arayan (Tagalog), huay (Bisaya). Cambodia: phdau â'nda:ëk, phdau sva:. Thailand: waai yep chaak, waai ling, waai lie. Vietnam: c[ur] kh[as]c (Ha Nam Ninh), (d[aa]y) giay v[oj]t (Binh Tri Tiên), m[aa]y v[os]c (Ho Chi Minh).

Distribution Tropical Africa, Sri Lanka, tropical South-East Asia (throughout Malesia), Taiwan, northern Australia, Melanesia and Polynesia.

Uses The stems, either entire or split, are used for tying, basket-making and stitching thatch, but they are considered inferior to rattan. In New Britain (Papua New Guinea) the stems serve as anchor ropes. The lower, more woody part of the stem is made into walking sticks. In the Philippines stem and rhizome decoctions are considered diuretic, while in India leaves and flowers are used. Young leaves and stems, pounded in coconut milk, are made into a hair wash. The leaves are also considered astringent and vulnerary. In New Guinea a solution of crushed stems is taken for stomach problems, and the leaves are eaten to induce infertility.

Observations A perennial climber, 2–15 m long; stem striated, glabrous, woody at base, rarely branched. Leaves distichously alternate, simple, sessile; leaf sheath terete, enclosing the node; blade oblong to linear, up to 48 cm × 7 cm, base rounded, margin entire, apex cirrhose (ending in a coiled tendril), glabrous, venation unicostate parallel. Inflorescence an erect panicle; flowers sessile, apetalous, bisexual; tepals erect, ovate-rounded, 2–2.8 mm long, thinly membranous, white; stamens and stigmas far exserted. Fruit a drupe, subglobose, about 6 mm in diameter, pink, 1(–2)-seeded. *F. indica* is usually found in light forest, forest borders, along forest roads and in disturbed open forest up to about 1600 m altitude. Flowering and fruiting is year-round. The plant contains hydrocyanic acid, and a flavonoid glycoside has been isolated from the root, stem and leaves.

Selected sources 6, 19, 20, 37, 45, 47, 50, 71, 74, 102, 107, 115, 138, 140, 150, 160.

Freycinetia Gaudich.

PANDANACEAE

Major species and synonyms
- *Freycinetia javanica* Blume, synonyms: *F. lucens* Ridl., *F. montana* Ridl.
- *Freycinetia scandens* Gaudich., synonyms: *F. gaudichaudii* R. Br. & Benn., *F. gonocarpa* Moore, *F. mulleri* Martelli.

Vernacular names
- *F. javanica*: Indonesia: lolo cacing (Sundanese), rotan kubu (Palembang), kepah belehang (Bangka).
- *F. scandens*: Indonesia: ojod sodomenek, singsim (Javanese), meyong tandang (Sundanese).

Distribution *Freycinetia* contains about 180–200 species and is found from Sri Lanka, the Andaman and Nicobar Islands (but not the rest of India), throughout South-East Asia to Taiwan, Australia (Queensland), New Zealand and the Pacific. The highest species density is observed in Borneo, the Philippines and New Guinea. *F. javanica* occurs in southern Thailand, Peninsular Malaysia, Sumatra, Java and Borneo. *F. scandens* is one of the most widely distributed species in the genus and occurs from Java and Sulawesi to New Guinea, the Solomon Islands and Australia (Queensland).

Uses Prop roots of *Freycinetia* are used to make high-quality ropes, sometimes after retting. The split prop roots of *F. javanica* are sought after because of their strength. Old prop roots of *F. scandens* form strong but not very durable tying material for fences and domestic use. In the Moluccas they are first placed in water to soak off the prickles and to increase suppleness. In the South Pacific, inflorescences of *Freycinetia* species are used as emergency food.

Observations Dioecious, woody lianas, usually with clasping, adventitious, aerial roots. Leaves simple, linear or lanceolate, densely crowded, sheathing at base and sheath usually with membranous, caducous margins (auricles). Inflorescence terminal, consisting of peduncled spadices which usually number 2–5 combined into an umbel or short raceme and initially enclosed by several, crowded, green or coloured spathes which fall off after anthesis; perianth absent; male spadix consisting of crowded simple stamens on a rachis, sometimes also with pistillodia; female spadix consisting of crowded pistils on a rachis, each with 1–12 stigmas, sometimes also with small staminodes. Fruit a red, yellow or white syncarp, usually consisting of berries with a hardened apex and a fleshy lower part, many-seeded.

- *F. javanica*. A climbing shrub, often clothing entire trunks, with stems 5–15 m long, about 1 cm in diameter. Leaves linear to elliptical-lanceolate, 12.5–25 cm × 1–3 cm, thick-coriaceous, nearly unarmed, auricles colourless, 3–6.5 cm × 1 cm. Inflorescences often 2, approximate, the second placed on a short, leafy branch; spadices usually 3; male spadix cylindrical, 2–3 cm long, peduncle 1 cm long; female spadix 2.5–5 cm long, peduncle 6–15 mm long, stigmas 4–8. Fruiting spadices 5–7 cm long, berries 1–1.5 mm long, flesh yellowish.
- *F. scandens*. A climbing shrub, stems terete, up to 15 m long, internodes up to 2 cm long, diameter up to 1 cm. Leaves not very closely crowded, linear to obovate, 8–10 cm × 1–2.7 cm, thin coriaceous, nearly unarmed, auricles colourless, up to 3 cm long. Spadices 1–4; male spadix cylindrical, peduncle about 2 cm long; female spadix ovoid-cylindrical, up to 6 cm × 2.5 cm, peduncle up to 2.5 cm long, stigmas 2–3. Fruiting spadices 3–6 cm long, berries clavate, 6–7 mm long, red-brown.

Within *F. javanica* two varieties have been distinguished: var. *javanica* and var. *expansa* B.C. Stone, the latter with broader leaves. *Freycinetia* is generally considered to be dioecious, but the breeding system seems more complex, as hermaphrodite individuals have been found for some species, including *F. scandens*. Monoecious individuals of *F. scandens* have been found to be self-compatible. Unlike in the related genus *Pandanus* Parkinson, apomixis is absent in *Freycinetia*. Pollination is effected by vertebrates such as flying foxes, smaller bats, squirrels and birds, which tend to be destructive. The seeds are probably dispersed by birds, bats, flying foxes and other vertebrates. *F. javanica* occurs in humid forests, commonly montane, at altitudes up to 2000 m. In West and Central Java *F. javanica* is found between 700–1600 m altitude and in Palembang (Sumatra) at 200 m altitude. *F. scandens* occurs in Java between 150 and 1200 m altitude. In Australia it is locally common in rain forest up to 1000 m altitude, frequently along streams and river banks. *F. angustifolia* Blume (syn. *F. malaccensis* Ridl.), occurring in Peninsular Malaysia, Sumatra, Java, Borneo and the Philippines, has no recorded use as a fibre plant, but its Malaysian vernacular name 'rotan musang' suggests use for cordage as well.

Selected sources 6, 20, 32, 33, 71, 81, 102, 138, 145, 172, 173, 180, 181.

Girardinia diversifolia (Link) Friis

URTICACEAE

Synonyms *Girardinia heterophylla* Decne., *Urtica heterophylla* Vahl.

Vernacular names Himalayan nettle, Nilgiri nettle (En). Thailand: kalangtang chaang, tamyae chaang, la-chaa.

Distribution In Asia from India, Nepal and Sri Lanka to Indonesia, southern China and Taiwan. Widespread in tropical Africa, also in Madagascar and Yemen. Cultivated as a fibre plant in South India.

Uses In India and Nepal the shiny, wool-like bast fibre from young stems is locally made into cordage and coarse textiles, sometimes blended with ramie (*Boehmeria nivea* (L.) Gaudich.), cotton (*Gossypium* spp.) or wool, but it has not attained any commercial importance. The leaves are eaten as vegetable in the western Himalayas. In north-eastern India the seeds are used as fish poison.

Observations An erect annual or short-lived perennial, 1.5(–2) m tall, monoecious or dioecious; stem sparsely branched, covered with stinging hairs 7–9 mm long and with short stiff hairs. Leaves alternate; stipules linear-lanceolate, fused for over four-fifths of their length; petiole 3–15 cm long; blade variously lobed or divided, 10–20(–25) cm × 10–18(–23) cm, base cuneate, truncate or cordate, margin dentate, apex acuminate. Inflorescence unisexual, cylindrical; male inflorescence a narrow, spicate panicle; peduncle up to 2 cm long; flowers on a 1 mm long pedicel, perianth 4–5-merous; female inflorescence a dense cymose, small dichasium 2–3 cm long at anthesis, elongating to 10–15 cm long in fruit. Fruit an ovoid to subcordate achene, compressed. In tropical areas *G. diversifolia* is found in montane forest. The fibre is extracted by stripping the bark off the stem, after which it is washed or scraped until the fibre is clean. Alternatively, the stripped-off bark is dried, and the fibre is freed by pounding, after which it is boiled with an alkaline solution made from wood ash, and then washed until it is clean. Indian fibre has been recorded as containing 7% moisture and 90% holocellulose. In studies in Indo-China in the 1940s, the bark of *G. diversifolia* yielded 61% fibre. Rough bark strips contained 16% moisture, 38% cellulose, 8% hemicelluloses, 8% lignin and 7% ash. After degumming the fibre contained 11% moisture, 67% cellulose, 8% hemicelluloses, 4% lignin and 3% ash. The fibre is of good quality, but the presence of irritating hairs on all plant parts makes handling unpleasant.

Selected sources 21, 31, 55, 66, 94, 109, 125, 197.

Gnetum gnemonoides Brongn.

GNETACEAE

Synonyms *Gnetum wrayi* Gamble.

Vernacular names Indonesia: tali ganemu (Moluccas), rukiti gumi gumini (Halmahera), wali sowa (Ambon).

Distribution Peninsular Malaysia, Belitung, Borneo, Sulawesi, the Moluccas, the Philippines, New Guinea and the Bismarck Archipelago.

Uses The stems are used as ropes; young stems are split as binding material for fish-hooks. Roasted seeds are edible, but not very palatable.

Observations A large dioecious liana. Leaves decussately opposite, petiolate, simple, elliptical, up to 20 cm × 8 cm, entire, glabrous, pinnately veined, finely striate above. Inflorescence an axillary spike up to 4 cm long, with collars containing sessile flowers; male flowers with a claw-shaped perianth and 1 stamen; female flowers with single ovule enclosed in a fleshy envelope. Seed ellipsoid, enclosed in a fleshy, pink, warty outer envelope, a woody, ribbed middle one and a thin, silky inner one. *G. gnemonoides* occurs in lowland rain forest, up to 300 m altitude. The inner bark fibre of several other *Gnetum* species is used in Malesia for twisting thread, string and cordage, especially valued for fishing lines and nets, e.g. *G. gnemon* L. and *G. latifolium* Blume, of which, however, the edible seeds are more important. *G. cuspidatum* Blume, *G. leptostachyum* Blume and *G. macrostachyum* Hook.f. are used for similar purposes in Indo-China. *Gnetum* fibre is strong and durable.

Selected sources 47, 49, 50, 66.

Goniothalamus malayanus Hook.f. & Thomson

ANNONACEAE

Synonyms *Goniothalamus puncticulatus* Boerl. & Koord.

Vernacular names Indonesia: sugi lado itam (Palembang). Malaysia: pisang-pisang, kenanga paya, dada kura.

Distribution Andaman and Nicobar Islands, Thailand (peninsular & south-western), Peninsular Malaysia, Sumatra, Borneo.

Uses In Indonesia the strong and durable inner bark is made into rope and string. The wood may be used as timber. The leaves when burnt are effective as a mosquito repellent.

Observations A small tree, up to 15 m tall. Leaves alternate, simple, entire; stipules absent; petiole 5–14 mm long; blade obovate-elliptical, 12.5–22(–28) cm × 3.5–9 cm, base acute to obtuse rounded, apex acuminate, veins 14–16 pairs. Flowers solitary, axillary, pendent; sepals 2–8 mm × 3–7.5 mm, green; outer petals up to 6.2 cm long, greenish-yellow; inner petals up to 14 mm long, golden-yellow; stamens 80–250; carpels 8–20. Fruit composed of several monocarps; monocarp 16–37 mm long, 1–3-seeded. *G. malayanus* is found in freshwater-swamp and peat-swamp forests up to 100(–400) m altitude. Flowering and fruiting is year-round. All parts of the plant contain the styrylpyrone derivative goniothalamin, which has antifertility effects. The synonym *G. puncticulatus* is often misspelled as *G. punctilatus*. The related species *G. tapis* Miq. (synonym: *G. sumatranus* Miq.) has medicinal properties, while the bark is used for tying and for weaving mats.

Selected sources 20, 71, 89, 151, 191.

Grewia abutilifolia Vent. ex Juss.

TILIACEAE

Vernacular names Thailand: ya bit (northern), khao chi (north-eastern), po yap (south-western).

Distribution India, Burma (Myanmar), China, Indo-China, Thailand, Peninsular Malaysia and Indonesia (Java).

Uses The bark yields good quality fibre that is made into rope. A decoction of the roots is taken to relieve fever.

Observations A shrub, up to 3 m tall. Leaves alternate; petiole 1–2 cm long, stellate-pubescent; blade broadly ovate, 2.5–12 cm × 2–11 cm, base cordate, margin serrate or doubly serrate, apex acute, obtuse or obtusely acuminate and often shallowly lobed. Inflorescence an axillary cyme, 1–2 cm long; sepals 5, oblong; petals 5, oblong, 3–4 mm × 1–1.5 mm. Fruit a globose, glabrescent capsule. *G. abutilifolia* is found in open, dry, mixed, deciduous forest up to 1000 m altitude.

Selected sources 6, 49.

Grewia bilamellata Gagnep.

TILIACEAE

Vernacular names Philippines: benglaleng (Ilokano, Igorot), dongrareng, durareng (Ilokano).

Distribution Indo-China, the Philippines (Ilocos region).

Uses The bast is made into weak rope that deteriorates rapidly under wet conditions.

Observations A shrub, 3–4 m tall. Leaves alternate; stipules 1.5 mm long, caducous; petiole 3–5 mm long; blade lanceolate, 4–6 cm × 1.5–2 cm, base obtuse, margin dentate, apex pointed. Inflorescence an axillary, 3-flowered cyme; sepals 5, 7–8 mm long; petals 5, half as long as sepals. Fruit a subglobose, glabrous capsule. *G. bilamellata* occurs in thickets at low altitudes. Flowering and fruiting are recorded in October in Indo-China. In Philippine studies in the 1910s, dry and wet rope made from the bast of *G. bilamellata* had a mean tensile strength of 320 kg per cm^2 and 180 kg per cm^2, respectively. The elongation at break of dry and wet rope was 11%.

G. laevigata Vahl (synonyms: *G. acuminata* Juss., *G. multiflora* Juss.) is a timber tree. In Indonesia its dried bast is used for tying; in the Philippines the bast fibres are extracted and made into rope, string, cloth, fishing nets and bird scares. The bast fibre cells are (1.1–)1.8(–2.7) mm long and (6–)15(–24) μm wide, with a lumen width of (1–)3(–5) μm and a cell-wall thickness of 1–10 μm. Dry and wet rope made from the bast had a mean tensile strength of 376 kg per cm^2 and 332 kg per cm^2, respectively, and an elongation at break of 10% and 11%, respectively. *G. eriocarpa* Juss. (synonym: *G. celtidifolia* Juss.) is also used as a timber tree. In Indonesia its bark is used for tying; in the Philippines fibres are extracted and made into rope or used for braiding hats. Dry and wet rope made from the bast had a mean tensile strength of 394 kg per cm^2 and 381 kg per cm^2, respectively, and an elongation at break of 6% and 9%, respectively.

Selected sources 15, 19, 59, 71, 93, 112.

Helicteres hirsuta Lour.

STERCULIACEAE

Synonyms *Helicteres hispida* (C. Presl) Walp., *H. oblonga* G. Don, *H. spicata* Colebr. ex G. Don.

Vernacular names Pink isora (En). Indonesia: jelumpang, kucingan abang (Javanese), kekusin hendak (Lampung). Philippines: malamansanita (Ilokano, Tagalog), tongtongking (Amburayan), buntot-usa (Tagalog). Cambodia: priël chrouk, kantuy kâmprôk. Thailand: khee on, potaohai. Vietnam: du[oo]i ch[oo]n.

Distribution From India through Burma (Myanmar), Thailand and Indo-China to southern China, the Philippines and Java.

Uses The fibrous bast is made into rough cordage. In Sumatra this is done by tearing the bast into narrow strips, which are dried and twisted into rope. The fibre strips obtained from *H. hirsuta* are harsh, stiff and light brown-yellow. Contradictory reports exist on the durability of *H. hirsuta* cordage under humid conditions. The rope made in Sumatra is said to be made and used in the dry season only.

Observations A straggling shrub, 1–2.5 m tall, densely covered with stellate hairs which are not viscid. Leaves lanceolate to elliptical, up to 22 cm × 8 cm, rather rough above. Inflorescence spiciform to racemose, 6 cm long with flowers usually dark red or pink and bearing a large, sessile red-purple gland at base, gynandrophore 1–2 cm long, petals 1–3 cm. Fruit composed of 5 follicles, straight (not twisted), up to 4 cm long, woolly hairy. In Java *H. hirsuta* is found up to 1200 m altitude in brushwood, fences, forest and grassy wilds. In the Philippines it is found at low and medium altitudes in thickets, clearings and secondary forest. *H. hirsuta* flowers year-round in Java, but flowering and fruiting in Indo-China have been recorded from July to November. In studies in Indo-China in the 1940s, the fibre of *H. hirsuta*, separated by retting for 8 days, contained 55% cellulose, 17% pentosans, 14% lignin and 1% ash. In Philippine studies in the 1910s, dry and wet rope made from the bast of *H. hirsuta* had a mean tensile strength of 438 kg per cm^2 and 396 kg per cm^2, respectively. The elongation at break of dry or wet rope was 13%.

Selected sources 19, 20, 21, 34, 36, 59, 71, 93, 147.

Helicteres viscida Blume

STERCULIACEAE

Synonyms *Helicteres hirsuta* Lour. var. *viscida* (Blume) Kuntze, *Orthothecium viscidum* (Blume) Hassk., *Oudemansia viscida* (Blume) Miq.

Vernacular names White isora (En). Indonesia: dlumpangan (Javanese), kakapasan (Sundanese), kerkuching (Lampung). Laos: dok ki on. Thailand: khee on, po khee on (Chiang Rai). Vietnam: du[oo]i ch[oo]n.

Distribution Burma (Myanmar) (Tenasserim), Thailand, Indo-China, China, Peninsular Malaysia and Java.

Uses The tough bast is used like that of *H. isora* L. for making ropes, e.g. in Java and Indo-China.

Observations A straggling shrub, up to 3 m tall, densely covered with viscid, stellate hairs. Leaves ovate-oblong, up to 16 cm × 12 cm, base cordate, apex often shallowly 3-lobed, beneath often whitish-woolly. Inflorescence spiciform or racemose, up to 3 cm long with flowers white with a yellow blotch, bearing a distinctly stalked, green gland at their base, gynandrophore up to 3 cm long, petals 1–3 cm. Fruit consisting of 5 follicles, straight (not twisted), 2–3.5 cm long, woolly hairy. In Java *H. viscida* occurs up to 300 m altitude on slopes and in brushwood. *H. viscida* flowers year-round in Java, whereas flowering and fruiting in Indo-China has been recorded as taking place from September to April. In studies in Indo-China in the 1940s, the fibre of *H. viscida*, separated by retting for 13 days, contained 61% cellulose, 16% pentosans, 16% lignin and 1% ash.

Selected sources 20, 21, 34, 59, 71, 109, 147.

Herissantia crispa (L.) Brizicky

MALVACEAE

Synonyms *Abutilon crispum* (L.) Medik., *Sida crispa* L.

Vernacular names Indonesia: cemplak, cemplok (Javanese).

Distribution Native of America but now a pantropical weed. In Malesia only found in Indonesia (Java, Madura, Kangean Islands, Lesser Sunda Islands, Sulawesi).

Uses Good quality fibre can be obtained from the bark, but the branched habit forms a limitation to commercial exploitation.

Observations A herb, 1–1.5 m tall; stem branching, covered with stellate and simple hairs. Leaves simple, alternate; stipules 2, one erect, the other deflexed, filiform, 3–8 mm long; petiole 0.5–7 cm long, accrescent in fruit to about 4 cm; blade ovate, 4.5–10 cm × 3–7.5 cm, base cordate, apex acuminate, 7–9-veined, stellate-hairy, tomentose especially beneath, with simple hairs on veins. Flowers axillary, solitary, 10–12 mm in diameter; pedicel 1.5–2.5 cm long, accrescent in fruit to about 4 cm; calyx 7–8 mm in diameter, 5-parted, segments ovate to long triangular, reflexed after flowering; corolla 10–12 mm in diameter, consisting of 5 broadly ovate petals 6–10 mm long, pale yellow to white; staminal column 2–3 mm long; styles 10–11. Fruit a globular schizocarp, indented at apex, about 15 mm in diameter; mericarps 10–15. Seed reniform, up to 1.7 mm in diameter. *H. crispa* is a sun-loving plant; in Indonesia it is restricted to periodically very dry regions. It occurs in waste places and along roadsides from sea-level up to 700 m altitude. The variability of the species in Indonesia is small and restricted to the density of the indumentum. The seeds (4.3% moisture) contain 12.5% oil and 18.4% protein. The main fatty acids of the seed oil are linoleic acid (61.2%), palmitic acid (15.7%) and oleic acid (12.2%). The seed oil also contains cyclopropenoid fatty acids such as malvalic acid (4.5%) and sterculic acid (1.3%), which are known to cause abnormal physiological reactions in animals. Therefore, human consumption of seeds or seed oil is not advisable.

Selected sources 6, 20, 57, 71, 141, 189.

Hibiscus grewiifolius Hassk.

MALVACEAE

Vernacular names Indonesia: taluki, waru geni (Javanese), ki oray (Sundanese). Thailand: ngaa chaang (Ranong), chong phian (Surat Thani).

Distribution Southern Burma (Myanmar), peninsular Thailand, Laos, Vietnam, southern China (Hainan) and Indonesia (Java, Sumbawa).

Uses The bast fibre seems to be used in Indonesia for making cordage similar to that of *Talipariti tiliaceum* (L.) Fryxell (synonym: *Hibiscus tiliaceus* L.) and other *Talipariti* species. The wood is not very durable and too small in size to be of major use. The attractive flowers give *H. grewiifolius* ornamental value.

Observations A small tree, 10–20 m tall; trunk 25–35 cm in diameter. Twigs stellate-pubescent. Leaves simple, alternate; stipules ovate to lanceolate, 4–15 mm × 2–4 mm long; petiole 1–1.5(–4) cm long, stellate pubescent; blade ovate to oblong or nearly lanceolate, 7–27 cm × 3–8.5 cm, base obtuse, rounded or shallowly cordate and somewhat unequal, apex gradually acuminate, penninerved, 3–5-nerved at base, minutely stellate-hairy to glabrous. Flowers large, axillary, solitary; pedicel 7–15 mm long; epicalyx segments 6–10, linear to lanceolate, acute, 5–15 mm × 2–4 mm; calyx campanulate, 1.5–3 cm tall, strongly accrescent; corolla yellow with dark purple centre, consisting of 5 obovate petals 6–8.5 cm long; staminal column about 2 cm long; ovary conical, about 3.5 mm long, 10-celled. Fruit a globose, acuminate capsule, up to 23 mm × 17 mm. Seed reniform, 3.5–4 mm in diameter, with long, woolly, red-brown hairs. *H. grewiifolius* occurs in secondary or rarely in primary forest at altitudes up to 1000 m. In Java it flowers from February to June. *H. grewiifolius* is sometimes written as *H. grewiaefolius*.

Selected sources 6, 58, 71, 189.

Hypserpa nitida Miers

MENISPERMACEAE

Synonyms *Hypserpa cuspidata* (Hook.f. & Thoms.) Miers.

Vernacular names Indonesia: akar sencaw (Bangka), akar suganda (Kalimantan). Malaysia: akar minjak. Philippines: lalapau, mamana (Subanon), pagduh-bay. Thailand: haen kuem.

Distribution From India and Sri Lanka through Burma (Myanmar), Indo-China, Thailand, Peninsular Malaysia, Sumatra, Borneo and Sulawesi to the Philippines.

Uses The stems are used for tying and are made into rough rope. In the Philippines the bast fibre has been made into bow string. Unspecified medicinal use is recorded from Thailand.

Observations A scandent, dioecious shrub. Leaves alternate; petiole 0.8–2 cm long; blade elliptical to ovate, up to 12 cm × 7 cm, base obtuse, rounded or obtuse, usually 3-veined. Inflorescence cymose to thyrsoid; flowers yellow, 1–2 mm long, sepals 7–11, petals 5. Fruit a drupe, 5–8 mm in diameter, yellow to red. *H. nitida* is a forest species occurring up to 2000 m altitude.

Selected sources 20, 30, 45, 47, 49, 51, 54, 115.

Ichnocarpus frutescens (L.) W.T. Aiton

APOCYNACEAE

Synonyms *Apocynum frutescens* L., *Ichnocarpus volubilis* (Lour.) Merr., *I. frutescens* (L.) R. Br. (nom. inval.).

Vernacular names Malaysia: gerit jantan, gerip jantan. Philippines: sigid (Bisaya), hinggiw (Tagalog), sadak (Ilokano). Burma (Myanmar): tansapai. Thailand: khruea chen, chai song, po tohai.

Distribution From Pakistan, India, Sri Lanka, Bangladesh, Bhutan and Nepal through Burma (Myanmar), Indo-China, Thailand, Malaysia, Indonesia and the Philippines to southern China, New Guinea and Australia.

Uses The stems are used for handicrafts and as rough rope, e.g. for fishing gear and fencing. They are popular among handicraft manufacturers in Quezon Province (the Philippines), because of their strength and appearance. In China the fine, strong fibre obtained from the bast is made into rope and sacks. In India the flowers are used in treating diabetes, and the roots, stems and leaves for fever, dyspepsia and skin complaints. In China the seeds are used for the treatment of rheumatism and the stems and leaves for acute urticaria.

Observations A liana, up to 20 m long. Branchlets pubescent when young, soon glabrous. Leaves opposite; petiole 0.5–2.9 cm long; leaf blade elliptical or ovate, up to 15 cm × 8.5 cm, base cuneate to rounded, apex shortly acuminate, lateral veins 4–8 pairs. Inflorescence many-flowered, 3–8 cm long, most flowers in pedunculate heads; calyx densely pubescent; corolla tube about 2.5 mm long, lobes narrowly oblong, about 5 mm long; anthers elliptical, disk lobes free, linear, longer than ovary; ovary pubescent. Fruit a pair of follicles, each one cylindrical, 8–15 cm × 4–5 mm, slightly torulose, pubescent. Seed linear, coma about 2.5 cm long. *I. frutescens* grows in a range of habitats, but most often in moist to dry evergreen or deciduous forest, up to 900 m altitude. In the Philippines it is threatened by over-exploitation.

Selected sources 6, 14, 19, 20, 45, 53, 111, 115, 118, 160, 201.

Johannesteijsmannia altifrons (H.G.L. Rchb. & Zoll.) H.E. Moore

PALMAE

Synonyms *Teysmannia altifrons* H.G.L. Rchb. & Zoll.

Vernacular names Joey palm, diamond palm, diamond Joey (En). Indonesia: belawan sang (eastern Sumatra), daun ekor buaya (Borneo). Malaysia: daun payong, daun sal, pokok koh.

Distribution Widespread but very local throughout southern Thailand, Peninsular Malaysia, Sumatra and Borneo. Cultivated on a limited scale.

Uses In Indonesia and Malaysia the leaves are used to make thatched roofs of huts, and in Sumatra also for partition walls. The leaves are very large, strong, durable and easily thatched. They are, however, less durable than those of sago palm (*Metroxylon sagu* Rottboell) and nipa palm (*Nypa* *fruticans* Wurmb), and are said to last for only about 3–4 years. The leaves are also used as umbrellas. The endosperm is edible. In many tropical and subtropical areas, *J. altifrons* is grown as an ornamental.

Observations A solitary, acaulescent palm tree. Stem subterranean. Leaves simple, diamond-shaped, up to 6 m tall; petiole up to 2.5 m long, armed with short thorns; blade up to 3.5 m × 1.8 m. Inflorescence axillary; spathes tubular at base, brown hairy, 10–20 cm × 6–8 cm; peduncle 30–50 cm long; three orders of branches, floriferous branches 20–100, up to 1 m long; flowers white, glabrous; calyx 2 mm long; petals fleshy, 4 mm long. Fruit drupaceous, subglobose, 3.9–4.6 cm in diameter, covered in 60–80 brown, corky warts 6.2–8.2 mm long. Seed globose; endocarp woody up to 1 mm thick; endosperm bony, up to 2.5 cm in diameter. *J. altifrons* occurs from sea level up to about 1200 m altitude, but most populations are above 300 m altitude. In Sarawak it is confined to heath forest, elsewhere it seems less restricted but it avoids wet valley bottoms. In much of its range it is threatened by shifting cultivation, logging and over-collection; in Sarawak its protection is recommended.

Selected sources 43, 71, 90, 91, 119, 134, 147, 193.

Kydia calycina Roxb.

MALVACEAE

Synonyms *Kydia glabrescens* Mast.

Distribution Pakistan, India, Burma (Myanmar) and China. Cultivated as an ornamental. It may have been grown in Peninsular Malaysia.

Uses In India the bast is made into coarse rope, used e.g. for tying rafts. The fibre is strong when green, but becomes brittle on drying. The wood yields a mechanical pulp of low strength, which can be used in admixture with 30% chemical bamboo pulp in the production of newsprint. It is used as firewood, for charcoal and as timber for interior construction work, agricultural implements and domestic articles. The leaves are applied in poultices for skin diseases and body pains, and serve as fodder. A cold infusion of the young, mucilaginous bark is used for clarifying sugar.

Observations A monoecious tree, up to 20 m tall. Leaves simple, alternate; stipules ovate, 1 cm × 0.5 cm; petiole 2–7.5 cm long; blade entire or 3–5-angled, 4–16.5 cm × 3–12.5 cm, base truncate-subcordate, apex acute-obtuse, 7-veined, midrib with gland near the base beneath. Inflorescence a panicle; pedicel ferruginous, 4–8 mm long, in fruit up to 1.5 cm long; epicalyx segments 4–6, obovate or spatulate; calyx 5–8 mm long with 5 triangular, acute lobes; corolla 1–1.5 cm in diameter, petals 5, clawed, white or pink; male flowers with 15–30 stamens, staminal column 3–5 mm long; female flowers with ovary 2 mm in diameter, woolly. Fruit a capsule, 4–5 mm in diameter. Seed reniform, glabrous, dark brown. *K. calycina* is generally found on banks of rivers and streams. It coppices well. Natural reproduction is by seed; root suckers are also produced. Propagation is usually by seed in nurseries, but stem, branch or root cuttings can also be used. The main fatty acids of the seed oil are oleic acid (60.6%), stearic acid (11.4%), myristic acid (6.0%), linoleic acid (5.3%), palmitic acid (4.9%) and lauric acid (3.8%). It also contains 2.9% cyclopropenoid fatty acids.

Selected sources 20, 23, 30, 40, 121, 124, 189.

Licuala Thunberg

PALMAE

Major species

- *Licuala ferruginea* Becc.
- *Licuala kunstleri* Becc.
- *Licuala triphylla* Griffith.

Vernacular names General: licuala palm (En). Indonesia: palas (Malay), leko wala (Makassar). Malaysia: gerenis (Sarawak), loyar (Besisi, Peninsular), palas (Peninsular). Philippines: balatbat (Tagalog). Burma (Myanmar): salu. Thailand: ka pho. Vietnam: l[uj]i.

- *L. ferruginea*. Indonesia: lipai talang (Kubu).
- *L. triphylla*. Malaysia: palas rewang, palas tikus, gurcheng. Thailand: ka pho nok aen, kha pho nuu (Pattani), paa-la ti-ku.

Distribution The approximately 130 species of the genus occur from north-eastern India, southern China, throughout Malesia, up to northern Australia, the Solomon Islands and Vanuatu. The largest diversity is found in Malaysia, Borneo and New Guinea. *L. ferruginea* is found in Peninsular Malaysia and Sumatra, *L. kunstleri* and *L. triphylla* in Thailand, Peninsular Malaysia and Borneo.

Uses The leaves of many *Licuala* species are used to make mats and for tying. They also serve for thatching, e.g. *L. ferruginea* in Indonesia, though they are not durable. Young leaves serve to wrap food and as cigarette-wrappers. The split petioles are used for basketry. The palm heart and palm cabbage are edible. The stems of the few species that produce larger stems are used for construction. Several species are widely grown as ornamentals in the tropics and subtropics.

Observations Palms, usually small, stemless to shrubby, seldom tree-like; clustered or solitary. Leaves palmate; petiole unarmed or with teeth or spines; sheaths disintegrating into fibres; blade many-folded, undivided or split along the ribs, segments wedge-shaped, reduplicate, blunt. Inflorescence spicate to branched, 2(–3) orders, between leaves; flowers solitary or in groups of 2–3. Fruit a 1-seeded drupe.

- *L. ferruginea*. A stemless or almost stemless palm. Leaves palmate, emerging leaves covered with long, brown hairs and scales; petiole spiny, up to 1.3 m long; blade about 1 m in diameter, divided in 3–7, broadly wedge-shaped segments. Inflorescence spicate, stout, up to 75 cm long; spathe brown-pubescent; rachis red-tomentose; flowers crowded, sessile; calyx cup-shaped, lobes ovate, pubescent; petals triangular, yellow. Fruit brilliant red.
- *L. kunstleri*. A small palm, solitary, stemless or stem up to 1 m tall. Leaves palmate; petiole slender, 1–2 m long, with prominent stout thorns on margin; blade about 1 m across, divided into 11–19 spreading lobes, with central lobe larger than the rest, marginal lobes with prominent apical teeth of up to 5 cm long. Inflorescence spicate, 20–70 cm long; spathe with silvery scales; rachis brown-tomentose; flowers crowded, pedicel 1–2 mm long; calyx campanulate, lobes blunt; petals lanceolate, acute. Fruit globose, about 1 cm in diameter, brilliant red.
- *L. triphylla*. A solitary palm with subterranean stem. Leaves palmate, very variable in morphology; petiole slender, up to 75 cm long, with few basal thorns; blade divided into 3–11 segments, with translucent spots. Inflorescence branched; spadix slender, up to 20 cm long; spathe 2.5 cm long; flowers very small, sessile; sepals ovate, acute and tomentose; petals triangular, yellow. Fruit globose, 8–10 mm in diameter, red.

Licuala is closely related to *Livistona* R. Br. and *Johannesteijsmannia* H.E. Moore. It is found in the undergrowth of primary forest, occasionally in secondary forest at low altitudes. Collection for trade as ornamentals could pose a threat to several species. Although they are slow-growing and sometimes have particular requirements for growth, they are popular ornamentals.

Selected sources 9, 20, 71, 90, 91, 147, 163, 188.

Lonicera acuminata Wallich

CAPRIFOLIACEAE

Synonyms *Lonicera philippinensis* Merr.

Vernacular names Indonesia: ki seroh (Sumatra). Philippines: bualtik (Benguet).

Distribution From eastern India to Indo-China, southern China, Taiwan and western Malesia (Sumatra, Java, Bali and Luzon in the Philippines).

Uses In the Philippines the stem is used for tying fences.

Observations A liana or scrambling shrub, with patently hirsute twigs. Leaves decussately opposite, simple, ovate-oblong to lanceolate, 3–8 cm × 1.5–4 cm; petiole up to 1 cm long. Inflorescence a cyme, near the twig-ends; flowers bisexual, zygomorphous, 5-merous; calyx with ciliate lobes; corolla 2-lipped, 2–2.5 cm long, sulphureous; stamens 5; ovary inferior, style filiform. Fruit a black berry, few-seeded. *L. acuminata* occurs in forest borders, thickets and mossy forest in the mountains, at 1800–3300 m altitude.

Selected sources 6, 19, 47, 115.

Machaerina gunnii (Hook.f.) Kern

CYPERACEAE

Synonyms *Cladium brevipaniculatum* Kük., *C. gunnii* Hook.f.

Vernacular names Papua New Guinea: guli (Enga language, Kepilan).

Distribution Papua New Guinea and Australia.

Uses In Papua New Guinea the stems are used by women for making skirts.

Observations A perennial herb, up to 1 m tall, with a short, creeping rhizome. Stems approximate on the creeping rhizome, terete or with a longitudinal furrow, 20–60(–100) cm × 1–2 mm, rigid and pithy, finely striate. Leaves distichously arranged, lowest ones often reduced to bladeless sheaths that clasp the stem tightly, normal ones 1–2, basal, similar to the stems. Inflorescence paniculate, erect, narrowly oblong, 5–10(–25) cm long, consisting of few to several partial panicles with branches in twos or threes with few spikelets; spikelet shortly peduncled, 1-flowered, 5–7 mm long; bristles absent; stamens 3, anthers with distinct, 0.5 mm long appendage to the connective; pistil with thick-based style persistent in fruit, stigmas 3. Fruit a nut, ellipsoid, 2.5–3.5 mm long, trigonous with 3 indistinct ribs, brown to blackish.

M. gunnii is found in swampy grasslands at 2250–3000 m altitude. From a slightly more robust species, *M. mariscoides* (Gaudich.) J. Kern, distributed more widely from New Guinea to other Pacific islands as far as Hawaii, the leaves are used in Hawaii for tying and for lashing thatch to houses.

Selected sources 39, 47, 158.

Machaerina rubiginosa (Spreng.) T. Koyama

CYPERACEAE

Synonyms *Cladium glomeratum* R. Br., *C. rubiginosum* (Spreng.) Domin., *Fuirena rubiginosa* Spreng.

Vernacular names Indonesia: rumput pohon (general), walingi (Sundanese), endong (Javanese). Papua New Guinea: kalke ka (Kaugel), gouldi (Enga).

Distribution From Sri Lanka and India through South-East Asia to Japan, Australia, New Zealand and New Caledonia. In Malesia in Peninsular Malaysia, Sumatra, West and Central Java, the Moluccas (Buru), the Philippines (Mindanao) and New Guinea.

Uses In Sumatra and West Java the leaves are sometimes used for making mats, which are of low quality because they are not damp-proof. In New Guinea they are used as temporary tying material and for plaiting children's baskets. In Australia *M. rubiginosa* is made into bags.

Observations A perennial herb, up to 1.8 m tall, with a short rhizome emitting long horizontal stolons. Stems tufted, slender, compressed biconvex to subterete, 30–180 cm × 2–6 mm, pithy. Leaves distichously arranged, basal ones up to as long as the stem, biconvex to subterete, spongy, 2–7 mm wide, cauline leaf long-sheathing with a short blade. Inflorescence paniculate, erect, narrow, dense or interrupted, 10–50 cm long, consisting of 3–7 fascicles of branches, lower ones distant and often solitary, upper ones approximate and 2–4 together and erect, rigid, scaberulous, much shorter than lower ones; spikelets in numerous clusters, 2–3-flowered, lanceolate to ovoid, 4–7 mm × 2–2.5 mm; bristles absent; stamens 3, anthers with distinct short appendage to the connective; pistil with thick, pubescent style-base, persistent in fruit, stigmas 3. Fruit a sessile nut, ellipsoid, 3–5 mm × 1.5–2 mm, trigonous, orange to red-brown. *M. rubiginosa* is extremely polymorphic and the extremes look like different species. Sometimes 2 subspecies are distinguished:

- subsp. *rubiginosa*, with subglobose partial panicles, spikelets 4–6 mm long, fruits 3.5–4 mm long, leaves narrow, up to 5 mm wide; occurring in the eastern part of the distribution area, including eastern Malesia;
- subsp. *crassa* (Thwaites) T. Koyama (synonym: *Cladium crassum* Kük.), with narrow panicles, spikelets about 7 mm long, fruits 4–5 mm long, leaves 3.5–11 mm wide, occurring in the western part, including western Malesia.

M. rubiginosa is found in swamps and on lake margins, up to 2700(–3200) m altitude. It is sometimes dominant over wide areas of a marsh, but only successful where the plant base is below the water table.

Selected sources 6, 39, 47, 158.

Malvastrum coromandelianum (L.) Garcke

MALVACEAE

Synonyms *Malva coromandeliana* L.

Vernacular names Philippines: salsaluyut, babara (Ilokano), kinay-lumpay (Tagalog).

Distribution Of tropical American origin, but now pantropically distributed.

Uses In the Philippines the stems are made into brooms. The bast can be twisted into rope or woven into handicrafts. Bast fibre can be extracted from the stem by retting for 1 week or more in stagnant water. It is lustrous, strong and durable, creamy white, in older stems greyish-white. The leaves are employed to treat carbuncles.

Observations An erect, annual herb or undershrub, up to 1 m tall; stem with appressed, 4-armed stellate hairs. Leaves simple, alternate; stipules linear to lanceolate, 3–7 mm long; petiole 0.5–4 cm long; blade ovate to oblong, 2–6 cm × 0.7–4 cm, base acute, obtuse, rounded or truncate, apex obtuse to acute. Flowers axillary, often in clusters of 2–4; pedicel 2–5 mm long; epicalyx segments linear to lanceolate, shorter than the calyx; calyx widely campanulate, 5-fid, 7–9 mm long, 10–15 mm in diameter; corolla stellate, about 1.5 cm in diameter, yellow; staminal column 2–3 mm long, conical. Fruit a discoid schizocarp; mericarps 10–14. Seed reniform, up to 1.5 mm in diameter, glabrous. *M. coromandelianum* occurs in disturbed habitats up to about 1250 m altitude. It is sun-loving and prefers areas with a dry season. It is considered a weed in much of its range. The aerial parts of *M. coromandelianum* have shown analgesic effects in tests with mice.

Selected sources 6, 19, 46, 115, 131, 142, 189.

Maoutia diversifolia (Blume) Wedd.

URTICACEAE

Vernacular names Indonesia: beubeunteuran, ki beunteur (Sundanese), bale (Javanese).

Distribution Indonesia (Java).

Uses The tough bark is used for binding.

Observations A shrub, 2–5 m tall. Leaves simple, spirally arranged; stipules connate into axillary scale, broadly triangular, early caducous; petiole 2.5–10 cm long; blade ovate-oblong or lanceolate, 8–25 cm × 3–10 cm, base obtuse, rounded or subcordate, margin crenate-serrate, basal veins extending upwards over 2/3–4/5 of the leaf length. Inflorescence an axillary, mostly paired, lax cyme, 3–15 cm long; flowers unisexual; male flowers with 5-parted perianth, 5 stamens, rudiment of pistil lanate; female flowers with minute or absent perianth, perianth and ovary hairy, stigma recurved, oblong. Fruit rostrate. In Java *M. diversifolia* occurs from 500–1800 m altitude. It is found along terraces, in forest margins, on water sides and in young secondary forest. The bast fibre of *M. setosa* Wedd., found in the Philippines, Taiwan and Japan, is recorded as being used in the Philippines for making coarse cloth, rope and nets. *M. puya* (Hook.) Wedd. ('puya-hemp' or 'Nepal-hemp') grows wild in India, Nepal, Burma (Myanmar) and south-western China; it is occasionally cultivated for its strong bast fibre, which resembles ramie (*Boehmeria nivea* (L.) Gaudich.) and is made into rope, twine, nets, bags, cloth and sails. It has also been recorded in Java. In New Guinea the bark of an unidentified *Maoutia* species is used for string, which is made into aprons and other items.

Selected sources 6, 27, 30, 66, 71, 138, 197, 201.

Mapania bancana (Miq.) Benth. & Hook.f. ex B.D. Jacks.

CYPERACEAE

Synonyms *Lepironia bancana* Miq., *Thoracostachyum bancanum* (Miq.) Kurz, *T. ridleyi* C.B. Clarke.

Vernacular names Indonesia: mingsing (general), sending ayer (Bangka), belingi (western Kalimantan). Malaysia: rumput senayan batu, rumput senderayan, seratit (Peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, Borneo, Sulawesi and New Guinea.

Uses *M. bancana* may serve for matting, but is smaller than *M. sumatrana* (Hassk. ex Steud.) F.-Vill. and is therefore less suitable. In Sabah the roots have unspecified medicinal uses.

Observations A perennial, robust herb, up to 1.2 m tall, with long-creeping stolons. Stem erect, arising from the centre of a basal tuft of normal leaves, rarely 1–2 lateral, trigonous to subtriquetrous, 15–80 cm × 1–3 mm, scabrid on angles near apex, green. Leaves longer than the stems, equitant, in 3 rows, mostly basal, 1 cauline, subcoriaceous; blade linear, 40–105 cm × 0.8–1.8 cm, base gradually narrowed into sheath, margins serrulate, apex acuminate, 3-veined, flat in cross-section, septate-nodulose when dry. Involucral bracts 2–4, long, leaf-like; inflorescence paniculate, terminal, 3–7 cm in diameter, composed of up to 8 primary branches, each subtending 1–6 sessile or shortly pedunculate, ellipsoid to subglobose, few-flowered spikelets 2–4 mm in diameter (sometimes spikelets are infested by a *Ustilago* fungus and reach 1 cm length); flowers bisexual, about 2 mm long, stamens 3, stigmas 3. Fruit a nut, ellipsoid to ovoid, about 3 mm × 1.5 mm, apex abruptly narrowed, exocarp hard, thick, shiny brown with 2–3 longitudinal furrows. *M. bancana* is found in swamp and peat forest, often plentiful as a ground cover in wet, open locations, usually at low altitudes.

Selected sources 20, 47, 156, 158.

Mapania palustris (Hassk. ex Steud.) F.-Vill.

CYPERACEAE

Synonyms *Mapania andamanica* C.B. Clarke, *M. javana* Uittien, *Pandanophyllum palustre* Hassk. ex Steud.

Vernacular names Indonesia: harashas, bangkonoh (Sundanese), assingsing (eastern and central Sumatra). Malaysia: menkuang tedong, menkuang lobo (from its resemblance to *Pandanus*). Philippines: kulibang, blas (Subanon).

Distribution From the Andaman Islands, peninsular Thailand, Peninsular Malaysia and Singapore through Sumatra, Java, Borneo, the Philippines and the Moluccas to New Guinea, the Solomon Islands and the New Hebrides.

Uses The leaves are made into mats and baskets in Peninsular Malaysia and Brunei. *M. palustris* is also grown as an ornamental.

Observations A perennial, robust to very robust, rhizomatous herb, up to 2.5 m tall. Stems erect, 2–4 per plant, lateral, terete to trigonous, 7–37 cm × 1.5–5.5 mm, glabrous to densely hispid, greenish to red-brown. Leaves longer than the stems, basal, coriaceous; blade linear, 70–200 cm × 1.5–5 cm, base gradually narrowed into sheath, margins entire to serrulate, apex acuminate, 3-veined, flat to inverse W-shaped in cross-section, septate-nodulose when dry. Involucral bracts several, about 3 cm long; inflorescence capitate, subglobose, terminal, 1–8 cm in diameter, composed of 3–100, often densely packed spikelets; spikelets ellipsoidal, 1–3 cm long; flowers bisexual, stamens 3, stigmas 3. Fruit a nut, ellipsoid to obovoid, 3.5–5 mm × 2.5–3.5 mm, apex with small recurved beak, exocarp succulent, thin, brown. *M. palustris* is a very variable species and the extremes have often been treated as separate species. At present 2 varieties have been distinguished, mainly based on the inflorescence:

- var. *andamanica* (C.B. Clarke) D.A. Simpson (synonym: *Mapania andamanica*): spikelets up to 6 per inflorescence, forming an open head, each spikelet subtended by a prominent involucral bract; distributed in the Andaman Islands, peninsular Thailand and northern Peninsular Malaysia;
- var. *palustris* (synonyms: *Mapania javana*, *Pandanophyllum palustre*): spikelets usually more than 6 per inflorescence, forming a dense head, the head (not the individual spikelets) subtended by prominent involucral bracts; distribution as the species but not in Andaman Islands.

M. palustris is a very common and widespread species, found in wet or muddy locations in damp primary forest, along streams and on wet rocks, at altitudes up to 1500 m. In Java it flowers from June to December.

Selected sources 6, 20, 47, 156, 158.

Mapania sumatrana (Hassk. ex Steud.) F.-Vill.

CYPERACEAE

Synonyms *Hypolytrum pandanophyllum* F. Muell., *Lepironia sumatrana* Miq., *Mapania heyneana* Back., *Thoracostachyum hypolytroides* (F. Muell. ex Benth.) C.B. Clarke, *T. sumatranum* (Miq.) Kurz.

Vernacular names Indonesia: rumbai lilin, rumbai ijo (Palembang), selingsing (Lampung). Malaysia: umbai, rumput pandan biru (Peninsular).

Distribution Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi, New Guinea, northern Australia and western Caroline Islands. In Sumatra and Peninsular Malaysia sometimes cultivated.

Uses In Peninsular Malaysia and Sumatra the leaves are made into mats. In Australia the leaves are a favourite nesting material for salt-water crocodiles.

Observations A perennial, robust to very robust herb, up to 2.5 m tall, with long-creeping stolons or short rhizomes. Stem erect, arising from the centre of a basal tuft of normal leaves, trigonous to subtriquetrous, 25–200 cm × 2–10 mm, smooth, green. Leaves longer than the stems, basal, equitant, in 3 rows, subcoriaceous, distinctly reticulate when dry; blade linear, up to 2.2 m × 3.8 cm, base gradually narrowed into sheath, margins serrulate, apex acuminate, 3-veined. Involucral bracts 2–3, long, leaf-like; inflorescence paniculate, terminal, globose to ovoid, 3–20 cm in diameter, composed of 4–12 or more long primary branches, each subtending 1–12 secondary branches bearing 1–several sessile or shortly pedunculate, ovoid to subglobose, many-flowered spikelets 5–10 mm in diameter; flowers bisexual, about 3 mm long, stamens 3, stigmas 3. Fruit a nut, broadly obovoid, about 3 mm × 2 mm, apex abruptly narrowed into a beak, obtusely 3–5-angled, grey-brown. *M. sumatrana* has been subdivided into 2 subspecies based on differences in the size and branching pattern of the inflorescence:

- subsp. *sumatrana* (synonyms: *Lepironia sumatrana*, *Thoracostachyum hypolytroides*, *T. sumatranum*): primary branches 0.5–1.5 cm long, bearing 1–4(–6) sessile or shortly pedunculate spikelets; distributed only in Sumatra, Java and Borneo;
- subsp. *pandanophylla* (F. Muell.) D.A. Simpson (synonyms: *Hypolytrum pandanophyllum*, *Mapania heyneana*): primary branches 2.5–13 cm long, each subtending up to 12 secondary branches bearing clusters of 2 or more sessile or shortly pedunculate spikelets; more widely distributed as the species, but not in Java and Sumatra.

M. sumatrana is found in swamps, marshy areas which are periodically flooded, and margins of peat swamp forest, at low altitudes. It is cultivated in swamps and inundated fields. In Java it flowers throughout the year. Harvested leaves are exposed to the sun at daytime and to dew at nighttime, for a period of 2–3 days. Subsequently they are cut into strips and dried further, resulting in beautiful and supple material for weaving mats, which however are less durable than those made from *Pandanus* leaves.

Selected sources 6, 20, 47, 66, 71, 156, 158.

Mitragyna diversifolia (Wall. ex G. Don) Havil.

RUBIACEAE

Synonyms *Mitragyna javanica* Koord. & Valeton.

Vernacular names Indonesia: sepatan, wuru sapi (Java), ki sepat (Sundanese). Thailand: tawm na, tawm ki mu, katum nam.

Distribution Burma (Myanmar), Thailand, Indo-China, China, Peninsular Malaysia, Indonesia (Java) and the Philippines.

Uses The wood is recorded as being useful for paper making. In Java it is occasionally used as timber.

Observations A tree, up to 13(–17) m tall. Leaves opposite; stipules interpetiolar, 10–12 mm long; petiole 1.2–2.5 cm long; blade oblong obovate or broadly ovate-orbicular, 6–16 cm × 3.5–8 cm, base obtuse or rounded, apex rounded or very obtuse, with 8–12 pairs of nerves. Inflorescence corymbose, consisting of globose heads 1–1.8 cm in diameter; flowers sessile; calyx-tube and limb up to 2 mm each; corolla white, funnel-shaped, about 6 mm long, lobes as long as tube. Fruit 2-celled, dehiscent. Seed small, winged. *M. diversifolia* is locally abundant in open or periodically dry forest. *M. speciosa* (Korth.) Havil. is used medicinally throughout South-East Asia.

Selected sources 6, 20, 148, 191.

Nepenthes reinwardtiana Miq.

NEPENTHACEAE

Synonyms *Nepenthes reinwardtii* Hook.f., *N. reinwardtiana* var. *samarindaiensis* J.H. Adam & Wilcock.

Vernacular names Indonesia: gendi kere (Lingga), ketakong kijang (Bangka).

Distribution Sumatra and Borneo.

Uses The stems have been mentioned as being used for tying material in Indonesia, but this has been questioned. On Bangka the leaves are applied against skin problems. Root decoctions are said to be used as an astringent, but this is not certain.

Observations A dioecious, terrestrial or epiphytic shrub or climber, 2–8(–20) m tall. Stem triangular, 3–7.5 mm in diameter, the corners rounded or 2 with wings up to 3 mm broad. Leaves leathery, sessile; basal rosette leaves not known; blade of climbing leaves narrowly elliptical to rectangular, 8–28 cm × 1–4.5 cm, base often decurrent as wings; lower pitchers ellipsoid in the basal half, slightly constricted towards the subcylindrical upper half, up to 11 cm × 4 cm, with 2 fringed wings, mouth ovate, peristome 0.5–1.3 mm wide, without ribs; lid ovate to elliptical, up to 3.9 cm × 3.7 cm, lower surface without appendages; spur simple, up to 3 mm long; upper pitchers slightly ventricose, 9–31 cm × 3–7 cm, light green, with 2 ridges up to 1 mm broad lacking fringing elements, inner pitcher surface glaucous with 2 conspicuous darker eye-like dots; lid 2–8 cm × 2–6.5 cm. Male inflorescence 20–38 cm long; partial peduncles 2-flowered; pedicel 1–1.5 cm long; tepals 4, elliptical, 3.5–4 mm × 2.5 mm, reddish-black; androphore 0.3 mm long. Female inflorescence similar to male one but on average shorter; tepals lanceolate, acute; ovary superior, 4-locular with numerous ovules, stigmas 4, sessile. Fruit with valves 3–4 cm long. Seed fusiform, 18–20 mm. *N. reinwardtiana* is found in lowland peat-swamp forest, high altitude sandstone or limestone ridges, or, more rarely, moss forest, sometimes on ultrabasic soils, at altitudes up to 1450(–2100) m. It often grows as an epiphyte. *N. reinwardtiana* is currently not considered a threatened species, but it is listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II, which means that international trade in wild and artificially propagated material is permitted subject to licence.

Selected sources 1, 38, 47, 70, 71, 88, 146, 157, 184.

Oreocnide rubescens (Blume) Miq.

URTICACEAE

Synonyms *Villebrunea rubescens* (Blume) Blume, *V. semierecta* Blume sensu Heyne, *V. sylvatica* (Blume) Blume.

Vernacular names Indonesia: urang-urangan (Javanese), nangsi (Sundanese), palanggungan (Madurese).

Distribution From the Himalayas through South-East Asia to Japan and New Guinea.

Uses Fibre can be extracted from the bast. Medicinal uses are recorded for Sumatra, Java, Lesser Sunda Islands and New Guinea. Ailments treated include fever, smallpox, eye inflammation, headache and urinary complaints. The bark yields a red dye that is used for basketry. In Java the young leaves and shoots are eaten raw or steamed as a vegetable. In Central Java it has been used as a living fence.

Observations A dioecious tree or erect shrub, 3–8 m tall. Leaves alternate; stipules connate at base, 0.5–1.5 cm long; petiole 1–9 cm long; blade oblong-obovate, pinnately nerved, base subcordate, rounded, obtuse or cuneate, apex acuminate. Inflorescence axillary, simple or sparingly forked, 1–2 cm long, often deformed into witches' broom; male flowers 4-merous, with 4 stamens; female flowers with basal cupule becoming fleshy at maturity, enclosing the dry perianth and fruit. Spurious fruit globose, white, about 5 mm across. *O. rubescens* is found up to about 1700 m altitude in Java, in forests and elsewhere in shaded positions, usually in somewhat moist locations. It has shown anti-inflammatory activity. It is easily propagated by cuttings. The related species *O. integrifolia* (Gaudich.) Miq. (synonym: *Villebrunea integrifolia* Gaudich.), found wild from the eastern Himalayas to Orissa and the Western Ghats (India), has been cultivated in the eastern Himalayas and Assam (India) as a fibre plant. Its bast fibre (ultimate fibre cells 25–30 mm long and 13 μm wide) has been made into rope, nets, fishing lines and sackcloth. Nowadays it is mainly planted for erosion control. If indeed distinct, the two species seem to have been confused in the literature.

Selected sources 2, 6, 20, 30, 66, 71, 92, 129.

Pandanus adinobotrys Merr. et Perry

PANDANACEAE

Synonyms *Pandanus angiensis* Kanehira.

Distribution Wild in New Guinea; also semi-cultivated in Irian Jaya.

Uses The leaves are used for thatching. Fibre from the leaves is used in male initiation rituals.

Observations A dioecious, branched shrub or unbranched tree, up to 8 m tall, lacking prop roots. Leaves coriaceous, up to 3.25 m × 7–10 cm, margins serrate-dentate, underside of midrib spiny. Female inflorescence with peduncle 30 cm long, bearing spicately about 9 heads of 17 cm × 10–12 cm; drupes numerous, about 2 cm × 0.5 cm, style spiniform, 7–12 mm long; upper mesocarp concave, endocarp 11–13 mm long. Fruit a syncarpous polydrupe, red at maturity. *P. adinobotrys* is a plant of high altitudes (1400–2000 m) in mossy forest, occupying the same ecological niche as *P. antaresensis* St. John, but it is less robust. According to B.C. Stone, *P. adinobotrys* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 66, 82, 116, 176, 179.

Pandanus amboinensis Warb.

PANDANACEAE

Synonyms *Pandanus biciliatus* St. John, *P. luteus* St. John, *P. sylvestris* Kunth.

Vernacular names Indonesia: pandan gunung (Moluccas), keker ewang, leit ewang (Ambon).

Distribution Indonesia (Ambon, Halmahera), New Guinea.

Uses Because of their great length, the leaves are sought after in the Moluccas for the production of mats, which, however, are less durable than those made from the leaves of *P. tectorius* Parkinson. The wood is used to make tools for pounding sago ('nani'), and in Sulawesi it is split into laths, which are used to fix leaves for roofs. Durable gutters are made from the stem because the outer layer is harder than that of other *Pandanus* species; inside the stem is spongy and fibrous.

Observations A dioecious tree 6–12 m tall, branched above, bearing prop roots. Leaves 2–2.5 m × 5–7 cm, stiff-coriaceous, margins and midrib with antrorse prickles, on margins large and small prickles alternating. Male inflorescence with boat-shaped bracts 45 cm × 8 cm, bearing 9–11, cylindrical spikes 20–25 cm × 7–10 mm, each with numerous phalanges with almost free stamens. Female inflorescence pendulous, solitary, peduncle longer than 25 cm; head ellipsoid-ovoid, 17 cm × 3.5 cm at anthesis, composed of numerous drupes. Fruit a syncarpous, yellow polydrupe, 35–42 cm × 8–10 cm; drupes 15–19 mm × 4–6 mm, 5- or 6-angled. *P. amboinensis* occurs in dense forest from sea-level up to about 1600 m altitude. According to B.C. Stone, *P. adinobotrys* is classified in subgenus *Lophostigma*, section *Maysops*.

Selected sources 71, 183.

Pandanus andersonii St. John

PANDANACEAE

Vernacular names Malaysia: geronggang kerupok (Iban), surong irit (Sarawak).

Distribution Borneo (Sarawak, south-western Sabah).

Uses The leaves are used for thatching.

Observations A dioecious, ascending, forking shrub forming dense thickets, stem 20–25 cm × 1 cm, with ramifying roots below water table and rhizome at surface level. Leaves coriaceous, linear-oblong but M-shaped in cross-section, 3–7 m × 3 cm, base amplexicaul, margin with stout serrations 2.5 mm long and 5–13 mm apart, apex abruptly narrowed into a point, underside of midrib at base and apex with reflexed prickles. Female inflorescence ascending, peduncle 10 cm × 2.5 cm, heads often 2–3 together in a spike 15 cm long, sometimes solitary. Fruit a syncarpous polydrupe, subglobose to ellipsoid when ripe, 12–14 cm × 13–14 cm, yellow, bearing several hundreds of drupes; drupe fusiform, 35–40 mm × 5–6 mm, 5–6-angled, upper mesocarp concave, basal mesocarp fleshy-fibrous, endocarp 18–21 mm long, style 5–7 mm long, stigma 4–5 mm long. *P. andersonii* is restricted to freshwater swamp forest. According to B.C. Stone, *P. andersonii* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 165, 179.

Pandanus antaresensis St. John

PANDANACEAE

Synonyms *P. bowersae* St. John.

Vernacular names New Guinea: malaye (Kakoli).

Distribution Endemic to New Guinea. In semi-cultivation in Irian Jaya.

Uses The leaves are used for thatching and the fruit and seeds as food. *P. antaresensis* is applied in healing rituals to treat fever, headache, diarrhoea and difficult breathing. Fibres from the leaves are used in male initiation rituals.

Observations A dioecious tree 8–23 m tall, trunk 16 m, upper part branched to form a crown, prop roots up to 10 m or longer. Leaves 1.8–2.3 m × 8–10 cm, coriaceous, widely U-sulcate, parallel veins 170–200, margins and upper part of midrib underside with prickles 1–3 mm long. Male inflorescence pendent, peduncle 30 cm long, rachis 1.6 m long with yellow-white bracts; spikes numerous, cylindrical, 10–16 cm × 2–3 cm; staminal phalanges 12 mm long with 3–7 stamens. Female inflorescence a large solitary head on peduncle 0.3–1 m long. Fruit an ovoid syncarp, 20–35 cm × 17–25 cm; carpellate phalanges 4–6-angled pyramidal, 7–9 cm × 4.5–6 cm × 3–5 cm, orange, apex concave, brown, stigmas 5–9; upper mesocarp with cavities, lower mesocarp fleshy-fibrous 1–1.5 cm long; endocarp 5–6 cm long, wall 4–5 mm thick. Seed cylindrical, 2–3 cm long. *P. antaresensis* is found in primary forest at higher elevations (1500 m or higher). It occupies the same ecological niche as *P. adinobotrys* Merr. et Perry. It may form extensive mixed or almost pure stands. In contrast with other pandans *P. antaresensis* bears fruits year-round. In Papua New Guinea the fruits are simply collected from the ground, because the prominent spiny prop roots make climbing the tree too difficult. *P. antaresensis* is classified by B.C. Stone in subgenus *Pandanus* section *Excavata*.

Selected sources 66, 82, 167, 168, 175, 176, 182.

Pandanus bicornis Ridley

PANDANACEAE

Vernacular names Indonesia: pandan sepejam (Palembang).

Distribution Peninsular Malaysia and Indonesia (Sumatra).

Uses Older leaves are woven into mats and coarse hats which are worn in the field. The durability is less than that of material from *P. furcatus* Roxb.

Observations A dioecious shrub, 30–60 cm tall. Leaves linear, 60 cm × 5 cm, margins and underside of midrib with prickles, apex abruptly caudate with 7 cm long tail. Male inflorescence unknown. Female inflorescence a solitary head, cylindrical to subglobose, about 10 cm in diameter, in axil of broad ovate bract 15 cm long with 5 cm long tail at apex; drupes 18 mm × 12 mm, with free, obscurely angled, broad top; stigma with 2 short horns 3 mm long. *P. bicornis* grows in dense forest at 800–1000 m altitude. According to B.C. Stone, *P. bicornis* is classified in subgenus *Rykia*, section *Rykia*.

Selected sources 71, 147, 176.

Pandanus copelandii Merr.

PANDANACEAE

Synonyms *Pandanus muricatus* Elmer.

Vernacular names Philippines: bariu (Bikol), baleo (Bisaya), lagutlut (Tagalog).

Distribution The Philippines, wild and cultivated from northern Luzon to southern Mindanao.

Uses The leaves contain strong fibres and are used in the Philippines to make mats, baskets, bags and hats of good quality.

Observations A dioecious, thicket-forming shrub 2–4 m tall or almost unbranched tree 6–9 m tall with trunk 7–15 cm in diameter ringed with leaf scars and blunt spines; prop roots short. Leaves 1–3 m × 3–8 cm, margins and underside of midrib with prickles 1–3 mm long, coriaceous, ascending, recurving above the middle, M-shaped in cross-section, with up to 160 parallel secondary veins. Male inflorescence a raceme of 4 or more spikes, 80 cm or longer, each spike in axil of a bract; bracts 75 cm × 5 cm, lower ones largest; spike cylindrical, 7–10 cm × 10–12 mm, consisting of dense staminate phalanges with free filament tips 0.2 mm long, anthers 4.5 mm long with pointed connective 0.5 mm long. Female inflorescence (inodorous) with trigonal peduncle 50–100 cm long; rachis with (1–)3–8 spicate syncarpous heads, each subtended by a 10 cm long bract; head ellipsoid, 7–15 cm × 4–7 cm, bearing numerous drupes; drupe 19–23 mm × 4–5 mm × 2–3 mm, 5–6-angled pyramidal, lower fused part 4–6 mm long, stigma 4 mm long, lower mesocarp fibrous outside, fleshy inside, endocarp bullet-shaped, hard but very thin. Seed 2–3 mm in diameter. In the Philippines *P. copelandii* occurs widely at low and medium altitudes. Leaf harvesting can start when the plants are 3–4 years old. Although H. St. John is of the opinion that inflorescences with solitary heads are rare, B.C. Stone has given variety status to those specimens: var. *panchoi* B.C. Stone (head solitary, pendulous, cylindrical, 14 cm × 4.5 cm on peduncle 50–60 cm long). According to B.C. Stone, *P. copelandii* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 19, 36, 132, 166, 176, 179.

Pandanus dubius Spreng.

PANDANACEAE

Synonyms *Pandanus bidur* Jungh. ex Miq., *P. compressus* Martelli, *P. pacificus* hort.

Vernacular names Knob-fruited screwpine (En). Indonesia: pung (Halmahera), boku (Ternate), haun pantai (Ambon). Philippines: bakong, taboan (Bisaya). Thailand: toei kaeo (Bangkok).

Distribution The seacoasts of Peninsular Malaysia, Indonesia (south-western Java, the Moluccas), the Philippines, Papua New Guinea, northern Polynesia and Vanuatu. Also cultivated in this area. Outside this area grown as a potplant or a garden ornamental (known as *P. pacificus* hort., often trimmed to a certain size, usually remaining sterile).

Uses The very broad and thick leaves are used for coarse weaving, e.g. in Halmahera (Indonesia), the Philippines and New Guinea to make mats. The thick leaves tend to make a springy mat and the waxy epidermis makes them suitable as protection against rain. The leaves are stiff but can be made more flexible by heating them. Fibres from the core of the prop roots are used in Indonesia for tying and plaiting work in chairs. In the northern Moluccas they are popular for making durable thread and rope, in particular fishing lines. In the Bismarck Archipelago (Papua New Guinea) the leaves are used to wrap fish and cassava for baking, and to wrap taro to be softened by being stamped on. They also serve as material for floors and walls and as thatch. Traditionally they were folded into packets for carrying lime for betel chewing. Root fibres are extracted, dried and woven into mats. In the Solomon Islands the leaves are used to cover tobacco during the drying and curing phase, for thatching and to make mats, hats and 'custom umbrellas', durable shields against sun and rain. These shields, 40 cm long and 20 cm wide, consist of *Pandanus* leaves sewn together with thread, often made from *Donax canniformis* (G. Forster) K. Schumann. The large seeds of *P. dubius* are edible and taste like coconut, they are eaten as a relish on Guam. *P. dubius* is grown as an ornamental.

Observations A dioecious, finally stout, sparingly branched tree, 8–20 m tall with numerous massive prickly prop roots 2–5 m long, but often remaining a rather slow-growing low-rosette shrub; bark brownish, rather smooth. Leaves thick-spongy-coriaceous, 1–5 m × 10–15 cm, rigid toward the base, margins and underside of midrib prickly, outer one-third folded down, veins tessellate with 140–170 parallel secondary veins and conspicuous tertiary cross veins. Male inflorescence a stout raceme 40 cm long, with up to 12 spikes subtended by softly leathery, yellow, boat-shaped, spiny bracts; spike creamy-white, cylindrical, 12–20 cm long, consisting of staminate phalanges 7–14 mm long, with about 6–15 stamens (filaments 1–3 mm, anthers 3–6 mm long) borne subumbellately at apex of a column of 4–6 mm length. Female inflorescence a solitary, globular head, 20–35 cm in diameter, subtended by yellowish bracts; peduncle 60–85 cm long; head composed of 50–90, relatively large carpellate phalanges with 2–5 carpels or of 1-celled drupes, usually a combination of these in one head; ripe carpellate phalange ellipsoid or obovoid, large, 9–13.5 cm × 4–7.5 cm × 4–5 cm, 1–2(–4)-celled, upper one-third free; upper mesocarp solid, 4–7 cm long, consisting of dense parenchyma traversed by longitudinal fibres; lower mesocarp fibrous and fleshy, 3–5 cm long; endocarp 20–35 mm long, hard, thin; stigmas large, often in a row and facing the apex of the syncarp. Seed broad ellipsoid, 10–16 mm long. *P. dubius* is restricted to rocky coasts, lowland headlands, often in riverine or tidal mangrove swamps, but male plants are apparently rare. It is easy to cultivate, but rarely develops a tall trunk. According to B.C. Stone, *P. dubius* is classified in subgenus *Rykia*, section *Hombronia*.

Selected sources 6, 19, 24, 66, 71, 101, 145, 160, 169, 174, 176, 178.

Pandanus exaltatus Blanco

PANDANACEAE

Synonyms *Pandanus arayatensis* Merr., *P. banahaensis* Elmer.

Vernacular names Philippines: alasas (Tagalog), bamban (Ibanag), pangdan (Ilokano).

Distribution The Philippines (Luzon).

Uses The leaves are made into hats in the Philippines.

Observations A dioecious shrub, 3–4 m tall with forked branches. Leaves 2 m × 8 cm, margins and underside midrib with prickles. Inflorescence and fruits comparable to those of *P. tectorius* Parkinson. *P. exaltatus* occurs in primary forest up to 800 m altitude. According to B.C. Stone, it is classified in subgenus *Pandanus*, section *Fagerlindia*.

Selected sources 73, 176, 192.

Pandanus helicopus Kurz

PANDANACEAE

Synonyms *Pandanus johorensis* Martelli, *P. radula* Warb.

Vernacular names Indonesia: rasau, rasau tikus (Malay, Sumatra), selingsing (Kubu, Sumatra). Malaysia: pandan rasau. Thailand: kiang luang (Chiang Mai), toei (central).

Distribution Pensinsular Malaysia, Sumatra, Bangka and Borneo; perhaps Thailand.

Uses Where better pandans are not available, the leaves are made into coarse mats and sacks. It is not much in demand for this purpose, however, because the leaves are small, brittle and not durable. Male inflorescences have a strong and pleasant scent and flowers are placed between clothes and in the hair. The fruits have been used in Sumatra as a bait in fish traps.

Observations A dioecious tree, 5–7 m × 7.5 cm, with strongly and irregularly branched stem, branches 2 cm in diameter. Leaves up to 180 cm × 7.5 cm, base orange and erect, upper part deflexed, margins and underside of midrib with black prickles. Male inflorescence pendent, a long raceme of spikes, with white bracts 10–12 cm long; spikes cylindrical, about 22 cm × 1.5 cm, closely packed with staminate phalanges. Female inflorescence solitary, cylindrical, 5 cm long on 20 cm long peduncle. Fruit a syncarpous polydrupe, cylindrical, 12.5 cm × 7.5 cm, golden-brown; drupes narrow, 2–3 mm in diameter; stigma slender. *P. helicopus* is found in marshland, pools or along rivers, where it forms large, impenetrable complexes, which may obstruct rivers. The carpellate phalanges of *P. helicopus* can be dispersed by turtles. According to B.C. Stone, *P. helicopus* is classified in subgenus *Rykia*, section *Solmsia*.

Selected sources 20, 32, 71, 160, 176.

Pandanus humilis Lour.

PANDANACEAE

Synonyms *Pandanus ovatus* (Gaudich.) Kurz ex Warburg, *P. perakensis* Ridley, *P. pierrei* Martelli.

Vernacular names Malaysia: mengkuang tikus, pandan tikus, sendayan masing. Cambodia: rumche:k (general). Laos: chiê:d (Louang Prabang). Thailand: kuu-wae teeku (Narathiwat), toei (Trat), toei nuu (Trang, Narathiwat). Vietnam: d[uwr]a n[uwr]i (Binh Tri Thiên), gi[uwr]a (d[uwr]a) d[aj]i (Ha Nam Ninh).

Distribution From north-eastern India through Burma (Myanmar), Thailand and Indo-China to Peninsular Malaysia.

Uses The leaves are used to weave small articles such as pouches and bags. The fruits are edible although quite acidic.

Observations A small, dioecious shrub with short stems and branches, up to 2.5 m tall. Leaves up to 2 m × 2.5 cm, margins and underside of midrib covered with prickles 1–3 mm long, longitudinal parallel veins about 50. Male inflorescence spicate with a raceme of 5–9 spikes; each spike 5–6 cm long, consisting of numerous, apparently free but compacted, almost sessile stamens. Female inflorescence with peduncle 20 cm long bearing 1–4 heads each one subtended by a bract; bracts navicular, up to 9 cm × 5 cm; cephalium ovoid, 7 cm × 6 cm, consisting of numerous distinct carpels. Fruit a syncarpous polydrupe; drupe 5–6-angled pyramidal, 25 mm × 4–5 mm, stigma spiniform, 10 mm long; upper mesocarp cavernose, lower mesocarp fibrous and fleshy; endocarp 8–9 mm long, hard. *P. humilis* is generally found in tropical monsoon forest and thickets on low hills, on rocky, often granitic soils, up to 1000 m altitude. According to B.C. Stone, *P. humilis* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 20, 50, 160, 179.

Pandanus kurzii Merr.

PANDANACEAE

Synonyms *Pandanus asper* St. John, *P. caricosus* sensu Kurz, non Sprengel.

Vernacular names Indonesia: pandan sepejam (Palembang), pandan sili (Javanese), harashas (Sundanese).

Distribution Indonesia (Java and Sumatra).

Uses The leaves are used in the production of mats and hats, and for thatching and packing. They are, however, brittle and not very durable.

Observations A dioecious, stemless, densely tufted shrub, 0.75–1.5 m tall, or tree with short, decumbent or leaning stem. Leaves linear, 1.5–2.5 m × 2–5 cm, margins and upper surface of the 2 lateral folds with prickles, dark green above, glaucous beneath. Male inflorescence an erect raceme of spikes subtended by boat-shaped, yellow bracts, offensively smelling; spikes 10–20 cm long, consisting of densely packed staminate phalanges, each phalange with very short filaments and 7–20 mm long anthers. Female inflorescence erect, subellipsoid, in fruit a syncarpous polydrupe 8–12 cm × 6–9 cm, upper parts of drupes free, lower parts connate; mature drupe juicy, cylindrical-obovoid or conical, about 2 cm long (top falling off as a hood), free part beset with small tubercles, stigma simple, 4–9 mm long, pointed; endocarp about in the middle of the drupe. *P. kurzii* occurs and is locally numerous, both in wet and dry regions, in forest shade, up to 1100 m altitude. It flowers year-round in Java. According to B.C. Stone, *P. kurzii* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 6, 71, 176, 179.

Pandanus labyrinthicus Kurz

PANDANACEAE

Vernacular names Indonesia: pandan (tunjang) rasau (Sumatra), alohakai (Simeuluë). Malaysia: pandan rasau.

Distribution West coast of Sumatra, perhaps Java.

Uses The leaves are brittle and less suitable for plaiting work, though they are used for this purpose. The split stems, with the spiny outer layer and the core removed, are made into fairly durable plaited walls.

Observations A dioecious shrub, 3–6 m tall, with the stem growing in an erecto-patent or horizontal direction for a long time, turning to all sides, emitting many criss-cross growing prop roots, which form an impenetrable labyrinth. Leaves linear, 1.3–2 m × 2.5–4.5 cm, margin and midrib below armed with prickles up to 4 mm long, apex gradually tapering into a triquetrous point, shiny green. Male inflorescence spicate, pendulous, 50–60 cm long, with numerous spikes arranged in a raceme; bracts linear-lanceolate; staminal phalanges 8–15 mm long, apically with 12–18 umbellate, distinctly stalked anthers. Female inflorescence pendulous, consisting of 8–13 spicately arranged heads; carpels ellipsoid-obovoid, 1.5–2.5 cm long, ripening as a bright orange drupe, stigma subulate or forked, endocarp near the middle, with a flat top. Fruit a syncarpous polydrupe, rounded-ellipsoid, 8–12 cm × 6–8 cm. *P. labyrinthicus* occurs in swampy locations and along river banks. According to B.C. Stone, *P. labyrinthicus* is classified in subgenus *Rykia*, section *Rykia*.

Selected sources 6, 20, 71, 176.

Pandanus leram Jones ex Fontana var. andamanensium (Kurz) B.C. Stone

PANDANACEAE

Synonyms *Pandanus andamanensium* Kurz.

Vernacular names Indonesia: pandan wong (Sundanese).

Distribution The Andaman Islands, Indonesia (southern coast of Java).

Uses The leaves are used in Java to make mats for local use. However, the leaves are thick and leathery and only suitable for coarse work. In the Andaman Islands (India) the leaves are used to make various articles of apparel (e.g. ceremonial waist girdles) and for thatching. The fruits are eaten after cooking and the fibrous parts of the fruits are made into paintbrushes.

Observations A dioecious tree, 5–15(–18) m tall, not or sparingly branched, with a robust, fairly annulate trunk and more or less developed prop roots. Leaves rather thick and rigid, linear, 1.5–3 m × 8–12 cm, margin and underside of midrib with numerous slender prickles, apex tail-like, pellucid cross lines or transverse ribs absent. Male inflorescence a massive branched raceme of spikes; spikes oblong, composed of numerous phalanges each consisting of about 20 stamens on a stout column 6–7 mm long. Female inflorescence a solitary, globose head, composed of several-celled carpellate phalanges. Fruit a syncarpous polydrupe, ellipsoid to globose, 18–31 cm × 18–24 cm; carpels in fruit 7–15 cm × 3–7 cm, much broader than thick, red when ripe; stigmas 3–14, distributed over the top of the carpel, broad, flat, erecto-patent, in ripe carpels often caducous; connate endocarps slightly below the middle of the carpel. In Java *P. leram* var. *andamanensium* is found in *Barringtonia*-association. In the Andaman Islands it is common in swampy locations. *P. leram* var. *andamanensium* is presumably the wild form of *P. leram*, whereas the other variety, *P. leram* var. *leram* (*P. leram* sensu stricto), is a more or less cultivated form (cultivar or group of cultivars), grown for its large edible fruits. According to B.C. Stone, *P. leram* is classified in subgenus *Rykia*, section *Hombronia*.

Selected sources 3, 4, 6, 30, 71, 139, 177.

Pandanus luzonensis Merr.

PANDANACEAE

Synonyms *Pandanus calicarpus* Martelli.

Vernacular names Philippines: alasás (Tagalog, Zambal), dasa (Tagalog).

Distribution Philippines (Luzon).

Uses The leaves of *P. luzonensis* are made into baskets and mats. Decoctions of the tips of fresh or dried prop roots are credited with diuretic properties.

Observations A dioecious tree, up to 7 m tall, with ventral pleats of leaves prickly denticulate and with solitary heads. Carpellate phalanges ribbed and grooved longitudinally, apex first acuminoid, later truncate, closely crowded with stigmas. *P. luzonensis* occurs in secondary forest and in thickets along streams, up to 400 m altitude. According to B.C. Stone, *P. luzonensis* is classified in subgenus *Pandanus* sensu B.C. Stone, section *Athrostigma*.

Selected sources 19, 114, 135, 140, 176.

Pandanus papuanus Solms-Laubach

PANDANACEAE

Vernacular names Indonesia: im, mandim bepos (southern Halmahera), tobaluko (northern Halmahera).

Distribution The entire northern coast of New Guinea and the nearby island groups. Cultivated in Halmahera.

Uses The strong and very seawater-resistant fibres from the prop roots are used in New Guinea to make fishing lines and nets. The fibre is strong enough to be used for shoelaces. The leaves are not suitable for plaiting, but on Halmahera they are used to make tacked 'kakoja' mats. The prop roots are made into torches in New Guinea.

Observations A dioecious tree with a straight stem 10–15 m tall, branching at about three-quarters of its height and emitting from not far below this point many straight, spiny prop roots. Leaves 2 m × 10–12 cm, margins prickly. Female inflorescence a pedunculate, pendant, solitary, subglobose head, about 45 cm in diameter; drupes 8 cm × 3–4 cm, up to 11-locular, apex truncate to subconcave. *P. papuanus* grows gregariously and locally forms large groups in permanent moist or swampy locations along the coast and on the shores of rivers and lakes. The coarse, white, shiny and up to 7–8 m long fibres are obtained from prop roots which have not yet become too woody. To obtain the fibre, the roots are cut off near the stem, or, if the roots have become too hard in that place, further away from the stem, and soaked in water. The hard outer layer is removed and the core is divided in strips, from which the fibre is freed by putting them between two bamboo laths which are moved up and down. The fibre is dried in the shade, because full sunlight might adversely affect colour and strength. Prop roots can be removed regularly without damaging the plant. According to B.C. Stone, *P. papuanus* is classified in subgenus *Pandanus* sensu B.C. Stone, section *Intraobtutus*.

Selected sources 71, 138, 176.

Pandanus piricus St. John

PANDANACEAE

Distribution Philippines (Leyte).

Uses The leaves are used in the production of baskets and mats.

Observations A dioecious shrub, 4 m tall, branches 3 cm in diameter. Leaves 2 m × 9 cm, at midsection the margins undulate and bearing, as does the midrib underside, ascending prickles 2 mm long, 5–13 mm apart; each half of the leaf with about 64 parallel secondary veins. Infructescence spicate, bearing 4 pale red fruits; peduncle 43 cm long; syncarp subglobose, 10 cm in diameter; carpels narrowly pear-shaped, 3.5 cm × 1–2 cm × 1 cm, 5–6-angled and with reniform stigmas, upper fourth part free, lower part connate; upper mesocarp fibrous, lower mesocarp fleshy and fibrous; endocarp black, 24 mm × 3–4 mm. Seed ellipsoidal, 3–4 mm long. H. St. John has placed *P. piricus* in subgenus *Pandanus* sensu B.C. Stone, section *Elmeria*, which also contains the closely related *P. radicans* Blanco.

Selected sources 170.

Pandanus polycephalus Lamk

PANDANACEAE

Synonyms *Pandanus kurzianus* Solms, *P. rechingerii* Martelli, *P. wallichianus* Martelli.

Vernacular names Indonesia: panreng (southern Sulawesi), pandan kecil (Malay, Moluccas), oro-oro (northern Halmahera).

Distribution Indonesia (Sulawesi, the Moluccas), the Solomon Islands and New Britain. Occasionally cultivated (e.g. in Java).

Uses When no other pandans are present, older leaves are used in the Moluccas to make mats, which are not very durable. On Halmahera, where *P. polycephalus* is sometimes planted, the leaves are used for fine woven articles and they are preferred to those of *P. tectorius* Parkinson for this purpose. Young leaves are white, tender and sweet like palm cabbage, and are eaten raw in the Moluccas. They are also recommended for people who have eaten bad seafood. Fresh fruits are used in Sulawesi as an abortifacient.

Observations A dioecious tree, rarely taller than 6 m, with short prop roots and a large crown of numerous very short leafy branches. Leaves linear, 0.8–1.5 m × 3–4 cm, margins dentate, especially basally and apically, midrib dorsally dentate. Male inflorescence a raceme of about 9 spikes, in total about 21 cm × 9 cm; each spike about 5 cm × 2 cm, with numerous, congested, sessile, 6–8 mm long flowers (each male flower is again a spike of 3–11 stamens) which smell faintly of carrion. Female inflorescence an axillary raceme of 4, 5 or 6 subellipsoid syncarps each subtended by an early falling bract; peduncle 6–9 cm long, raceme 9–14 cm long; syncarp 3–7 cm × 2–5 cm, light green in flower, turning deep bright orange-red in fruit and then smelling of fermented apples; drupes 50–150 per syncarp, irregularly penta-hexagonal subpyramidal, 6–17 mm × 4–10 mm; stigmas 1–2(–3), 1-seeded. Fruits fall as units, the drupes separating thereafter. *P. polycephalus* is found in various coastal and swamp-like habitats. According to B.C. Stone, *P. polycephalus* is classified in subgenus *Kurzia*, section *Jeanneretia*.

Selected sources 6, 20, 71, 174, 176.

Pandanus radicans Blanco

PANDANACEAE

Synonyms *Pandanus olango* Blanco ex Espejo & Garcia.

Vernacular names Philippines: oyañgo (Bikol), olañgo (Bisaya), uyañgo (Manobo).

Distribution Widely found in the Philippines.

Uses The leaves are used in the Philippines to make coarse mats, bags and hats. Fibres have been extracted from the long prop roots and woven into fine cloth, but these fibres are not used anymore. In Mindanao the wood has been used for the manufacture of splints for basket-making.

Observations A dioecious tree, stem up to 8 m tall and 20 cm in diameter. Leaves 6 m × 12 cm, margin with ascending 3–4 mm long prickles 3–8 mm apart; each half with 74 parallel secondary veins and no visible tertiary veins. Female inflorescence racemose-spicate with several heads; carpellate phalanges broadly cylindrical-ellipsoid, 25 mm × 13 mm, the upper third free, lower part connate; stigmas cordate. Fruit a syncarpous polydrupe, dark, brick-red. *P. radicans* occurs in forests at low altitudes. According to B.C. Stone, *P. radicans* is classified in subgenus *Pandanus* sensu Stone, section *Elmeria*.

Selected sources 19, 170, 176.

Pandanus simplex Merr.

PANDANACEAE

Synonyms *Pandanus utilissimus* Elmer.

Vernacular names Louisiana pandan (En). Philippines: karagomoi (Bikol), kalagimai, pandan-totoo (Tagalog).

Distribution Endemic to the Philippines; also planted there.

Uses Strips from the large leaves are extensively used in the Philippines for the production of fine or coarse mats, hats, bags and baskets known as 'tampipis', which are used as suitcases. They are also applied in articles like wall pockets, picture frames, fans, pencil boxes and slippers. The finer mats serve as sleeping mats, whereas the coarser ones are mainly used for spreading out and drying products such as copra and rice in the sun. Souvenir and fancy items such as bags, slippers, fans and placemats are exported to the United States, Europe and Australia. The fruit and shoot are edible.

Observations A dioecious tree with erect stem 8 m tall and 12–15 cm in diameter, unbranched or with a few branches, bearing prominent prop roots. Leaves very thick, linear-oblong, 3–6 m × 6–10 cm, margins and underside midrib with prickles and apical ventral pleats prickly. Male inflorescence unknown. Fruit a very large syncarpous polydrupe resembling a jackfruit, 60 cm or longer × 20 cm or wider, weighing up to 25 kg, on a long peduncle; drupes 4–5 cm long. *P. simplex* grows in forests at low and medium altitudes. In certain areas in the Philippines, e.g. in Laguna Province, *P. simplex* has considerable economic importance, with many farmers devoting part of their land to it, the area ranging from 50 m^2 to 1 ha. Here it is propagated by means of suckers, which are planted at 5 m × 5 m spacing. After 10–15 years, however, this planting arrangement is no longer distinguishable because of the proliferation of new suckers. Minimal weeding and maintenance is applied. Leaf harvesting starts 2–3 years after establishment of the crop and 3–5 leaves are gathered per plant per harvest, leaving 30–50 immature leaves on the plant. Subsequent harvests are done at 3-month intervals and may continue for 50 years or more. Harvesting is usually carried out by women and children using sickles. Weaving material from *P. simplex* is prepared by removing the spiny margins and midribs from the leaves and cutting the leaves into strips of the appropriate width. These strips are dried in the sun and allowed to wilt. They are flattened and made pliable by rolling them under a heavy log, and after further drying they are ready for use. In Laguna Province, the harvested leaves are stripped of their spiny margins and midrib and flattened with an indigenous roller, consisting of a small log mounted in a platform with heavy flat rocks tied to the log. The log is rolled back and forth using a handle while the leaves are passed under its weight. Subsequently they are dried in the sun for 2–3 hours and split into the desired width (0.5–1 cm) with a locally designed metal splitter, after which they are ready for use. About 100 leaves are needed for a mat of 2.5 m × 3.5 m. According to B.C. Stone, *P. simplex* is classified in subgenus *Kurzia*, section *Utilissima*.

Selected sources 19, 66, 152, 176.

Pandanus terrestris Warb.

PANDANACEAE

Synonyms *Pandanus montanus* Miq.

Vernacular names Indonesia: daun tikar, pandan utan, haun tain (Ambon).

Distribution Indonesia (Ambon).

Uses Because of their length, the leaves are sought after for the production of tacked mats, though they are not very durable. The fruits are eaten cooked.

Observations A dioecious tree with short, tortuous, spiny stem. Leaves 1–1.5 m × 6 cm, margins and underside of midrib with prickles. Male inflorescence spicate and fragrant. Fruits similar to those of *P. dubius* Spreng. *P. terrestris* is found in valleys in lower mountains and deserted forest gardens.

Selected sources 71, 192.

Pandanus verruculosus Backer ex B.C. Stone

PANDANACEAE

Synonyms *Pandanus kokoa* St. John.

Vernacular names Indonesia: jare (southern Halmahera), kokoa, manarama (northern Halmahera).

Distribution Indonesia (Halmahera), wild and cultivated.

Uses The leaves are used to tack 'kakoja' mats consisting of two layers: the outer layer is made from *P. verruculosus* leaves, and the lining is from leaves of *P. papuanus* Solms-Laubach.

Observations A dioecious tree, stem up to 6 m tall and 13 cm in diameter, usually unbranched, without prop roots, somewhat tortuous, dark brown, with some greyish-white spines. Leaves linear, 5 m × 14 cm, margins and underside midrib with prickles, underside glaucous. Male inflorescence unknown. Female inflorescence an axillary head, subglobose, 12–15 cm in diameter, on a short peduncle; drupes numerous, narrowly 5–6-angular pyramidal, 6 mm wide, endocarp 5–6 mm long. *P. verruculosus* occurs dispersed at low altitudes. According to B.C. Stone, *P. verruculosus* is classified in subgenus *Acrostigma*, section *Acrostigma*.

Selected sources 71, 179.

Petraeovitex multiflora (J.E. Smith) Merr.

VERBENACEAE

Synonyms *Petraeovitex riedelii* Oliv.

Vernacular names Indonesia: tali bubu, hahiat, seru wari (Ambon).

Distribution The Moluccas, New Guinea, the Bismarck Archipelago and the Solomon Islands.

Uses In the Moluccas the branches are used for fixing fishing nets and hoop nets, and as anchor cables. They are tough and flexible, do not break easily and are seawater-resistant.

Observations A slender liana or herbaceous scrambler; stems up to 3 cm in diameter, branches tetragonal. Leaves decussately opposite, once or twice 3-foliolate; leaflets ovate-elliptical to ovate-oblong, up to 11 cm × 6 cm. Inflorescence a loose cymose panicle up to 50 cm long; flowers bisexual, small, 5-merous; calyx about 1 mm long but lobes much enlarging in fruit; corolla about 3 mm long, 5-lobed, white to yellowish; stamens 4; ovary superior, puberulous at apex, style long-exserted. Fruit a capsule about 1.5 mm long, enclosed by the enlarged calyx having lobes up to 1.5 cm long. *P. multiflora* occurs in lowland forest, primary as well as secondary, also in swamp forest, sometimes in open localities and roadside regrowth, up to 800 m altitude.

Selected sources 71, 120, 122.

Phaleria capitata Jack

THYMELAEACEAE

Synonyms *Drimyspermum phaleria* Meisn., *Phaleria cauliflora* (Thw.) Beddome, *P. cumingii* F.-Vill.

Vernacular names Indonesia: lawe (Javanese), kakapasan (Sundanese), suwa lansat (Simeuluë). Philippines: salagong-gubat, bari (Tagalog), tuka (Ibanag).

Distribution From Sumatra and Java through Borneo, Sulawesi, the Moluccas (Buru), the Philippines and Irian Jaya (Waigeo) to the Caroline Islands. In Sri Lanka collected only once. Cultivated as an ornamental in Peninsular Malaysia and Java (Indonesia), and naturalized in Peninsular Malaysia.

Uses In the Philippines and West Java (Indonesia) the tough fibre from the inner bark is used as tying material and for making cordage. The sweet fruits are edible, but the seed cotyledons contain a biting poison. In Java the seeds are applied externally against scurf in children.

Observations A shrub or small tree, up to 9 m tall with trunk up to 16 cm in diameter. Leaves decussate or opposite; petiole 5 mm long; blade elliptic-oblong, (11–)15–21(–26) cm × (3.5–)5.5–7(–10) cm, base acute to attenuate, apex narrowly acute to acuminate, with 8–10 pairs of veins. Inflorescence usually terminal, sometimes in leaf axils of terminal node, solitary, cauliflorous, subsessile or with about 3 cm long peduncle, usually 8-flowered; flowers bisexual, 2.5–4.5 cm long, sessile; calyx lobes oblong to elliptical, 6–7 mm × 2–3.5 mm; corolla tube cylindrical, white, gradually enlarged towards the top; stamens and style exserted up to 5 mm; ovary ellipsoid, glabrous, stigma capitate, 1.5 mm × 1 mm. Fruit drupaceous, (1–)2-seeded. Seed subglobose or slightly ovate, about 1.5 cm × 1.3 mm. *P. capitata* is found in primary and secondary forest, up to 1200 m altitude. In Java it flowers throughout the year. The fibre is obtained by peeling the branches and scraping off the outer bark from the peel. The ultimate bast fibres are (1.5–)4.6(–7) mm long and (10–)16(–24) μm wide.

Selected sources 6, 19, 20, 39, 47, 71, 111, 115.

Phaleria macrocarpa (Scheff.) Boerl.

THYMELAEACEAE

Synonyms *Drimyspermum macrocarpum* Scheff., *Phaleria papuana* Warb. ex K. Schum. & Lauterb., *P. wichmannii* Valeton.

Vernacular names Indonesia: mahkota dewa (Indonesian), makuto dewo, makuto rojo (Javanese).

Distribution New-Guinea. Cultivated in Papua New Guinea, Irian Jaya, Java and elsewhere in Indonesia.

Uses In New Guinea the bark is made into string for bags. In central Java (Indonesia) *P. macrocarpa* has long been planted in the palace gardens in Yogyakarta and Surakarta as an ornamental and medicinal plant. In Indonesia it is now gaining importance as a medicinal plant. For safe use, *P. macrocarpa* material is first dried in the shade, and then sun- or fire-dried. A decoction of the dried peel and pulp of the ripe fruits with added sugar is made into a dried instant tea, which is produced and distributed commercially. It is taken singly in hot water as a health drink, or in a decoction with ground dried leaves of *Andrographis paniculata* (Burm.f.) Wallich ex Nees, leaves and tubers of *Gynura pseudochina* (L.) DC. and tubers of *Curcuma zedoaria* (Christ.) Roscoe to treat a range of complaints including hepatitis, diabetes, rheumatism, cancer, hypertension and heart disorders. Ground, fire-dried seeds of *P. macrocarpa*, mixed with coconut oil and ground dried leaves and tubers of the three species mentioned above, are applied as an ointment to treat various skin diseases and disorders. Leaf decoctions are taken against allergy, dysentery and tumours.

Observations A laticiferous shrub or small tree, up to 18 m tall with trunk up to 15 cm in diameter. Young branches hollow. Leaves decussate or opposite; petiole 5 mm long; blade ovate-oblong, elliptical-oblong, or oblong-lanceolate, 10–25 cm × 3–10 cm, base cuneate to rounded, apex shortly acute to acuminate, with 6–11 pairs of veins. Inflorescence terminal and axillary, sometimes cauliflorous, with 1–5 peduncles in each axis; peduncle 0–2.5 cm long, each 2–5(–8)-flowered; flowers bisexual, 1.5–4 cm long, sessile; calyx lobes oblong, reflexed, 4 mm × 2 mm; corolla tube glabrous, white; stamens sessile or up to 5 mm exserted; ovary glabrous, style shorter than tube, as long as tube, or 5–10 mm exserted. Fruit drupaceous, subglobose to broadly ellipsoid or rounded, glossy red-maroon when ripe. Seed subglobose or slightly ovate, about 1.5 cm × 1.3 mm. *P. macrocarpa* is found in primary and secondary forest up to 1000 m altitude. Highland specimens identified in early literature as *P. macrocarpa* have been placed in new taxa. Two kinds of flowers are found on different plants: the first with exserted stamens and a short style; the second with short stamens and an exserted style. Propagation is by seed or vegetatively by grafting. Plants raised from seed bear the first flowers when they are 8–12 months old and the first fruits can be harvested 2–3 months later. *P. macrocarpa* is planted as a sole crop or intercropped, e.g. with *Andrographis paniculata* and *Gynura pseudochina*. The fruit of *P. macrocarpa* is astringent and bitter and said to be poisonous. Fruit and leaf extracts have shown antihistaminic activity.

Selected sources 47, 68, 138, 171.

Phaleria perrottetiana (Decne) F.-Vill.

THYMELAEACEAE

Synonyms *Drimyspermum perrottetianum* Decne, *Phaleria splendida* Valeton.

Vernacular names Philippines: tuka (Ibanag), bago (Tagalog), aligpagi (Bisaya).

Distribution Sabah, the Philippines (throughout), the Moluccas (Seram, Kai Islands, New Guinea (throughout), the Admiralty Islands (Bismarck Archipelago) and the Louisiade Archipelago.

Uses In the Philippines the bark is used as tying material. It is woven into a necklace against colds.

Observations A shrub, sometimes a tree up to 8 m tall. Leaves decussate or opposite; petiole 15 mm long, slightly winged; blade oblong-lanceolate, oblanceolate or ovate-oblong, 11.5–33 cm × 3.5–14 cm, base cuneate, rounded, apex acuminate, (8–)13–22 pairs of veins. Inflorescence terminal or axillary at terminal node, sometimes in axils of upper 2 nodes, 1 peduncle in each axil, 20–many-flowered; peduncle up to 3.5 cm long; flowers bisexual, (2–)3–4.5 cm long, sessile; calyx lobes oblong, reflexed, 5–9 mm long, corolla tube pubescent outside, white; stamens and style about 10 mm exserted beyond the tube; ovary 1–2-celled, usually hairy at apex or on one side. Fruit drupaceous, ovate, gradually narrowed towards the apex, usually 1-seeded. Seed ellipsoid, about 1 cm × 0.8 mm. *P. perrottetiana* is found in rain forest at low and medium altitudes. In New Guinea it occurs up to 1100 m altitude, with one population at 1400–1700 m altitude that is likely to be a new species. A special form is found in Davao (the Philippines), which differs from the main type by its small flowers (about 2 cm long) and the floral tube being glabrous outside.

Selected sources 19, 47, 115, 135, 171.

Phoenix loureiri Kunth

PALMAE

Synonyms *Phoenix hanceana* Naudin.

Vernacular names Philippines: voyayoi, voyavoy, suot (Ivatan). Thailand: peng. Vietnam: ch[af] l[af] d[oof]i.

Distribution From the sub-Himalayan belt southwards through India and eastwards through Indo-China to southern China, Taiwan and the Philippines (Batanes and Sabtang Islands).

Uses The hard, durable and rain-resistant leaves are used for rough fencing. The leaflets have many domestic uses, such as the manufacture of mats, hats, baskets and brooms. In the Philippines, split leaflets are woven into effective raincapes ('vakol' and 'suot', the latter referring to hooded capes worn by women). The apical bud can be eaten as a vegetable. The fruits are sweet and are commonly eaten by children. The floury pith is eaten after baking or some other form of preparation.

Observations A dioecious solitary or clustering palm; stem up to 5 m tall, up to 40 cm in diameter. Leaves up to 2 m long; pseudo-petiole 20–40 cm long; leaflets fascicled in 3s and 4s, up to 130 on each side of the rachis, 20–45 cm × 0.5– 2.3 cm, flaccid or stiff. Inflorescence unisexual; male inflorescence erect; peduncle up to 15 cm long; female inflorescence erect, arching with fruit maturity; peduncle up to 1.5 m long. Fruit an ovoid to obovoid, 1-seeded berry, 1.8 cm × 0.9 cm, blue-black when ripe. *P. loureiri* is found up to 1700 m altitude in various habitats. It prefers sunny locations and is common in disturbed, anthropogenic areas such as seasonally-burnt grassland, along roads, and on raised ground bordering paddy fields.

Selected sources 10, 19, 20, 35, 90, 91, 149, 187.

Phoenix paludosa Roxb.

PALMAE

Synonyms *Phoenix siamensis* Miq.

Vernacular names Mangrove date palm, Bengal date palm (En). Malaysia: dangsa (Penang). Burma (Myanmar): thin-boung. Cambodia: peng. Thailand: peng-tha-le. Vietnam: (cay) cha la r[uwf]ng.

Distribution India, Bangladesh, Burma (Myanmar), Thailand, Indo-China, Peninsular Malaysia and northern Sumatra.

Uses The leaves are made into rough rope, mats, umbrellas and fences, and are used for thatching. They have been tried for paper making, but the pulp yield was only 25%. The stems are used for walking sticks, rafters and fence posts. The terminal bud and the pith are edible. In Thailand the fruits are eaten in curries.

Observations A dioecious clustering palm, growing in dense clumps; stem up to 5(–8) m tall, up to 9 cm in diameter. Leaves up to 2–3 m long; pseudo-petiole 70–100 cm long; leaflets fascicled in 3s and 4s, about 34 on each side of the rachis, 12–40 cm × 0.4–2.2 cm, flaccid, often recurved. Inflorescence unisexual; male inflorescence compact; peduncle 20–30 cm long; female inflorescence erect, opening out and elongating in fruit; peduncle up to 30 cm long. Fruit an ovoid-ellipsoid, 1-seeded berry, 10–12 mm × 7–10 mm, maturing from yellow-green to orange to blue-black. *P. paludosa* grows in pure stands at the edges of mangrove and in estuarine coastal swamps. In its native habitat it flowers from February to April; fruits ripen from June to December. Its conservation status varies regionally, being at risk from increasing urban development in both Thailand and Peninsular Malaysia.

Selected sources 10, 20, 30, 66, 91, 187, 197.

Phrynium placentarium (Lour.) Merr.

MARANTACEAE

Synonyms *Phrynium densiflorum* Blume, *P. parviflorum* Roxb.

Vernacular names Indonesia: patat lipung (Sundanese), angkrik (Javanese), daun nasi (Manado). Thailand: saat khaao (northern), saat tong khaao (Chiang Mai). Vietnam: c[aa]y l[as] dong, c[aa]y dong, c[aa]y l[uf]n.

Distribution Bhutan, India, Burma (Myanmar), Indo-China, southern China, Thailand, Java; probably also elsewhere in Malesia.

Uses The leaves of *P. placentarium* (and sometimes other *Phrynium* species and species of the related genus *Phacelophrynium* K. Schum.) are commonly used for wrapping food, e.g. meat, fish, cooked rice, and vegetables in Java and cakes in Vietnam. In New Guinea *Phrynium* Willd. is also used for thatching. In Vietnam leaves are soaked in rice alcohol or in a solution of sugar in water to make a vinegar, and a leaf juice is applied as an antidote for alcohol intoxication and snake bites.

Observations An erect herb up to 1.5(–2) m tall with creeping rhizome. Leaves 1(–2) basal and 1 cauline, ovate to elliptical or lanceolate, 25–55 cm × 6–23 cm; petiole with sheath-like basal part. Inflorescence head-like, seemingly axillary to cauline leaf, subsessile, 4–6(–8) cm in diameter, consisting of many bracteate spikes; flowers in pairs, zygomorphous, bisexual, white; sepals 3, free; corolla with narrow tube up to 13 mm long, lobes slightly shorter; stamen 1, anther with 1 fertile cell and 1 sterile, petaloid cell, staminodes 4. Fruit an oblong-ellipsoid capsule, about 1 cm long, hidden among the bracts, greyish-blue, 1-seeded. Seed ellipsoid, with red aril. *P. placentarium* occurs in secondary forest and brushwood, usually in wet localities, up to 1500 m altitude.

Selected sources 6, 20, 71, 127, 129, 138.

Poikilospermum acuminatum (Trec.) Merr.

CECROPIACEAE

Synonyms *Conocephalus acuminatus* Trec., *Poikilospermum warburghii* (Elmer) Merr.

Vernacular names Philippines: anupul, bukol, himbabalud.

Distribution Endemic to the Philippines.

Uses The stems are used for tying, and the stem fibres are made into cloth and fishing nets. Potable water is obtained from the cut stems.

Observations An epiphytic, dioecious woody climber. Leaves spirally arranged; stipules 2.5–5 cm long, persistent; petiole 4–9 cm long; blade ovate to rhombic, 15–25 cm × 7–16 cm, base cuneate, round to cordate, apex acuminate, with 9–11 pairs of lateral veins. Male inflorescence solitary, branched dichotomously 8–9 times, widespread, up to 20 cm across; primary peduncles 2–4 cm long, secondary ones as long or longer; flowers in numerous floral agglomerations (a bit head-like) 2–3 mm in diameter; solitary terminal flowers at the axils of the ultimate dichotomies; flowers sessile, 1–1.25 mm × 0.75–1 mm, with 4 tepals, 4 stamens and a pistillode. Female inflorescence similar to the male inflorescence, but without solitary terminal flowers; flowers sessile, 0.75–1 mm long, with 4 tepals and a pistil. Fruit an achene, 1–2 mm × 0.5–1 mm, with the persistent perianth at the base as a small cup. *P. acuminatum* is widespread in rain forest and secondary forest, up to 1500 m altitude.

Selected sources 15, 26.

Poikilospermum microstachys (Barg.-Petr.) Merr.

CECROPIACEAE

Synonyms *Conocephalus microstachys* Barg.-Petr.

Vernacular names Malaysia: akar sasaran, landong padi.

Distribution Peninsular Malaysia, Sumatra and Borneo. Cultivated in Java (Indonesia).

Uses The stems seem to be used as rope in Peninsular Malaysia.

Observations An epiphytic, dioecious woody climber. Leaves spirally arranged; stipules 1–2 cm long, persistent; petiole (3–)4–13 cm long; blade oblanceolate, 12–27 cm × 3–7 cm, base cuneate to round, apex acuminate, with (6–)7–9 pairs of lateral veins. Male inflorescence solitary, paired or numerous, branched once, 0.5–2 cm × 0.5–1.5 cm; flowers sessile or subsessile, 1.5–2 mm × 1.5–2 mm, perianth up to 1.5 mm long, tepals 4, stamens 4, pistillode about 1 mm long. Female inflorescence solitary (rarely paired), branched once, 1–2 cm × 1.5–3 cm; flowers pedicellate, perianth up to 3.5 mm long, 4-lobed. Fruit an achene, 2.5–3.5 mm × 1–1.25 mm, enclosed by persistent perianth. *P. microstachys* is commonly found in damp forest and along rivers, it is rare in dry and exposed habitats and in dark forest interior. *P. subtrinervium* (Miq.) Chew (synonym: *Conocephalus subtrinervium* Miq.), an endemic of Sumatra, has often incorrectly been considered the name for *P. microstachys*, hence there is confusion in older literature. *P. lanceolatum* (Trec.) Merr., restricted to the Indian subcontinent and southern China, has been considered a synonym of *P. subtrinervium* as well but is a species in its own right.

Selected sources 20, 26.

Pothoidium lobbianum Schott

ARACEAE

Vernacular names Philippines: baralta (Tagalog), balong-kahinai (Bisaya), ariman (Ibanag).

Distribution Sumatra, Sulawesi, the Moluccas, the Philippines and Taiwan.

Uses In the Philippines the lignified, tough central cylinder of the stem is used for binding (e.g. as tying material for fish corrals) and basketry, in the same way as other *Araceae* such as *Pothos* species.

Observations A herb climbing by roots, with hanging flowering branches. Leaves distichously alternate, up to 17 cm × 3 cm, with oblong, flattened petiole resembling blade, joined to much shorter true blade by constricted articulation. Flowers in a spadix borne in a terminal branching system, with or without spathe, usually unisexual; male flowers with 3–6 stamens; female flowers with 1-celled ovary. Fruit an ellipsoid to ovoid, red berry. *P. lobbianum* occurs in humid, primary and secondary, lowland forest.

Selected sources 19, 45, 62, 110, 115, 150.

Pottsia laxiflora (Blume) Kuntze

APOCYNACEAE

Synonyms *Pottsia cantonensis* Hook. & Arn.

Vernacular names Indonesia: tembelekan (Javanese).

Distribution India, southern China, Indo-China, Thailand, Malaysia and Indonesia.

Uses In Indonesia the stems are split, and the splits twisted into rough cordage. In China the stems serve as cordage, and stems and leaves are used to treat fractures and injury, while latex and roots are applied for anaemia and rheumatism.

Observations A liana up to 10 m long. Branches and branchlets slender, pubescent or glabrous. Leaves opposite; petiole 1.5–4 cm; blade ovate, narrowly ovate or elliptical, 6–12 cm × 3–7 cm, base obtuse to rounded or subcordate, lateral veins 4–6 pairs. Inflorescence a cyme, up to 25 cm long, long-pedunculate, many-flowered; corolla purple or rose, about 7 mm, tube glabrous, longer than lobes, lobes spreading, narrowly ovate, about 2 mm long; ovary pilose, style thickened at middle. Fruit consisting of paired linear follicles up to 55 cm × 3–5 mm. Seed linear, about 2 cm, coma 2.5–3 cm. *P. laxiflora* occurs in open forest, forest borders and brushwood at altitudes of 200–1100 m. In southern China it flowers from April to August.

Selected sources 6, 20, 30, 71, 201.

Pouzolzia sanguinea (Blume) Merr.

URTICACEAE

Synonyms *Pouzolzia viminea* Wedd.

Vernacular names Ramie sauvage (Fr). Indonesia: jurang rambat, dlundum (Javanese), kepirit (Sundanese).

Distribution From Indonesia (Java) to India and China.

Uses The bark fibres are made into strong ropes, used for fishing nets. In Java an infusion of the roots is prescribed for patients vomiting blood. In Nepal a paste made from the roots is applied to boils.

Observations A multi-stemmed, monoecious shrub, 1.5–3.0 m tall. Leaves simple, alternate; stipules small, inconspicuous; petiole 0.5–3 cm long; blade ovate-oblong or lanceolate, 2.5–17 cm × 1.5–6.5 cm, base obtuse, rounded or rarely subcordate, apex acuminate. Inflorescence axillary, rarely partly lateral clusters; male flowers shortly pedicellate; female flowers sessile, stigma 4–6 mm long. Fruit an achene, enclosed in wingless perianth. In Java *P. sanguinea* grows at altitudes from 100–1400 m in forest margins, brushwood and young secondary forest. It is easily propagated using cuttings. In studies in Indo-China in the 1940s, the bark of *P. sanguinea* yielded about 13% fibre. Rough bark strips contained 15% moisture, 37% cellulose, 5% hemicelluloses, 11% lignin and 11% ash. After degumming the fibre contained 7% moisture, 80% cellulose, 7% hemicelluloses and 1% lignin. The ultimate bast fibres were (2–)4.2(–6) mm long.

Selected sources 6, 20, 21, 71, 106, 111, 191.

Ripidium arundinaceum (Retz.) Grassl

GRAMINEAE

Synonyms *Erianthus arundinaceus* (Retz.) Jeswiet, *Saccharum arundinaceum* Retz.

Vernacular names Indonesia: galunggung (Sundanese), glonggong (Javanese), tibarau (Minangkabau). Malaysia: buloh teberau, tebu salah, riong. Philippines: gatbo, lakbo (Tagalog), bagiunas (Ilokano). Thailand: khaem (general), pong (northern), ta-po (Karen, Mae Hong Son). Vietnam: lau, ranh.

Distribution India, Sri Lanka, Nepal, Burma (Myanmar), southern China, Indo-China, Thailand, Peninsular Malaysia, Singapore, Sumatra, Java, Sulawesi, the Philippines and southern Japan; possibly also elsewhere in Malesia.

Uses The leaf sheaths are plaited into baskets, chairs and screens. They are strong, elastic and resistant to humidity. *R. arundinaceum* is considered valuable for paper making. The stems are used for construction purposes. In Java they have been used for the handles of the special device called 'canting' applied in the batik process. A decoction is used to treat boils and skin complaints. Leaf buds are eaten as a vegetable. Young shoots are used as a fodder. *R. arundinaceum* is sometimes planted as a hedge. It is useful in breeding work in sugar cane (*Saccharum officinarum* L.), to obtain better ratoonability, vigour, tolerance to environmental stress and disease resistance.

Observations A tall, tufted grass up to 4(–7) m tall, with solid culms up to 2 cm in diameter. Leaves linear, up to 150 cm × 6 cm, long-hairy above the ligule. Inflorescence a dense, erect panicle up to 100 cm long; spikelets paired, one sessile and one pedicelled, 3–4 mm long, 2-flowered but lower flower sterile, with hairy base; lemma awned. Fruit an oblong caryopsis. *R. arundinaceum* occurs in the lowland, along watercourses and at edges of swamps, where it may be abundant. It is usually included in the genera *Saccharum* L. or *Erianthus* Michaux. However, on the basis of DNA sequence data it is different and may best be treated in a separate genus *Ripidium* Bernh., together with *R. ravennae* (L.) Trin. (synonym: *Saccharum ravennae* (L.) Murray), which is occasionally used in India for paper making, although the pulp is of poor quality.

Selected sources 6, 20, 61, 66, 71, 72, 111, 115, 136, 187.

Rosa luciae Franch. & Rochebr. ex Crép.

ROSACEAE

Synonyms *Rosa philippinensis* Merr.

Vernacular names Philippines: sibsibit (Bontoc).

Distribution Philippines (Luzon), Japan, Taiwan, eastern China and Korea.

Uses In the Philippines the stems are used for binding and fencing. *R. luciae* is cultivated as an ornamental.

Observations Suberect to straggling, more or less scandent shrub, up to 4 m tall. Stems with 2 prickles under each leaf. Leaves imparipinnate, spirally arranged, up to 10 cm long; stipules adnate; petiole up to 2.6 cm long; leaflets 7 or 9, base obtuse to rounded, margin serrate, apex obtuse to acute. Inflorescence a terminal raceme or thyrsus, 7–30-flowered; flowers strongly fragrant; sepals 5, up to 7 mm × 3.3 mm; petals 5, white, (broadly) obovate, up to 18 mm × 11 mm. Fruit a hypanthium (hip), bluish-black, enclosing 1-seeded achenes. *R. luciae* is found in thickets, in the Philippines at altitudes of 1200–1700 m. Several varieties are distinguished and hybrids occur of *R. luciae* and *R. multiflora* Thunb., the latter grown as an ornamental in Java and elsewhere.

Selected sources 15, 47, 197.

Shuteria involucrata (Wall.) Wight & Arn.

LEGUMINOSAE

Synonyms *Shuteria vestita* Wight & Arn.

Vernacular names Indonesia: tingtingsit (Javanese). Philippines: alitaitan, tayum (Bontoc), itlid (Igorot). Vietnam: tip.

Distribution India, Sri Lanka, Nepal, Bhutan, China, Indo-China, Thailand, Indonesia, the Philippines and New Guinea.

Uses In the Philippines the stems are used for stringing fish and for tying. In Java it has proved to be a useful cover crop in cinchona plantations at higher altitudes.

Observations Twining or creeping, perennial herb, 2–6 m long. Leaves alternate, trifoliate; stipules lanceolate, 5–7 mm long, persistent; petiole 2–7 cm long; blade of leaflets ovate-obovate, terminal leaflet subrhomboid, rounded or obtuse, 4 cm × 2.5 cm. Inflorescence an axillary raceme, 3–7(–10) cm long; calyx 5–6 mm long, long-hairy; corolla twice as long as calyx, red. Fruit a straight or slightly curved pod, 3–4 cm long, flat, 5–6-seeded. *S. involucrata* is found at altitudes of 600–2500 m, in forests and forest margins.

Selected sources 6, 15, 71, 128, 130, 197.

Sida glabra Mill.

MALVACEAE

Synonyms *Sida glutinosa* Comm. ex Cav.

Vernacular names Indonesia: pulutan lalaki, pungpurutan beunyir (Sundanese).

Distribution Native to tropical America; introduced into Java (Indonesia).

Uses *S. glabra* was considered a promising fibre plant for Indonesia, but experimentation was interrupted, and was not resumed. It was formerly cultivated as a fibre plant on Caribbean Islands.

Observations An erect, viscid undershrub, 1–2 m tall. Stems, petioles, inflorescence axis and pedicels with patent simple hairs, gland hairs and scattered, stellate hairs, glabrescent. Leaves simple, alternate; stipules linear, about 1 cm long; petiole 3–6 cm long; blade widely ovate to oblong, upper ones lanceolate, 1–10 cm × 0.5–6 cm, base cordate, apex acuminate, penninerved, 7–9-veined. Flowers axillary, solitary, by decrescence of upper leaves appearing as a branched, lax panicle; pedicel thin, jointed, 7–15 mm long, increasing up to about 20 cm in fruit; calyx widely campanulate, 4–5 mm long, 3–4 mm in diameter, 5-lobed; corolla 8 mm in diameter with 5 deeply emarginate petals, yellow. Fruit a pyramidal schizocarp, 3–3.5 mm in diameter; mericarps 5. Seed oblong to reniform, about 1.5 mm in diameter, brown-black. *S. glabra* is found in waste places and along road-sides up to about 300 m altitude. Other *Sida* spp. yielding fibre, but in South-East Asia with primary use as medicinal plants, include *S. acuta* Burm.f., *S. cordifolia* L. and *S. rhombifolia* L.

Selected sources 6, 30, 57, 66, 71, 189, 191.

Sida mysorensis Wight & Arnott

MALVACEAE

Synonyms *Sida glutinosa* Roxb.

Vernacular names Philippines: lagkitan, damong-mabaho, marbas (Tagalog).

Distribution Throughout South and South-East Asia.

Uses In the Philippines the bast fibres are used to make rope.

Observations An erect, viscid undershrub, 0.5–1.5 m tall. Stems, petioles and pedicels with patent simple hairs, gland hairs and minute, stellate hairs. Leaves simple, alternate; stipules filiform, 3–7 mm long; petiole 1–5 cm; blade usually ovate, 2–9 cm × 1–7 cm, base cordate, apex acuminate, palminerved, 5–9-veined. Flowers axillary, initially solitary, by development of accessory buds finally in condensed racemes or panicles; pedicel thin, jointed, 4–15 mm long; calyx widely campanulate, 6–8 mm long, 4.5–5 mm in diameter, 5-fid; corolla 10–12 mm in diameter with 5 obtriangular petals, yellow. Fruit a pyramidal schizocarp, 3–3.5 mm in diameter; mericarps 5. Seed ovoid, faintly trigonous, about 2 mm long, brown-black. *S. mysorensis* is found in waste places and on road-sides up to about 700 m altitude. *S. mysorensis* and *S. glabra* Mill. have often been confused but in the field distinction is possible by the different leaf-venation.

Selected sources 6, 19, 189.

Smythea lanceata (Tul.) Summerh.

RHAMNACEAE

Synonyms *Smythea pacifica* Seemann, *Ventilago lanceata* Tul.

Vernacular names Indonesia: lian, tali bubu (Ambon). Malaysia: bulang akar.

Distribution From Malaysia to the central Pacific.

Uses The long, slender branches are possibly used for tying fish traps and in boat-building, due to their toughness and durability under water. They are prepared by heating over a fire to make them supple, after which they are twisted together.

Observations A woody climber. Leaves distichous, simple, minutely stipulate; petiole about 3 mm long; blade ovate-oblong, 6–13.5 cm × 2.5–5.5 cm, base oblique or acute, margin shallowly serrate to entire-undulate, apex obtusely acuminate, with 3–5 pairs of veins. Inflorescence an axillary fascicle; flowers 4–5 mm in diameter; calyx 5-parted; petals cucullate, clawed, emarginate, greenish-yellow. Fruit a drupe, 3.5–4.5 cm long, 1-seeded. *S. lanceata* is found near the sea, on seashores, especially in mangroves. There is doubt about its identity. In the older literature it has been treated under the names *Ventilago madraspatana* Gaertner, *Ventilago cernua* Tul. and *Ventilago sp.* A revision of the genera *Smythea* Seem. ex A. Gray and *Ventilago* Gaertn. is overdue.

Selected sources 6, 20, 71, 147.

Sporobolus indicus (L.) R. Br.

GRAMINEAE

Synonyms *Agrostis indica* L., *Sporobolus berteroanus* Hitchc. & Chase, *S. elongatus* R.Br.

Vernacular names Smutgrass, West Indian dropseed (En). Indonesia: rumput rantai alat (Minangkabau), jukut nyenyerean (Sundanese), suket sadan (Javanese). Philippines: bakit (Panay Bisaya), lusai (Subanon), sangsangitan (Bontoc). Vietnam: c[or] l[oo]ng c[oo]ng, x[aj] t[uwr] [aas]n.

Distribution Widely distributed in the tropics. In South-East Asia it has been recorded throughout.

Uses In West Java the culms are used to make brooms ('sapu nyere'). In the Philippines the fairly fine straw of the flower stalks as well as the rough culms are plaited into hats and fans. The culms have also been used for plaiting in Brazil and Madagascar. The grain is eaten in Bengal in times of food scarcity. *S. indicus* is widely used as a forage but it appears only valuable when young, becoming tough and fibrous once old. Its growth habit makes it a feared weed, although it is a suitable crop for erosion control.

Observations A long-living annual grass, usually densely tufted, 0.5–1 m tall. Culm erect, slender, more or less compressed, glabrous, smooth. Leaves for the greater part crowded at base of culm; sheaths shortly ciliolate along margin, otherwise glabrous; ligule up to 0.5 mm long; blade linear, acute, margins smooth to scaberulous, 6–15 cm × 2–7 mm. Inflorescence a panicle; contracted, 7–60 cm long, dense; branches erect and often adpressed, lower ones 3–8 cm long; spikelets 1.3–2.6 mm long; lower glume up to 1 mm long; upper glume up to 1.7 mm long, oval-oblong, with attenuate or rounded, entire or slightly dentate apex, enervate or 1-nerved; palea as long as lemma or slightly shorter; stamens 2 or 3; anthers up to 1.1 mm long; stigma rather large, white. Fruit a utricle. Seed solitary, ovoid. Seedling with epigeal germination. Seed ellipsoid to oblong, about 1 mm in diameter, brown. *S. indicus* grows in dry sites, along roads and footpaths, in waste places, pastures and much trodden grass fields, preferring hard and stony soils. In Java it occurs in cool, rainy areas at 100–300 m altitude, and it flowers from January to December. Propagation is by seed and regrowth from rhizomes. *Helminthosporium ravenelii* may cause 'sooty spike disease' on *S. indicus*. Several *Bipolaris* spp. cause the fungal disease 'smut'. *S. indicus* is a polymorphous species with 5 varieties being distinguished in the Malesian region. In California (United States) it is reported to cause contact dermatitis in some people.

Selected sources 5, 6, 19, 20, 71, 111, 133, 187.

Tetracera akara (Burm.f.) Merr.

DILLENIACEAE

Vernacular names Indonesia: daun amplas (South Sumatra), areuy pengasaman (Sundanese). Malaysia: akar rusa-rusa, mumplas rimba (Peninsular).

Distribution Southern India, Sri Lanka, Cambodia, Peninsular Malaysia, Sumatra, West Java, Borneo and the Philippines.

Uses The stems are used for rope. There are records of the leaves being used as sandpaper, although they are not rough.

Observations A large climbing or creeping liana, up to 25 m long. Leaves simple, spirally arranged; stipules absent; petiole up to 7(–10) cm long; blade oblong to lanceolate, up to 22 cm × 10.5 cm, base acute, margin entire to slightly undulate or dentate, apex distinctly acuminate, usually with 6–8 pairs of veins, smooth to scabrid on both sides. Inflorescence a terminal or axillary panicle, 5–8-flowered; flowers bisexual, 25–30 mm in diameter; sepals 4; petals 3–4, greenish-white, up to 15 mm × 8 mm; stamens about 230, up to 8 mm long. Fruit a coriaceous capsule with (1–)2–3, 1–2-seeded carpels. Seed ovoid, 2–4 mm × 1–3 mm, glossy black. *T. akara* occurs in lowland forest and occurs up to 750 m altitude.

Selected sources 47, 76, 77, 78, 95, 191.

Tetracera korthalsii Miq.

DILLENIACEAE

Vernacular names Malaysia: empelas (Malay, Sabah), pampad (Dusun, Sabah).

Distribution Borneo (eastern), Sulawesi, the Moluccas and Palawan (the Philippines).

Uses The rough leaves are used for polishing wood. In the Philippines the stems serve as binding material and for handles, frames and other handicraft products.

Observations A large liana with scabrid branches. Leaves simple, spirally arranged; stipules absent; petiole winged, up to 20(–30) cm long; blade ovate, elliptical-oblong or obovate, up to 22 cm × 13 cm, base rounded, margin slightly dentate, apex rounded to acute, usually with 10–16 pairs of veins, smooth to scabrid on both sides. Inflorescence a terminal, many-flowered panicle; flowers bisexual, about 1 cm in diameter; sepals 5(–6); petals 3–5, 5 mm × 3.5 mm; stamens about 125, up to 4 mm long. Fruit a coriaceous capsule with 1–3, 1-seeded carpels. Seed ovoid, 4.5 mm × 3.5 mm, glossy black. *T. korthalsii* occurs in forest up to 700 m altitude. The leaves and stems of several other *Tetracera* species are used in Malesia as sandpaper and for tying, respectively. Examples are *T. indica* (Houtt. ex Christm. & Panz.) Merr., *T. sarmentosa* (L.) Vahl (synonym: *T. asiatica* (Lour.) Hoogl.) and *T. scandens* (L.) Merr., all three primarily used as medicinal plants.

Selected sources 47, 76, 77, 78, 95, 191.

Tetrastigma papillosum (Blume) Planchon

VITACEAE

Synonyms *Cissus papillosa* Blume, *Vitis papillosa* (Blume) Backer ex K. Heyne.

Vernacular names Indonesia: areuy ki barera (Sundanese), tlecer, antawali (Javanese). Malaysia: akar benang tikus. Philippines: danun (Bontoc).

Distribution Peninsular Thailand, Peninsular Malaysia, Java, Borneo, Sulawesi, Moluccas, the Philippines and New Guinea.

Uses In Indonesia the stems are used as strong rope, e.g. for hedges and stables. They are said to last longer than rattan. As they are difficult to bend, they should be soaked in water before use. Also in the Philippines the stems serve for tying, e.g. in making footbridges and in fencing. In Indonesia the aerial roots and leaves are ground and applied to stimulate hair growth of children.

Observations A climbing, dioecious liana, 10–15 m long; stems terete or flattened, densely studded with long spine-like corky excrescences; tendrils simple, leaf-opposed. Leaves digitately 3-foliolate; petiole 3.3–7.5 cm long; blade of terminal leaflet elliptical, 8.2–9.7 cm × 3.6–4.8 cm, base obtuse, apex acuminate. Inflorescence a corymbose cyme, often borne on old wood, widely branched, frequently long-peduncled; flowers unisexual, 4-merous, pedicellate. Fruit a berry, pyriform when dry, about 9 mm long, 3–4-seeded, red. Seed convex-carinate, about 5 mm × 4 mm. *T. papillosum* occurs on the margins of dipterocarp forest, rarely on limestone hills, up to 1200 m altitude.

Selected sources 6, 15, 71, 98, 100.

Trophis philippinensis (Bur.) Corner

MORACEAE

Synonyms *Sloetia minahassae* Koord.

Vernacular names Indonesia: daendong, laindong, bunta (Sulawesi).

Distribution From the Philippines and Sulawesi (Indonesia) to New Guinea and New Britain.

Uses In Sulawesi the pounded bast is traditionally used as barkcloth.

Observations A tree with unisexual, spicate inflorescences. Male flowers with 4 tepals, imbricate in bud. Female flowers with fleshy, dark purple to black perianth. Fruit adnate to the enlarged perianth. Seed with subequal cotyledons.

Selected sources 12, 71.

Trophis scandens (Lour.) Hook. & Arnott

MORACEAE

Synonyms *Caturus scandens* Lour., *Malaisia scandens* (Lour.) Planchon, *M. tortuosa* Blanco.

Vernacular names Crow ash (En). Philippines: malaisis (Tagalog), sadak (Ilokano), salimpagot (Tagbanua).

Distribution From China and Taiwan through South-East Asia (including Peninsular Malaysia and the Philippines) to Australia and New Caledonia.

Uses In Malaysia and the Philippines the stems are used for tying, e.g. for making fish traps. In the Philippines *T. scandens* is used and promoted as a fodder plant. A decoction of the leaves is administered to women after childbirth.

Observations A scandent shrub. Leaves alternate, simple; stipules small; petiole 0.5–1 cm long; blade ovate, elliptical to oblong, 8–10 cm × 2.5–5 cm. Inflorescence unisexual; male inflorescence spicate to subspicate, 1–1.5 cm long, tepals 3(–4), pubescent, valvate in bud; female inflorescence subcapitate up to 5 mm in diameter. Fruit an achene, free, somewhat drupaceous, about 8 mm × 5 mm; fruiting perianth enlarged, fleshy, red, containing 1–4 achenes. Seed with unequal cotyledons. *T. scandens* occurs widely in Philippine forest at low and medium altitudes.

Selected sources 12, 19, 20, 48, 83, 161.

Wissadula contracta (Link) R.E. Fries

MALVACEAE

Synonyms *Abutilon contractum* (Link) Sweet, *Sida contracta* Link.

Vernacular names Indonesia: bagori, pungpurutan (Sundanese).

Distribution Tropical America; elsewhere cultivated in gardens. In Malesia only cultivated in West Java (Indonesia). Here it is sometimes encountered as an escape from cultivation but it is not thoroughly naturalized.

Uses Experimental cultivation in Indonesia yielded high-quality bast fibre. The plants were pulled out before they flowered, the leaves and roots were removed, the green outer bark was scraped off the stem, and the bast was pulled off in strips from the woody stem core, after which the bast strips were retted, washed and sun-dried.

Observations An erect undershrub, 0.5–3 m tall. Leaves solitary, alternate; stipules linear to lanceolate, 6–9 mm long; petiole 0.5–12 cm long; blade orbicular or broadly ovate to oblong, 4–18 cm × 2–12 cm, base cordate, apex abruptly acuminate. Inflorescence a terminal, rather condensed panicle, 20–30 cm long; pedicel 0.2–0.5 cm long, up to about 1.5 cm long in fruit; calyx widely campanulate, 3–4 mm in diameter, 5-lobed to 5-parted; corolla 8–10 mm in diameter, petals 5, obovate, emarginate, white. Fruit a globular schizocarp, 7–10 mm in diameter. Seed globular to reniform, 2–2.5 mm in diameter. *W. contracta* occurs in waste grounds near villages and houses. Outside Malesia it is considered a weed.

Selected sources 6, 20, 57, 66, 71, 189.

Wissadula periplocifolia (L.) K. Presl ex Thwaites

MALVACEAE

Synonyms *Abutilon periplocifolium* (L.) Sweet, *Sida periplocifolia* L.

Vernacular names Indonesia: bulung-bulung pager (eastern Sumatra), nyung-nyungan (Kangean). Thailand: khaao tom, chan nok, se-saa-boh.

Distribution Pantropical. Cultivated as a fibre crop in India and Sri Lanka.

Uses The bast fibre is comparable in quality to that of kenaf (*Hibiscus cannabinus* L.) and is spinnable. In India the branches are used to make brooms.

Observations An annual or perennial subshrub, 0.5–1 m tall, more or less branched, stellate-pubescent, hairs frequently stipitate. Leaves simple, alternate; stipules filiform, 2–5 mm long; petiole 0.5–7 cm long; blade long-triangular, ovate or lanceolate, 3–15 cm × 0.5–7 cm, base shallowly cordate to truncate, apex long-acuminate to acute, mucronate, 5-veined. Flowers solitary, axillary; upper flowers in large, lax, terminal panicles, 20–80 cm long, pedicel thin, jointed, 1–4.5 cm long, accrescent in fruit to about 8 cm; calyx widely campanulate, 3–4 mm in diameter, 5-fid; corolla 9–13 mm in diameter, with 5 obovate petals, pale yellow with dark yellow veins, rarely white. Fruit an obconical schizocarp, 7–10 mm in diameter. Seed obconical to globose, about 2.5 mm in diameter, densely set with long simple hairs. *W. periplocifolia* occurs in waste places, roadsides and secondary vegetation.

Selected sources 6, 20, 30, 57, 66, 71, 189.

Xyris capensis Thunberg

XYRIDACEAE

Synonyms *Xyris melanocephala* Miq.

Vernacular names Indonesia: mendongan (Javanese), aga mancii (West Sumatra), sinar uluh uluh (Toba, Sumatra). Thailand: yaa hua khot (Loei).

Distribution Widely distributed from South America, South and Central Africa to Australia. In South-East Asia found in Peninsular Malaysia, Indonesia and New Guinea.

Uses On the Dieng plateau (Java) the peduncles are used to make coarse mats. It serves as a low-quality replacement for *Fimbristylis umbellaris* (Lamk) Vahl at higher altitudes where the latter does not thrive.

Observations A perennial, grass-like herb. Leaves rigid, ensiform, 10–50 cm × 2–4 mm; sheath 6–16 cm long; ligule 2–25 mm long. Peduncle 20–96 cm × 1.5–3 mm, subcompressed, ribbed with 1 distinct wing. Inflorescence a subglobose to obovoid head, up to 1 cm in diameter; bracts with 6–9 nerves, 4–9 mm × 3–6 mm; lateral sepals boat-shaped, 6–7 mm × 1–1.5 mm; median sepal cap-shaped, 3–4 mm × 2 mm; petals yellow or yellowish, obovate, 4–5.5 mm long, claw 6–7 mm long; stamens about 2 mm long; staminodes 1.5–2.5 mm long. Fruit a 3-valved capsule, 4–6 mm × about 2 mm. *X. capensis* is found in swamps, on stream- and lake banks associated with sedges and *Juncus* species at altitudes of (600–)900–2500 m. At high altitudes the vegetative appearance of *X. capensis* tends to differ from the lower altitude plants with shorter, equidistant leaves.

Selected sources 47, 50, 67, 71, 160.

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M. Brink, P.C.M. Jansen & C.H. Bosch,
with contributions from:
R.P. Escobin (*Agelaea borneensis, Bauhinia integrifolia, Ficus odorata, Flagellaria indica, Grewia bilamellata, Hypserpa nitida, Ichnocarpus frutescens, Malvastrum coromandelianum, Pothoidium lobbianum*)
R.H.M.J. Lemmens (*Agelaea borneensis, Dichapetalum timoriense, Eulaliopsis binata, Gnetum gnemonoides, Lonicera acuminata, Petraeovitex multiflora, Phrynium placentarium, Pothoidium lobbianum, Ripidium arundinaceum*)
N. Wulijarni-Soetjipto (*Cayratia geniculata, Commersonia bartramia, Johannesteijsmannia altifrons, Phaleria macrocarpa, Sporobolus indicus, Tetrastigma papillosum*)

4 Fibre plants with other primary use

List of species in other commodity groups (parenthesis), which are used also as fibre plant. Synonyms in the indented lines.

Abelmoschus esculentus (L.) Moench (vegetables)
    Hibiscus esculentus L.
Abelmoschus moschatus Medikus (essential-oil plants)
    Hibiscus abelmoschus L.
Abrus fruticulosus Wight & Arn. (medicinal and poisonous plants)
    Abrus melanospermus Hassk.
    Abrus pulchellus Wallich ex Thwaites
Abutilon hirtum (Lamk) Sweet (medicinal and poisonous plants)
    Abutilon graveolens (Roxb. ex Hornem.) Wight & Arnott ex Wight
Abutilon indicum (L.) Sweet (medicinal and poisonous plants)
Acacia aulacocarpa A. Cunn. ex Benth. (auxiliary plants/timber trees)
    Acacia aulacocarpa A. Cunn. ex Benth. var. *macrocarpa* Benth.
    Acacia lamprocarpa O. Schwarz
    Racosperma aulacocarpum (A. Cunn. ex Benth.) Pedley
Acacia auriculiformis A. Cunn. ex Benth. (auxiliary plants/timber trees)
    Racosperma auriculiforme (A. Cunn. ex Benth.) Pedley
Acacia catechu (L.f.) Willd. (timber trees/dye and tannin-producing plants)
    Acacia chundra Willd.
Acacia crassicarpa A. Cunn. ex Benth. (auxiliary plants/timber trees)
    Racosperma crassicarpum (A. Cunn. ex Benth.) Pedley
Acacia elata A. Cunn. ex Benth. (auxiliary plants)
    Acacia terminalis auct.
    Racosperma elatum (Benth.) Pedley
Acacia farnesiana (L.) Willd. (essential-oil plants)
    Acacia smallii Isely
    Mimosa farnesiana L.
    Vachellia farnesiana (L.) Wight & Arnott
Acacia leptocarpa A. Cunn. ex Benth. (timber trees)
    Racosperma leptocarpum (A. Cunn. ex Benth.) Pedley
Acacia leucophloea (Roxb.) Willd. (dye and tannin-producing plants/timber trees)
    Acacia melanochaetes Zoll.
    Delaportea ferox Gagnep.
    Delaportea microphylla Gagnep.
    Mimosa leucophloea Roxb.
Acacia mangium Willd. (timber trees)
    Racosperma mangium (Willd.) Pedley

Acacia mearnsii De Wild. (dye and tannin-producing plants/timber trees)
Acacia decurrens auct., non Willd.
Acacia decurrens (Wendl.) Willd. var. *mollis* Lindl.
Acacia mollissima auct., non Willd.
Acacia nilotica (L.) Willd. ex Del. (dye and tannin-producing plants)
Acacia arabica (Lamk) Willd.
Acacia tomentosa Willd. (auxiliary plants)
Acacia chrysocoma Miquel
Mimosa tomentosa (Willd.) Rottler
Achyranthes bidentata Blume (medicinal and poisonous plants)
Achyranthes javanica Moq.
Achyranthes mollicula Nakai
Acronychia pedunculata (L.) Miq. (timber trees)
Acronychia arborea Blume
Acronychia laurifolia Blume
Acronychia resinosa J.R. Forster ex Crevost & Lemarié
Acrostichum aureum L. (cryptogams)
Chrysodium aureum (L.) Mett.
Chrysodium vulgare Fée
Adenia cordifolia (Blume) Engl. (medicinal and poisonous plants)
Adenia obtusa (Blume) Engl.
Adenia populifolia auct. non (Blume) Engl.
Adenia macrophylla (Blume) Koord. (medicinal and poisonous plants)
Adenia acuminata auct. non (Blume) King
Adenia singaporeana (Wallich ex G. Don) Engl.
Adiantum capillus-veneris L. (cryptogams)
Aeschynomene afraspera J. Léonard (auxiliary plants)
Aeschynomene aspera auct., non L.
Sesbania leptocarpa auct., non DC.
Aganosma marginata (Roxb.) G. Don (medicinal and poisonous plants)
Aganosma acuminata G. Don
Agathis dammara (Lambert) Rich. (plants producing exudates)
Agathis celebica (Koord.) Warb.
Agathis hamii Meijer Drees
Agathis loranthifolia Salisb.
Agathis labillardieri Warb. (timber trees)
Agelaea macrophylla (Zoll.) Leenh. (medicinal and poisonous plants)
Agelaea trinervis (Llanos) Merr.
Agelaea wallichii Hook.f.
Castanola macrophylla Schellenb.
Agrostistachys borneensis Becc. (timber trees)
Agrostistachys latifolia (Hook.f.) Pax & K. Hoffm.
Agrostistachys leptostachya (Hook.f.) Pax & K. Hoffm.
Agrostistachys longifolia (Wight) Trimen, non (Müll. Arg.) Kurz
Ailanthus excelsa Roxb. (auxiliary plants)
Pongelion excelsum (Roxb.) Pierre
Pongelion wightii van Tiegh.
Alchornea villosa (Benth.) Müll. Arg. (medicinal and poisonous plants)
Aleurites moluccana (L.) Willd. (spices)

Aleurites triloba J.R. & G. Forst.
Jatropha moluccana L.
Juglans camirium Lour.
Alnus nepalensis D. Don (auxiliary plants)
Alphitonia excelsa (Fenzl) Reissek ex Endl. (timber trees)
Alphitonia incana (Roxb.) Kurz ex Hoogland
Alphitonia moluccana Teijsm. & Binnend.
Alphitonia philippinensis Braid
Alpinia regia R.M. Smith (vegetables)
Languas regia Burkill
Alpinia zerumbet (Pers.) Burtt & Smith (essential-oil plants/medicinal and poisonous plants)
Alpinia speciosa (J.C. Wendl.) K. Schum.
Catimbium speciosum (J.C. Wendl.) Holttum
Costus zerumbet Pers.
Languas speciosa (J.C. Wendl.) Small
Zerumbet speciosum J.C. Wendl.
Alstonia angustiloba Miq. (medicinal and poisonous plants)
Alstonia calophylla Miq.
Paladelpha angustiloba (Miq.) Pichon
Alstonia scholaris (L.) R.Br. (timber trees/medicinal and poisonous plants)
Echites pala Ham.
Echites scholaris L.
Tabernaemontana alternifolia Burm.
Alstonia spatulata Bl. (medicinal and poisonous plants)
Alstonia cuneata Wallich ex G. Don
Althaea rosea (L.) Cav. (ornamental plants)
Altingia excelsa Noroña (timber trees)
Amomum uliginosum J.G. König ex Retz. (medicinal and poisonous plants)
Amphineuron terminans (Hook.) Holttum (cryptogams)
Cyclosorus interruptus sensu Holttum
Nephrodium terminans Hook.
Thelypteris terminans (Hook.) Tagawa & K. Iwatsuki
Anamirta cocculus (L.) Wight & Arn. (medicinal and poisonous plants)
Anamirta paniculata Colebr.
Cocculus populifolius DC.
Menispermum cocculus L.
Menispermum lacunosum Lamk
Ananas comosus (L.) Merr. (edible fruits and nuts)
Ananas sativus (Lindley) Schultes f.
Bromelia comosa L.
Anaxagorea javanica Blume (medicinal and poisonous plants)
Anaxagorea scortechinii King
Ancistrocladus tectorius (Lour.) Merr. (medicinal and poisonous plants)
Ancistrocladus extensus Wallich ex Planchon
Ancistrocladus pinangianus Wallich ex Planchon
Andropogon gayanus Kunth (forages)
Andropogon bisquamulatus Hochst.
Andropogon squamulatus Hochst.

Andropogon tridentatus Hochst.
Annona reticulata L. (edible fruits and nuts)
Anthocephalus chinensis (Lamk) A. Rich. ex Walp. (timber trees)
Anthocephalus cadamba (Roxb.) Miquel
Anthocephalus indicus A. Rich.
Neolamarckia cadamba (Roxb.) Bosser
Anthocephalus macrophyllus (Roxb.) Havil. (timber trees)
Bancalus macrophyllus (Roxb.) Kuntze
Nauclea macrophylla Roxb.
Neolamarckia macrophylla (Roxb.) Bosser
Antiaris toxicaria Lesch. (medicinal and poisonous plants/timber trees)
Antiaris africana Engl.
Antiaris macrophylla R. Br.
Antiaris welwitschii Engl.
Apluda mutica L. (forages)
Apluda varia Hackel
Aquilaria crasna Pierre ex H. Lecomte (essential-oil plants)
Aquilaria agallocha auct., non Roxb.
Aquilaria malaccensis Lamk (essential-oil plants)
Agallochum malaccense (Lamk) Kuntze
Aquilaria agallocha Roxb.
Aquilariella malaccensis (Lamk) v. Tieghem
Areca catechu L. (stimulants)
Areca triandra Roxb. (stimulants)
Areca borneensis Becc.
Areca nagensis Griffith
Areca polystachya (Miquel) H. Wendl.
Arenga pinnata (Wurmb) Merr. (plants yielding non-seed carbohydrates)
Arenga saccharifera Labill.
Arenga tremula (Blanco) Becc. (plants yielding non-seed carbohydrates)
Caryota tremula Blanco
Didymosperma tremula (Blanco) H.A. Wendl. & Drude
Wallichia tremula (Blanco) Kunth
Arenga undulatifolia Becc. (plants yielding non-seed carbohydrates)
Arenga ambong Becc.
Arenga westerhoutii Griffith (plants yielding non-seed carbohydrates)
Argyreia mollis (Burm.f.) Choisy (medicinal and poisonous plants)
Artocarpus altilis (Parkinson) Fosberg (edible fruits and nuts)
Artocarpus camansi Blanco
Artocarpus communis J.R. & G. Forster
Artocarpus heterophyllus Lamk (edible fruits and nuts)
Artocarpus brasiliensis Gomez
Artocarpus maxima Blanco
Artocarpus philippensis Lamk
Artocarpus integer (Thunb.) Merr. (edible fruits and nuts)
Artocarpus champeden (Lour.) Stokes
Artocarpus integrifolia L.f.
Artocarpus polyphema Persoon
Artocarpus kemando Miq. (timber trees)

Artocarpus brunneifolius S. Moore
Artocarpus scortechinii King (timber trees)
Artocarpus sericicarpus Jarrett (edible fruits and nuts/timber trees)
Asclepias curassavica L. (medicinal and poisonous plants)
Asplenium nidus L. (cryptogams)
Asplenium musifolium J. Smith ex Mett.
Neottopteris nidus (L.) J. Smith
Thamnopteris nidus (L.) Presl.
Astrocaryum aculeatum G. Mey (vegetable oils and fats)
Astrocaryum aureum Griseb. & H. Wendl.
Astrocaryum chambira Burret
Astrocaryum tucuma Mart.
Astrocaryum vulgare Mart. (vegetable oils and fats)
Astrocaryum awarra de Vriese
Astrocaryum segregatum Drude
Astrocaryum tucumoides Drude
Attalea cohune Mart. (vegetable oils and fats)
Orbignya cohune (Mart.) Dahlgren
Atuna racemosa Raf. (timber trees)
Atuna elata (King) Kosterm.
Atuna excelsa (Jack) Kosterm.
Cyclandrophora excelsa (Jack) Kosterm.
Parinari glaberrimum (Hassk.) Hassk.
Azadirachta indica A.H.L. Juss. (auxiliary plants/timber trees)
Antelaea azadirachta (L.) Adelb.
Melia azadirachta L.
Melia indica (A.H.L. Juss.) Brandis
Bactris gasipaes Kunth (edible fruits and nuts)
Bactris utilis Benth. & Hook.f. ex Hemsley
Guilielma gasipaes (Kunth) L.H. Bailey
Guilielma speciosa Mart.
Baeckea frutescens L. (medicinal and poisonous plants)
Baeckea chinensis Gaertner
Baeckea cochinchinensis Blume
Baeckea cumingiana Schauer
Bambusa amahussana Lindley (bamboos)
Bambusa atra Lindley (bamboos)
Bambusa lineata Munro
Bambusa rumphiana Kurz
Dendrocalamus latifolius Laut. & K. Schum.
Bambusa balcooa Roxb. (bamboos)
Dendrocalamus balcooa (Roxb.) Voigt
Bambusa bambos (L.) Voss (bamboos)
Arundo bambos L.
Bambusa arundinacea (Retzius) Willd.
Bambusa spinosa Roxb.
Bambusa blumeana J.A. & J.H. Schultes (bamboos)
Bambus arundo Blanco
Bambusa pungens Blanco

Bambusa spinosa Blume ex Nees
Bambusa forbesii (Ridley) Holttum (bamboos)
Bambusa heterostachya (Munro) Holttum (bamboos)
Bambusa latispiculata (Gamble) Holttum
Gigantochloa heterostachya Munro
Gigantochloa latispiculata Gamble
Bambusa multiplex (Lour.) Raeuschel ex J.A. & J.H. Schultes (bamboos)
Arundo multiplex Lour.
Bambusa glaucescens (Willd.) Sieb. ex Munro
Bambusa nana Roxb.
Bambusa polymorpha Munro (bamboos)
Bambusa tulda Roxb. (bamboos)
Dendrocalamus tulda (Roxb.) Voigt
Bambusa tuldoides Munro (bamboos)
Bambusa longiflora W.T. Lin
Bambusa pallescens (Doell) Hackel
Bambusa ventricosa McClure
Bambusa vulgaris Schrader ex Wendland (bamboos)
Bambusa surinamensis Ruprecht
Bambusa thouarsii Kunth
Leleba vulgaris (Schrader ex Wendland) Nakai
Barringtonia acutangula (L.) Gaertner (timber trees/medicinal and poisonous plants)
Barringtonia edaphocarpa Gagnep.
Barringtonia luzonensis Vidal
Barringtonia pedicellata Ridley
Barringtonia spicata Blume
Barringtonia racemosa (L.) Spreng. (medicinal and poisonous plants/timber trees)
Barringtonia insignis Miq.
Barringtonia pallida (Miers) Koord. & Valeton
Barringtonia salomonensis Rech.
Bauhinia malabarica Roxb. (timber trees)
Piliostigma acidum (Reinw. ex Korth.) Benth.
Piliostigma malabaricum (Roxb.) Benth.
Bauhinia vahlii Wight & Arnott (dye and tannin-producing plants)
Benincasa hispida (Thunberg ex Murray) Cogniaux (vegetables)
Benincasa cerifera Savi
Cucurbita hispida Thunberg ex Murray
Bischofia javanica Blume (timber trees)
Bixa orellana L. (dye and tannin-producing plants)
Boesenbergia rotunda (L.) Mansfeld (spices)
Boesenbergia pandurata (Roxb.) Schlechter
Curcuma rotunda L.
Gastrochilus pandurata (Roxb.) Ridley
Kaempferia pandurata Roxb.
Bombax ceiba L. (timber trees)
Bombax malabaricum DC.
Gossampinus malabarica (DC.) Merr.

Salmalia malabarica (DC.) Schott & Endl.
Borassus flabellifer L. (plants yielding non-seed carbohydrates)
Borassus flabelliformis L.
Bothriochloa bladhii (Retzius) S.T. Blake (forages)
Amphilophis glabra Stapf
Amphilophis intermedia Stapf
Andropogon intermedius R. Br.
Broussonetia luzonica (Blanco) Bur. (vegetables/timber trees)
Allaeanthus glaber Warb.
Allaeanthus luzonicus (Blanco) Fern.-Vill.
Bruguiera gymnorhiza (L.) Savigny (dye and tannin-producing plants/timber trees)
Bruguiera conjugata Merr.
Bruguiera cylindrica (non Blume) Hance
Bruguiera rheedii Blume
Butea monosperma (Lamk) Taubert (dye and tannin-producing plants/ medicinal and poisonous plants)
Butea frondosa Roxb. ex Willd.
Cajanus cajan (L.) Millsp. (pulses)
Calamus andamanicus Kurz (rattans)
Calamus arugda Becc. (rattans)
Calamus axillaris Becc. (rattans)
Calamus blumei Becc. (rattans)
Calamus castaneus Becc. (rattans)
Calamus caesius Blume (rattans)
Calamus ciliaris Blume (rattans)
Calamus cumingianus Becc. (rattans)
Calamus densiflorus Becc. (rattans)
Calamus diepenhorstii Miq. (rattans)
Calamus dimorphacanthus Becc. var. *dimorphacanthus* (rattans)
Calamus discolor Becc. (rattans)
Calamus egregius Burret (rattans)
Calamus elmerianus Becc. (rattans)
Calamus exilis Griffith (rattans)
Calamus flabellatus Becc. (rattans)
Calamus gibbsianus Becc. (rattans)
Calamus halconensis (Becc.) Baja-Lapis var. *dimorphacanthus* Becc. (rattans)
Calamus halconensis Becc.
Calamus heteroideus Bl. (rattans)
Calamus hispidulus Becc. (rattans)
Calamus insignis Becc. (rattans)
Calamus javensis Blume (rattans)
Calamus filiformis Becc.
Calamus leptostachys Becc. ex Heyne (rattans)
Calamus longispathus Ridley (rattans)
Calamus luridus Becc. (rattans)
Calamus manillensis (Mart.) H. Wendl. (rattans)
Calamus marginatus (Bl.) Mart. (rattans)
Calamus mattanensis Becc. (rattans)

Calamus megaphyllus Becc. (rattans)
Calamus melanorhynchus Becc. (rattans)
Calamus merrillii Becc. (rattans)
    Calamus maximus Merr. non Blanco (rattans)
Calamus microcarpus Becc. (rattans)
Calamus microsphaerion Becc. (rattans)
Calamus minahassae Becc. (rattans)
Calamus mindorensis Becc. (rattans)
Calamus mitis Becc. (rattans)
Calamus myriacanthus Becc. (rattans)
Calamus optimus Becc. (rattans)
Calamus ovoidus Thwaites ex Trimen (rattans)
Calamus pogonacanthus Becc. ex H. Winkler (rattans)
Calamus reyesianus Becc. (rattans)
Calamus rhomboideus Blume (rattans)
Calamus rhytidomus Becc. (rattans)
Calamus ruvidus Becc. (rattans)
Calamus scabridulus Becc. (rattans)
Calamus simplex Becc. (rattans)
Calamus simplicifolius Wei (rattans)
Calamus spinifolius Becc. (rattans)
Calamus subinermis H. Wendl. ex Becc. (rattans)
Calamus tetradactylus Hance (rattans)
Calamus tomentosus Becc. (rattans)
Calamus trachycoleus Becc. (rattans)
Calamus ulur Becc. (rattans)
Calamus usitatus Becc. (rattans)
Calamus viminalis Willd. (rattans)
Calamus wailong S.J. Pei & S.Y. Chen (rattans)
    Calamus platyacanthus Wei
Calamus warburgii K. Schum. (rattans)
Calliandra calothyrsus Meissn. (auxiliary plants/forages)
    Calliandra acapulcensis (Britton & Rose) Standley
    Calliandra confusa Sprague & Riley
    Calliandra similis Sprague & Riley
Calotropis gigantea (L.) Aiton f. (medicinal and poisonous plants)
    Asclepias gigantea L.
Calotropis procera (Aiton) Aiton f. (medicinal and poisonous plants)
    Asclepias procera Aiton
Calophyllum vexans P.F. Stevens (timber trees)
Cananga odorata (Lamk) Hook.f. & Thomson (essential-oil plants)
    Canangium odoratum (Lamk) Baillon
    Canangium scortechinii King
    Uvaria odorata Lamk
Canarium luzonicum (Blume) A. Gray (timber trees)
    Canarium carapifolium Perkins
    Canarium oliganthum Merr.
    Canarium polyanthum Perkins
Canavalia cathartica du Petit-Thouars (auxiliary plants)

Canavalia ensiformis (L.) DC. var. *turgida* Baker
Canavalia microcarpa (DC.) Piper
Canavalia turgida Graham ex A. Gray
Canna indica L. (plants yielding non-seed carbohydrates)
Canna coccinea P. Miller
Canna edulis Ker-Gawler
Canna orientalis Roscoe
Cannabis sativa L. (medicinal and poisonous plants)
Cardiospermum halicacabum L. (medicinal and poisonous plants)
Cardiospermum corindum L.
Cardiospermum luridum Blume
Cardiospermum microcarpum Kunth
Careya arborea Roxb. (timber trees)
Caryota cumingii Lodd. ex Mart. (plants yielding non-seed carbohydrates/timber trees)
Caryota merrillii Becc.
Caryota maxima Blume ex Mart. (plants yielding non-seed carbohydrates/timber trees)
Caryota aequatorialis (Becc.) Ridley
Caryota macrantha Burret
Caryota rumphiana Mart. var. *javanica* Becc.
Caryota mitis Lour. (plants yielding non-seed carbohydrates/timber trees)
Caryota griffithii Becc.
Caryota no Becc. (plants yielding non-seed carbohydrates/timber trees)
Caryota rumphiana Mart. (plants yielding non-seed carbohydrates/timber trees)
Caryota urens L. (plants yielding non-seed carbohydrates)
Cayratia japonica (Thunb.) Gagnep. (medicinal and poisonous plants)
Cissus japonica Willd.
Cissus obovata Lawson
Vitis japonica Thunb.
Cassia auriculata L. (dye and tannin-producing plants)
Cassia densistipulata Taubert
Casuarina equisetifolia L. (auxiliary plants/timber trees)
Casuarina equisetifolia J.R. & G. Forster
Casuarina litorea L.
Casuarina muricata Roxb.
Casuarina junghuhniana Miquel (auxiliary plants/timber trees)
Casuarina montana Junghuhn ex Miquel
Cecropia peltata L. (medicinal and poisonous plants)
Cecropia surinamensis Miq.
Cedrela odorata L. (timber trees)
Cedrela glaziovii C. DC.
Cedrela guianensis Adr. Juss.
Cedrela mexicana M.J. Roemer
Celtis philippensis Blanco (timber trees)
Celtis collinsae Craib
Celtis strychnoides Planch.
Celtis wightii Planch.

Cephalostachyum pergracile Munro (bamboos)
 Schizostachyum pergracile (Munro) Majumdar
Cephalostachyum virgatum (Munro) Kurz (bamboos)
Ceriops decandra (Griffith) Ding Hou (dye and tannin-producing plants)
 Ceriops roxburghiana Arn.
Chrysopogon aciculatus (Retzius) Trinius (forages)
 Andropogon aciculatus Retzius
Chukrasia tabularis A.H.L. Juss. (timber trees)
 Chickrassia tabularis (A.H.L. Juss.) A.H.L. Juss.
 Chukrasia velutina A.H.L. Juss.
Cibotium barometz (L.) J. Sm. (cryptogams)
 Aspidium barometz Willd.
 Dicksonia baranetz Link
 Polypodium barometz L.
Cissampelos pareira L. (medicinal and poisonous plants)
Cissus adnata Roxb. (medicinal and poisonous plants)
 Vitis adnata Wight & Arnott
Cissus repens Lamk (vegetables)
 Vitis quadricornuta Miquel
 Vitis repens Wight & Arnott
Claoxylon longifolium (Blume) Endl. ex Hassk. (vegetables)
Clausena anisata (Willd.) Hook.f. ex Benth. (medicinal and poisonous plants)
 Amyris anisata Willd.
 Clausena dentata (Willd.) M. Roem.
 Clausena dunniana H. Lév.
 Clausena willdenowii Wight & Arn.
Cocos nucifera L. (vegetable oils and fats)
 Cocos nana Griff.
Coelostegia griffithii Benth. (timber trees)
 Coelostegia sumatrana Becc.
Coix lacryma-jobi L. (cereals)
 Coix agrestis Lour.
 Coix arundinacea Lamk
 Coix lacryma L.
Colocasia esculenta (L.) Schott (plants yielding non-seed carbohydrates/ medicinal and poisonous plants)
 Colocasia antiquorum Schott
 Colocasia esculenta (L.) Schott var. *antiquorum* (Schott) Hubb. & Rehder
Connarus monocarpus L. (medicinal and poisonous plants)
 Connarus oligophyllus Wallich ex Planchon
Connarus semidecandrus Jack (medicinal and poisonous plants)
 Connarus gibbosus Wallich ex Hook.f.
 Connarus mutabilis Blume
 Connarus neurocalyx Planchon
Cordia dichotoma J.G. Forster (medicinal and poisonous plants/timber trees)
 Cordia griffithii C.B. Clarke
 Cordia myxa auct. non L.
 Cordia obliqua auct. non Willd.
 Cordia premnifolia Ridley

Cordia suaveolens Blume
Cordyline fruticosa (L.) A. Chevalier (ornamental plants)
Cordyline terminalis (L.) Kunth
Dracaena aurantiaca Wallich
Dracaena congesta Ridley
Dracaena graminifolia Wallich
Corymbia citriodora (Hook.) K.D. Hill & L.A.S. Johnson (essential-oil plants)
Eucalyptus citriodora Hook.
Eucalyptus maculata Hook. var. *citriodora* (Hook.) Bailey
Eucalyptus melissiodora Lindley
Crotalaria juncea L. (forages)
Crotalaria quinquefolia L. (auxiliary plants)
Crotalaria heterophylla L.f.
Crotalaria retusa L. (auxiliary plants)
Crotalaria spectabilis Roth (auxiliary plants)
Crotalaria sericea Retzius, non Burm.f.
Crotalaria zanzibarica Benth.
Crotalaria trichotoma Bojer (auxiliary plants)
Crotalaria usaramoensis Baker f.
Croton caudatus Geiseler (medicinal and poisonous plants)
Cyathocalyx bancanus Boerl. (timber trees)
Cymbopogon citratus (DC.) Stapf (essential-oil plants)
Andropogon ceriferus Hackel
Andropogon citratus DC.
Andropogon nardus (L.) Rendle var. *ceriferus* Hackel
Cymbopogon flexuosus (Nees ex Steudel) J.F. Watson (essential-oil plants)
Andropogon flexuosus Nees ex Steudel
Andropogon nardus L. var. *flexuosus* (Nees ex Steudel) Hackel
Cymbopogon travancorensis Bor
Cyperus esculentus L. (plants yielding non-seed carbohydrates)
Cyrtosperma merkusii (Hassk.) Schott (plants yielding non-seed carbohydrates)
Cyrtosperma chamissonis (Schott) Merrill
Cyrtosperma edule Schott ex Seem.
Cyrtosperma lasioides Griffith
Dacryodes kingii (Engl.) Kalkm. (timber trees)
Dactylocladus stenostachys Oliv. (timber trees)
Daemonorops angustifolia (Griff.) Mart. (rattans)
Daemonorops calicarpa (Griff.) Mart. (rattans)
Daemonorops clemensiana Becc. (rattans)
Daemonorops crinita (Miq.) Bl. (rattans)
Daemonorops curranii Becc. (rattans)
Daemonorops didymophylla Becc. (rattans)
Daemonorops elongata Bl. (rattans)
Daemonorops grandis (Griff.) Mart. (rattans)
Daemonorops ingens J. Dransf. (rattans)
Daemonorops lamprolepis Becc. (rattans)
Daemonorops leptopus (Griff.) Mart. (rattans)
Daemonorops longispatha Becc. (rattans)
Daemonorops margaritae (Hance) Becc. (rattans)

Daemonorops micracantha (Griff.) Becc. (rattans)
  Daemonorops draconcella Ridley
Daemonorops oblonga (Reinw. ex Bl.) Bl. (rattans)
Daemonorops ochrolepis Becc. (rattans)
Daemonorops periacantha Miquel (rattans)
Daemonorops sabut Becc. (rattans)
Dalbergia pinnata (Lour.) Prain (medicinal and poisonous plants)
  Dalbergia tamarindifolia Roxb.
Dendrobium crumenatum Swartz (medicinal and poisonous plants)
  Dendrobium caninum (Burm.f.) Merr.
  Dendrobium cumulatum Kraenzl.
Dendrocalamus brandisii (Munro) Kurz (bamboos)
  Bambusa brandisii Munro
Dendrocalamus giganteus Wallich ex Munro (bamboos)
  Bambusa gigantea Wallich
Dendrocalamus hamiltonii Nees (bamboos)
Dendrocalamus hirtellus Ridley (bamboos)
Dendrocalamus latiflorus Munro (bamboos)
  Bambusa latiflora (Munro) Kurz
  Sinocalamus latiflorus (Munro) McClure
Dendrocalamus longispathus Kurz (bamboos)
Dendrocalamus membranaceus Munro (bamboos)
Dendrocalamus pendulus Ridley (bamboos)
  Cephalostachyum malayense Ridley
  Schizostachyum subcordatum Ridley
Dendrocalamus strictus (Roxb.) Nees (bamboos)
  Bambos stricta Roxb.
Dendrocnide stimulans (L.f.) Chew (medicinal and poisonous plants)
  Laportea stenophylla Quisumb.
  Laportea stimulans (L.f.) Miquel
Derris malaccensis (Benth.) Prain (medicinal and poisonous plants)
  Deguelia malaccensis (Benth.) Blake
Derris trifoliata Lour. (medicinal and poisonous plants)
  Derris heterophylla (Willd.) Backer ex K. Heyne
  Derris uliginosa (Willd.) Benth.
Desmodium gangeticum (L.) DC. (medicinal and poisonous plants)
  Hedysarum gangeticum L.
  Meibomia gangetica (L.) O. Kuntze
Desmostachya bipinnata (L.) Stapf (auxiliary plants)
  Eragrostis cynosuroides (Retz.) P. Beauv.
  Pogonarthria bipinnata (L.) Chiov.
  Stapfiola bipinnata (L.) O. Kuntze
Dicranopteris linearis (Burm.f.) Underw. (cryptogams)
  Dicranopteris dichotoma (Thunb. ex Murray) Bernh.
  Gleichenia hermannii R.Br.
  Gleichenia linearis Clarke
Digitaria longiflora (Retzius) Pers. (forages)
Dillenia papuana Martelli (timber trees)
  Dillenia calothyrsa Diels

Wormia calothyrsa (Diels) Gilg & Werderm.
Wormia papuana (Martelli) Gilg & Werderm.
Dinochloa scandens (Blume) Kuntze (bamboos)
Bambusa scandens Blume
Dinochloa tjankorreh (Schultes) Büse
Nastus tjankorreh Schultes
Dinochloa sublaevigata S. Dransf. (bamboos)
Dinochloa trichogona S. Dransf. (bamboos)
Dioscorea pyrifolia Kunth (plants yielding non-seed carbohydrates)
Dioscorea diepenhorstii Miquel
Dioscorea oppositifolia L. sensu auct. mult.
Dioscorea zollingeriana Kunth
Diplodiscus paniculatus Turcz. (edible fruits and nuts)
Dipterocarpus crinitus Dyer (timber trees)
Dipterocarpus hirtus Vesque
Dipterocarpus tampurau auct. non Korth.
Dipterocarpus grandiflorus (Blanco) Blanco (timber trees)
Dipterocarpus griffithii Miq.
Dipterocarpus pterygocalyx R. Scheffer
Dolichandrone spathacea (L.f.) K. Schumann (timber trees)
Dolichandrone longissima (Lour.) K. Schumann
Dolichandrone rheedii (Spreng.) Seem.
Dryobalanops sumatrensis (J.F. Gmelin) Kosterm. (timber trees)
Dryobalanops aromatica Gaertner f.
Dryobalanops camphora Colebr.
Drypetes longifolia (Blume) Pax & K. Hoffm. (timber trees)
Drypetes bordenii (Merr.) Pax & K. Hoffm.
Drypetes macrophylla (Blume) Pax & K. Hoffm.
Drypetes myrmecophila Merr.
Durio carinatus Masters (timber trees)
Eichhornia crassipes (Martius) Solms (auxiliary plants)
Eichhornia speciosa Kunth
Pontederia crassipes Martius
Elaeis guineensis N.J. Jacquin (vegetable oils and fats)
Elaeocarpus calomala (Blanco) Merr. (edible fruits and nuts/timber trees)
Elaeocarpus pustulatus Merr.
Elaeocarpus villosiusculus Warb.
Eleiodoxa conferta (Griffith) Burret (edible fruits and nuts)
Salacca conferta Griffith
Eleocharis dulcis (Burm.f.) Trinius ex Henschel (plants yielding non-seed carbohydrates)
Eleocharis plantaginea Roemer & Schultes
Eleocharis tuberosa Roemer & Schultes
Heleocharis plantaginoidea W.F. Wight
Eleusine coracana (L.) Gaertner cv. group Finger Millet (cereals)
Eleusine coracana (L.) Gaertner subsp. *coracana* sensu Hilu & de Wet
Eleusine indica (L.) Gaertner f. *coracana* (L.) Hook.f. ex Backer
Embelia philippensis A. DC. (spices)
Rhamnus lando Llanos

Ribesoides philippense O. Kuntze
Samara philippinensis Vidal
Enkleia malaccensis Griffith (essential-oil plants)
Enkleia coriacea Hallier f.
Enkleia malayana Griffith
Linostoma scandens (Endl.) Kurz
Entada phaseoloides (L.) Merr. (medicinal and poisonous plants)
Entada rumphii Scheff.
Entada scandens (L.) Benth. p.p.
Entada tonkinensis Gagnep.
Epipremnum pinnatum (L.) Engl. (medicinal and poisonous plants)
Rhaphidophora merrillii Engl.
Rhaphidophora pinnata (L.) Schott
Scindapsus pinnatus (L.) Schott
Equisetum ramosissimum Desf. (cryptogams)
Equisetum elongatum Willd.
Equisetum ramosum DC.
Hippochaete ramosissima (Desf.) Börner
Eragrostis elongata (Willd.) Jacq. (forages)
Eragrostis brownii Nees ex Hook. & Arnott
Eragrostis tef (Zuccagni) Trotter (cereals)
Eragrostis abyssinica (Jacq.) Link
Poa abyssinica Jacq.
Poa tef Zuccagni
Erythrina poeppigiana (Walpers) O.F. Cook (auxiliary plants)
Erythrina micropteryx Poeppig ex Walpers
Micropteryx poeppigiana Walpers
Erythrina variegata L. (auxiliary plants/timber trees/medicinal and poisonous plants)
Erythrina indica Lamk
Erythrina orientalis (L.) Murr.
Erythrina variegata L. var. *orientalis* (L.) Merr.
Etlingera elatior (Jack) R.M. Smith (spices)
Alpinia elatior Jack
Nicolaia speciosa (Blume) Horan.
Phaeomeria speciosa (Blume) Merr.
Eucalyptus camaldulensis Dehnh. (timber trees/auxiliary plants)
Eucalyptus rostrata Schlechtendal
Eucalyptus citriodora Hook. (timber trees)
Eucalyptus maculata Hook. var. *citriodora* (Hook.) Bailey
Eucalyptus melissiodora Lindley
Eucalyptus variegata F. v. Mueller
Eucalyptus deglupta Blume (timber trees)
Eucalyptus multiflora Rich. ex A. Gray non Poir.
Eucalyptus naudiniana F. v. Mueller
Eucalyptus schlechteri Diels
Eucalyptus robusta J.E. Smith (timber trees)
Eucalyptus multiflora Poir.
Eucalyptus tereticornis J.E. Smith (timber trees/auxiliary plants)

Eucalyptus insignis Naudin
Eucalyptus subulata Cunn. ex Schauer
Eucalyptus umbellata (Gaertner) Domin non Desf.
Eucalyptus urophylla S.T. Blake (timber trees/auxiliary plants)
Eucalyptus alba auct. non Reinw. ex Blume
Eucalyptus decaisneana auct. non Blume
Eugeissona insignis Becc. (plants yielding non-seed carbohydrates)
Eugeissona utilis Becc. (plants yielding non-seed carbohydrates)
Euterpe oleracea Martius (edible fruits and nuts)
Fagopyrum esculentum Moench (cereals)
Fagopyrum sagittatum Gilib.
Fagopyrum vulgare Hill
Polygonum fagopyrum L.
Ficus ampelas Burm.f. (medicinal and poisonous plants)
Ficus blepharosepala Warb.
Ficus kingiana Hemsley
Ficus soronensis King
Ficus annulata Blume (timber trees)
Ficus balabacensis Quisumb.
Ficus flavescens Blume
Ficus valida Blume
Ficus benghalensis L. (timber trees)
Ficus banyana Oken
Ficus indica L.
Ficus benjamina L. (timber trees/ornamental plants)
Ficus cuspidato-caudata Hayata
Ficus parvifolia Oken
Ficus umbrina Elmer
Ficus calopilina Diels (medicinal and poisonous plants)
Ficus setistyla Warb.
Ficus consociata Blume (plants producing exudates)
Ficus copiosa Steud. (medicinal and poisonous plants)
Ficus krausseana Rechinger
Ficus longipedunculata Rechinger
Ficus magnifolia F. v. Mueller
Ficus dammaropsis Diels (vegetables/medicinal and poisonous plants)
Dammaropsis kingiana Warb.
Ficus drupacea Thunb. (edible fruits and nuts/timber trees)
Ficus chrysochlamys Lauterb. & K. Schumann
Ficus chrysocoma Blume
Ficus payapa Blanco
Ficus pilosa Reinw. ex Blume
Ficus elastica Roxb. (plants producing exudates)
Urostigma elasticum (Roxb.) Miq.
Visiania elastica (Roxb.) Gasp.
Ficus grossularioides Burm.f. (vegetables/timber trees)
Ficus alba Reinw. ex Blume
Ficus hunteri Miq.
Ficus lobata Hunter ex Ridley

Ficus hispida L.f. (medicinal and poisonous plants)
Ficus letaqui Lév. & Van.
Ficus poilanei Gagnep.
Ficus magnoliifolia Blume (timber trees)
Ficus apoensis Elmer
Ficus edelfeltii auct. non King
Ficus nervosa auct. non Heyne ex Roth
Ficus melinocarpa Blume (timber trees)
Ficus alnifolia (Miq.) Miq.
Ficus haggeri Merr.
Ficus irosinensis Elmer
Ficus nodosa Teijsmann & Binnend. (vegetables/medicinal and poisonous plants)
Ficus du Lauterb. & K. Schumann
Ficus pachyrrachis Lauterb. & K. Schumann (medicinal and poisonous plants)
Ficus grandis King
Ficus hypoglauca Lauterb. & K. Schumann
Ficus pachythyrsa Diels
Ficus pachystemon Warb. (medicinal and poisonous plants)
Ficus aechmophylla Summerh.
Ficus brassii Summerh.
Ficus mangiferifolia Lauterb. & K. Schumann
Ficus padana Burm.f. (plants producing exudates)
Ficus elegans Hassk.
Ficus toxicaria L.
Ficus pungens Reinw. ex Blume (vegetables/medicinal and poisonous plants)
Ficus kalingaensis Merr.
Ficus myriocarpa Miq.
Ficus ovalifolia Ridley
Ficus racemosa L. (edible fruits and nuts)
Ficus glomerata Roxb.
Ficus religiosa L. (medicinal and poisonous plants)
Ficus caudata Stokes
Ficus peepul Griffith
Ficus superstitiosa Link
Ficus rumphii Blume (medicinal and poisonous plants)
Ficus conciliorum Oken
Ficus cordifolia Roxb.
Ficus damit Gagnep.
Ficus subcordata Blume (forages)
Ficus calophylloides Elmer
Ficus fairchildii Backer
Ficus garciniifolia Miquel
Ficus tinctoria Forster f. (vegetables)
Ficus gibbosa Blume
Ficus parasitica Willd.
Ficus ulmifolia Lamk (edible fruits and nuts)
Ficus variegata Blume (timber trees)
Ficus cordifolia Blume

Ficus laevigata Blanco
Ficus sum Gagnep.
Ficus wassa Roxb. (medicinal and poisonous plants)
Ficus eulampra K. Schumann
Ficus nubigena Diels
Ficus rhodocarpa Summerh.
Fimbristylis dichotoma (L.) Vahl (auxiliary plants)
Fimbristylis annua auct., non (All.) Roem. & Schult.
Fimbristylis diphylla (Retz.) Vahl
Fimbristylis ramosii Kük.
Funtumia elastica (Preuss) Stapf (plants producing exudates)
Kickxia elastica P. Preuss
Furcraea hexapetala (Jacq.) Urb. (ornamental plants)
Furcraea cubensis (Jacq.) Vent.
Furcraea selloa C. Koch (ornamental plants)
Garcinia indica (Thouars) Choisy (vegetable oils and fats)
Brindonia indica Thouars
Garcinia microstigma Kurz
Genipa americana L. (edible fruits and nuts)
Gigantochloa albociliata (Munro) Kurz (bamboos)
Oxytenanthera albociliata Munro
Gigantochloa apus (J.A. & J.H. Schultes) Kurz (bamboos)
Bambusa apus J.A. & J.H. Schultes
Gigantochloa kurzii Gamble
Gigantochloa atroviolacea Widjaja (bamboos)
Gigantochloa verticillata (Willd.) Munro sensu Backer
Gigantochloa atter (Hassk.) Kurz (bamboos)
Bambusa thouarsii Kunth var. *atter* Hassk.
Gigantochloa verticillata (Willd.) Munro sensu Backer
Gigantochloa balui K.M. Wong (bamboos)
Gigantochloa hasskarliana (Kurz) Backer ex Heyne (bamboos)
Schizostachyum hasskarlianum Kurz
Gigantochloa levis (Blanco) Merrill (bamboos)
Bambusa levis Blanco
Dendrocalamus curranii Gamble
Gigantochloa scribneriana Merrill
Gigantochloa ligulata Gamble (bamboos)
Gigantochloa manggong Widjaja (bamboos)
Gigantochloa nigrociliata (Büse) Kurz (bamboos)
Bambusa nigrociliata Büse
Oxytenanthera nigrociliata (Büse) Munro
Schizostachyum serpentinum Kurz
Gigantochloa pseudoarundinacea (Steudel) Widjaja (bamboos)
Bambusa pseudoarundinacea Steudel
Gigantochloa maxima Kurz
Gigantochloa verticillata (Willd.) Munro
Gigantochloa scortechnii Gamble (bamboos)
Gigantochloa wrayi Gamble (bamboos)
Gigantochloa kurzii Gamble

Gigantochloa maxima Kurz var. *viridis* Holttum
Glochidion molle Blume (medicinal and poisonous plants)
Gmelina arborea Roxb. (timber trees)
Gnetum costatum K. Schumann (edible fruits and nuts)
Gnetum gnemon L. (edible fruits and nuts)
Gnetum acutatum Miq.
Gnetum vinosum Elmer
Gnetum latifolium Blume (edible fruits and nuts)
Gnetum indicum (Lour.) Merr. (partly)
Goniothalamus amuyon (Blanco) Merr. (medicinal and poisonous plants)
Polyalthia sasakii Yamam.
Unona cauliflora Blanco
Uvaria amuyon Blanco
Goniothalamus giganteus Hook.f. & Thomson (medicinal and poisonous plants)
Goniothalamus tapis Miq. (medicinal and poisonous plants)
Goniothalamus sumatranus Miq.
Grevillea pteridifolia Knight (auxiliary plants)
Grevillea chrysodendron R. Br.
Grevillea robusta A. Cunn. ex R. Br. (auxiliary plants/timber trees)
Grewia abutilifolia Vent. ex Juss. (medicinal and poisonous plants)
Grewia aspera Roxb.
Grewia sclerophylla Roxb. ex G. Don
Grewia asiatica L. (edible fruits and nuts/timber trees)
Grewia conferta Warb. ex Burret
Grewia hainesiana Hole
Grewia humilis Wallich ex Mast.
Grewia subinaequalis DC.
Grewia vestita Mast.
Grewia eriocarpa Juss. (timber trees)
Grewia celtidifolia Juss.
Grewia hypotephra Pierre
Grewia koordersiana Burret
Grewia laevigata Vahl (timber trees)
Grewia acuminata Juss.
Grewia disperma Rottl. ex Spreng.
Grewia glabra Blume
Grewia multiflora Juss.
Grewia sepiaria Roxb. ex G. Don
Guazuma ulmifolia Lamk (medicinal and poisonous plants)
Guazuma tomentosa Kunth
Theobroma guazuma L.
Gymnostoma rumphianum (Miquel) L.A.S. Johnson (auxiliary plants)
Casuarina rumphiana Miquel
Halopegia blumei (Koernicke) K. Schumann (plants yielding non-seed carbohydrates)
Clinogyne blumei (Koernicke) Bentham
Donax blumei (Koernicke) K. Schumann
Maranta blumei Koernicke
Haplolobus floribundus (K. Schumann) H.J. Lam (timber trees)

Haplolobus celebicus H.J. Lam
Haplolobus leeifolius (Lauterb.) H.J. Lam
Haplolobus moluccanus H.J. Lam
Harmsiopanax harmsii K. Schumann ex K. Schumann & Lauterb. (medicinal and poisonous plants)
Hedychium coronarium J. König (medicinal and poisonous plants)
Hedychium flavescens Carey ex Roscoe
Helminthostachys zeylanica (L.) Hook. (cryptogams)
Helminthostachys dulcis Kaulfuss
Osmunda zeylanica L.
Heritiera littoralis Aiton (timber trees)
Heritiera minor (Gaertner) Lamk
Heterospathe elata Scheffer (ornamental plants)
Hevea brasiliensis (Willd. ex A.L. Juss.) Muell.-Arg. (plants producing exudates/timber trees)
Siphonia brasiliensis Willd. ex A.L. Juss.
Hibiscus acetosella Welwitsch ex Hiern (vegetables)
Hibiscus eetveldianus De Wild. & Th. Durand
Hibiscus floccosus Mast. (timber trees)
Hibiscus indicus (Burm.f.) Hochr. (ornamental plants)
Hibiscus venustus Blume
Hibiscus mutabilis L. (medicinal and poisonous plants)
Hibiscus rosa-sinensis L. (medicinal and poisonous plants)
Hibiscus surattensis L. (vegetables)
Homalanthus longistylus Lauterb. & K. Schumann (medicinal and poisonous plants)
Homalanthus papuanus Pax & K. Hoffm.
Homalanthus novoguineensis (Warb.) K. Schumann (medicinal and poisonous plants)
Homalanthus beguinii J.J. Smith
Homalanthus crinitus Gage
Homalanthus tetrandus J.J. Smith
Homalanthus populneus (Geiseler) Pax (medicinal and poisonous plants)
Homalanthus populifolius auct. non Graham
Homalomena philippinensis Engl. (medicinal and poisonous plants)
Homonoia riparia Lour. (auxiliary plants)
Adelia neriifolia Heyne ex Roth
Lumanaja fluviatilis Blanco
Ricinus salicinus Hassk.
Honckenya ficifolia Willd. (ornamental plants)
Hopea altocollina P. Ashton (timber trees)
Hopea bracteata Burck (timber trees)
Hopea mengarawan Miq. (timber trees)
Hopea pubescens Ridley (timber trees)
Hydnocarpus anthelmintica Pierre ex Lanessan (timber trees/medicinal and poisonous plants)
Hydnocarpus alpina Wight var. *elongata* Boerl.
Hydnocarpus alpina Wight var. *macrocarpa* Boerl.
Hymenodictyon orixense (Roxb.) Mabberley (timber trees)

Cinchona excelsa Roxb.
Cinchona orixensis Roxb.
Hymenodictyon excelsum (Roxb.) Wallich ex Roxb.
Imperata conferta (J.S. Presl) Ohwi (medicinal and poisonous plants)
Imperata exaltata (Roxb.) Brongn.
Saccharum confertum J.S. Presl
Imperata cylindrica (L.) Raeuschel (forages/medicinal and poisonous plants)
Imperata arundinacea Cyr.
Lagurus cylindricus L.
Ipomoea pes-caprae (L.) R. Br. (medicinal and poisonous plants)
Convolvulus pes-caprae L.
Ipomoea biloba Forssk.
Ipomoea maritima (Desr.) R. Br.
Irvingia malayana Oliv. ex A.W. Bennett (timber trees)
Irvingia harmandiana Pierre
Irvingia longipedicellata Gagnep.
Irvingia oliveri Pierre
Jasminum subtriplinerve Blume (medicinal and poisonous plants)
Jatropha curcas L. (medicinal and poisonous plants)
Curcas indica A. Rich
Curcas purgans Medik.
Jatropha afrocurcas Pax
Jessenia bataua (Mart.) Burret (vegetable oils and fats)
Jessenia polycarpa Karsten
Jessenia repanda Engel
Oenocarpus bataua Mart.
Kleinhovia hospita L. (auxiliary plants)
Koordersiodendron pinnatum (Blanco) Merr. (timber trees)
Koordersiodendron celebicum Engl.
Koordersiodendron papuanum Kaneh. & Hatus.
Lannea speciosa (Blume) Engl. ex Perk.
Korthalsia cheb Becc. (rattans)
Korthalsia echinometra Becc. (rattans)
Korthalsia flagellaris Miquel (rattans)
Korthalsia laciniosa Griff. ex Mart. (rattans)
Korthalsia grandis Ridley
Korthalsia rigida Blume (rattans)
Korthalsia robusta Blume (rattans)
Korthalsia macrocarpa Becc.
Korthalsia rostrata Blume (rattans)
Korthalsia scaphigera Griff. ex Mart.
Lactuca indica L. (vegetables)
Lactuca brevirostris Champ. ex Benth.
Lannea coromandelica (Houtt.) Merr. (ornamentals)
Lannea grandis (Dennst.) Engl.
Latania loddigesii Martius (ornamental plants)
Latania lontaroides (J. Gaertner) H.E. Moore (ornamental plants)
Latania commersonii J.F. Gmelin
Latania verschaffeltii Lemaire (ornamental plants)

Laurus nobilis L. (spices)
Laurus undulata Miller
Lawsonia inermis L. (dye and tannin-producing plants)
Lawsonia alba Lamk
Lawsonia spinosa L.
Leucaena leucocephala (Lamk) de Wit (forages/auxiliary plants)
Leucaena glauca (Willd.) Benth.
Leucaena latisiliqua (L.) Gillis
Leucosyke capitellata (Poir.) Wedd. (medicinal and poisonous plants)
Libocedrus papuana F. v. Mueller (timber trees)
Libocedrus torricellensis Schlechter ex Lauterb.
Papuacedrus papuana (F. v. Mueller) Li
Papuacedrus torricellensis (Schlechter ex Lauterb.) Li
Licuala acutifida Mart. (timber trees)
Licuala paludosa Griffith (timber trees)
Licuala amplifrons Miq.
Licuala paniculata Ridley
Licuala pumila Blume (stimulants)
Licuala elegans Blume
Licuala rumphii Blume (stimulants)
Licuala spinosa Wurmb (timber trees)
Litsea glutinosa (Lour.) C.B. Robinson (timber trees)
Litsea chinensis Lamk
Litsea geminata Blume
Litsea glabraria A.L. Juss.
Litsea tetranthera (Willd.) Pers.
Livistona merrillii Becc. (timber trees)
Livistona whitfordii Becc.
Livistona robinsoniana Becc. (timber trees)
Livistona rotundifolia (Lamk) Mart. (timber trees)
Livistona blancoi Merr.
Livistona saribus (Lour.) Merr. ex A. Chev. (timber trees)
Livistona cochinchinensis Mart.
Livistona inaequisecta Becc.
Livistona spectabilis Griffith
Lophopyxis maingayi Hook.f. (medicinal and poisonous plants)
Lophopyxis pentaptera (K. Schumann) Engl.
Lophopyxis pierrei Boerl.
Loxogramme scolopendrina (Bory) C. Presl. (cryptogams)
Anthrophyum involutum Blume
Grammitis scolopendrina Bory
Loxogramme involuta auct. non (D. Don) C. Presl.
Luffa acutangula (L.) Roxb. (vegetables)
Cucumis acutangulus L.
Luffa aegyptiaca P. Miller (vegetables)
Luffa cylindrica (L.) M.J. Roemer sensu auct.
Momordica cylindrica L.
Momordica luffa L.
Lycopodiella cernua (L.) Pic. Serm. (cryptogams)

Lepidotis cernua (L.) P. Beauv.
Lycopodium cernuum L.
Palhinhaea cernua (L.) Vasc. & Franco
Lygodium auriculatum (Willd.) Alston (cryptogams)
Lygodium circinnatum (Burm.f.) Swartz var. *semihastatum* Fosb.
Lygodium semihastatum Desv.
Lygodium circinnatum (Burm.f.) Swartz (cryptogams)
Lygodium basilanicum Christ.
Lygodium dichotomum (Cav.) Swartz
Lygodium pedatum (Burm.f.) Swartz
Lygodium flexuosum (L.) Swartz (cryptogams)
Lygodium pinnatifidum Swartz
Lygodium serrulatum Blume
Lygodium japonicum (Thunb.) Swartz (cryptogams)
Lygodium dissectum Desv.
Lygodium mearnsii Copel.
Lygodium tenue Blume
Lygodium microphyllum (Cav.) R. Br. (cryptogams)
Lygodium scandens Swartz
Macaranga gigantea (Reichenb.f. & Zoll.) Müll. Arg. (timber trees/medicinal and poisonous plants)
Macaranga incisa Gage
Macaranga megalophylla (Müll. Arg.) Müll. Arg.
Macaranga mappa (L.) Müll. Arg. (timber trees)
Macaranga tanarius (L.) Muell. Arg. (dye and tannin-producing plants/timber trees)
Macaranga molliuscula Kurz
Macaranga tomentosa Blume
Mappa tanarius (L.) Blume
Maesopis eminii Engler (auxiliary plants)
Maesopis berchemioides (Pierre) A. Chev.
Mallotus paniculatus (Lamk) Müll. Arg. (timber trees/medicinal and poisonous plants)
Croton appendiculatus Elmer
Croton paniculatus Lamk
Mallotus cochinchinensis Lour.
Mallotus philippensis (Lamk) Muell. Arg. (dye and tannin-producing plants/timber trees/medicinal and poisonous plants)
Croton philippense Lamk
Mallotus reticulatus Dunn
Rottlera tinctoria Roxb.
Maranta arundinacea L. (plants yielding non-seed carbohydrates)
Maranta sylvatica Roscoe ex J.E. Smith
Marsdenia tinctoria R. Br.(dye and tannin-producing plants)
Asclepias tinctoria Roxb.
Melaleuca cajuputi Powell (essential-oil plants)
Melaleuca leucadendron (L.) L. var. *minor* (Smith) Duthie
Melaleuca minor Smith
Myrtus saligna Burm.f.

Melaleuca quinquenervia (Cav.) S.T. Blake (essential-oil plants)
Melaleuca viridiflora Sol. ex Gaertner var. *angustifolia* (L.f.) N.B. Byrnes, non Blume
Melaleuca viridiflora Sol. ex Gaertner var. *rubriflora* Brong. & Gris
Metrosideros quinquenervia Cav.
Melocalamus compactiflorus (Kurz) Benth. (bamboos)
Melocanna baccifera (Roxb.) Kurz (bamboos)
Bambusa baccifera Roxb.
Melocanna bambusoides Trin.
Melochia corchorifolia L. (medicinal and poisonous plants)
Melochia concatenata L.
Melochia umbellata (Houtt.) O. Stapf (ornamental plants)
Melodinus orientalis Blume (plants producing exudates)
Merremia mammosa (Lour.) Hallier f. (medicinal and poisonous plants)
Convolvulus mammosus Lour.
Ipomoea gomezii Clarke
Merremia peltata (L.) Merr. (medicinal and poisonous plants)
Convolvulus peltatus L.
Merremia nymphaeifolia H. Hallier
Metroxylon sagu Rottboell (plants yielding non-seed carbohydrates)
Metroxylon rumphii Mart.
Metroxylon squarrosum Becc.
Metroxylon salomonense (Warburg) Becc. (plants yielding non-seed carbohydrates)
Coelococcus salomonensis Warburg
Metroxylon bougainvillense Becc.
Metroxylon vitiense (H.A. Wendland) Becc. (plants yielding non-seed carbohydrates)
Coelococcus vitiensis H.A. Wendland
Sagus vitiensis H.A. Wendland
Metroxylon warburgii (Heim) Becc. (plants yielding non-seed carbohydrates)
Coelococcus warburgii Heim
Metroxylon upoluense Becc.
Microcos paniculata L. (stimulants)
Grewia glabra Jack
Grewia microcos L.
Grewia ulmifolia Roxb.
Millingtonia hortensis L.f. (ornamental plants)
Mnesithea rottboellioides (R.Br.) Koning & Sosef (forages)
Rottboellia ophiurioides Benth.
Morinda umbellata L. (medicinal and poisonous plants)
Moringa oleifera Lamk (vegetables)
Guilandina moringa L.
Moringa polygona DC.
Moringa pterygosperma Gaertner
Morus alba L. (medicinal and poisonous plants/timber trees)
Morus atropurpurea Roxb.
Morus indica L.
Morus morettiana Jacq. ex Burr.

Morus macrophylla Moretti
Morus nervosa Deless. ex Spach
Muntingia calabura L. (edible fruits and nuts)
Musa L. (edible cultivars) (edible fruits and nuts)
Musa acuminata Colla (plants producing exudates)
Musa malaccensis Ridl.
Musa truncata Ridl.
Musa zebrina Van Houtte ex Planchon
Musa salaccensis Zoll. (vegetables)
Myrialepis paradoxa (Kurz) J. Dransfield (rattans)
Myrialepis scortechinii Becc.
Nelumbo nucifera Gaertner (plants yielding non-seed carbohydrates)
Nelumbium nelumbo (L.) Druce
Nelumbium speciosum Willd.
Nymphaea nelumbo L.
Neonauclea hagenii (Lauterb. & K. Schumann) Merr. (timber trees)
Nauclea hagenii (Lauterb. & K. Schumann)
Neonauclea dahlii (Valeton) Merr. & L.M. Perry
Neonauclea papuana (Valeton) Merr. & L.M. Perry
Nephrolepis hirsutula (Forst.) C. Presl (cryptogams)
Nephrolepis exaltata (L.) Schott var. *hirsutula* (Forst.) Baker
Polypodium hirsutulum Forst.
Nyctanthes arbor-tristis L. (dye and tannin-producing plants)
Nyctanthes dentata Blume
Nypa fruticans Wurmb (plants yielding non-seed carbohydrates)
Cocos nypa Lour.
Nipa fruticans Thunb.
Nipa litoralis Blanco
Ochroma pyramidale (Cav. ex Lamk) Urban (timber trees)
Ochroma bicolor Rowlee
Ochroma grandiflora Rowlee
Ochroma lagopus Sw.
Octomeles sumatrana Miq. (timber trees)
Octomeles moluccana Teijsm. & Binnend. ex Hassk.
Omalanthus populneus (Geiseler) Pax (dye and tannin-producing plants)
Homalanthus populifolius (Reinw.) Hook.f., non *Omalanthus populifolius* Graham
Homalanthus populneus (Geiseler) Pax
Omalanthus leschenaultianus A.H.L. Jussieu
Oncosperma tigillarium (Jack) Ridley (timber trees)
Oncosperma filamentosum Blume
Operculina turpethum (L.) S. Manso (medicinal and poisonous plants)
Convolvulus turphetum L.
Ipomoea anceps Roem. & Schult.
Ophiurus exaltatus (L.) O. Kuntze (forages)
Orchidantha fimbriatum Holttum (medicinal and poisonous plants)
Orchidantha longiflora auct. non (Scort.) Ridley
Oryza sativa L. (cereals)
Oryza aristata Blanco

Oryza glutinosa Lour.
Oryza montana Lour.
Oryza praecox Lour.
Osbornia octodonta F. v. Mueller (timber trees)
Paederia foetida L. (medicinal and poisonous plants)
Paederia chinensis Hance
Paederia scandens (Lour.) Merr.
Paederia tomentosa Blume
Pandanus amaryllifolius Roxb. (spices)
Pandanus hasskarlii Merrill
Pandanus latifolius Hassk.
Pandanus odorus Ridley
Panicum miliaceum L. cv. group Proso Millet (cereals)
Panicum miliaceum L. subsp. *miliaceum* sensu Tsvelev
Paraserianthes falcataria (L.) Nielsen (auxiliary plants/timber trees)
Albizia falcata sensu Backer
Albizia falcataria (L.) Fosberg
Albizia moluccana Miq.
Parkinsonia aculeata L. (ornamental plants)
Pennisetum glaucum (L.) R. Br. (cereals)
Pennisetum americanum (L.) Leeke
Pennisetum typhoides (Burm.f.) Stapf & Hubbard
Pennisetum polystachion (L.) Schultes (forages)
Panicum polystachion L.
Pennisetum atrichum Stapf & Hubbard
Pennisetum setosum (Swartz) L. Rich.
Pennisetum subangustum (Schum.) Stapf & Hubbard
Pentace corneri Kosterm. (timber trees)
Pentace triptera Masters (timber trees)
Pericampylus glaucus (Lamk) Merr. (medicinal and poisonous plants)
Cocculus glaucus (Lamk) DC.
Pericampylus incanus (Colebr.) Hook.f. & Thomson
Pericampylus membranaceus Miers
Petersianthus quadrialatus (Merr.) Merr. (timber trees)
Combretodendron quadrialatum (Merr.) Knuth
Phaeanthus splendens Miq. (medicinal and poisonous plants)
Phaeanthus crassipetalus Becc.
Phaeanthus lucidus Oliver
Phalaris arundinacea L. (forages)
Phoenix dactylifera L. (edible fruits and nuts)
Phoenix humilis Royle (ornamental plants)
Phoenix sylvestris (L.) Roxb. (plants yielding non-seed carbohydrates)
Elate sylvestris L. p.p.
Pholidocarpus ihur (Giseke) Blume (plants yielding non-seed carbohydrates/timber trees)
Borassus ihur Giseke
Pholidocarpus macrocarpus Becc. (timber trees)
Pholidocarpus majadum Becc. (timber trees)
Phragmites australis (Cav.) Trin. ex Steudel (auxiliary plants)

Phragmites communis Trin.
Phragmites vulgaris (Lamk) Crépin
Pigafetta elata (Blume) H. Wendl. (timber trees)
Pigafetta filaris (Giseke) Becc. (timber trees)
Pigafetta filifera Merr.
Pigafetta papuana Becc.
Pinanga punicea Merr. (timber trees)
Pinanga ternatensis R. Scheffer
Pinus caribaea Morelet (timber trees)
Pinus kesiya Royle ex Gordon (timber trees/plants producing exudates)
Pinus insularis Endl.
Pinus khasya Hook.f.
Pinus merkusii Junghuhn & de Vriese (timber trees/plants producing exudates)
Pinus merkusiana Cooling & Gaussen
Pinus sumatrana Junghuhn
Pinus oocarpa Schiede ex Schlechtendal (timber trees)
Pinus patula Schlechtendal & Chamisso (timber trees)
Pinus subpatula Roezl ex Gordon
Pipturus argenteus (J.G. Forster) Wedd. (medicinal and poisonous plants)
Pipturus incanus (Blume) Wedd.
Pipturus propinquus (Decne.) Wedd.
Pipturus velutinus (Decne.) Wedd.
Urtica argentea J.G. Forster
Plagiostachys crocydocalyx (K. Schumann) Burtt & Smith (vegetables)
Alpinia crocydocalyx K. Schumann
Languas crocydocalyx (K. Schumann) Merr.
Plectocomiopsis geminiflora (Griff.) Becc. (rattans)
Poikilospermum suaveolens (Blume) Merr. (stimulants)
Conocephalus suaveolens Blume
Conocephalus violaceus (Blanco) Merr.
Poikilospermum amoenum (King ex Hook.f.) Merr.
Polyalthia hypoleuca Hook.f. & Thomson (timber trees/medicinal and poisonous plants)
Polyalthia sumatrana (Miq.) Kurz (timber trees)
Monoon sumatranum (Miq.) Miq.
Polyscias scutellaria (Burm.f.) Fosb. (ornamental plants)
Nothopanax scutellarium (Burm.f.) Merr.
Pongamia pinnata (L.) Pierre (auxiliary plants)
Derris indica (Lamk) J.J. Bennett
Millettia novo-guineensis Kanehira & Hatusima
Pongamia glabra Ventenat
Pothos scandens L. (medicinal and poisonous plants)
Pothos hermaphroditus (Blanco) Merr.
Pothos zollingerianus Schott
Pouteria firma (Miq.) Baehni (timber trees)
Planchonella firma (Miq.) Dubard
Pouzolzia hirta (Blume) Hassk. (medicinal and poisonous plants)
Gonostegia hirta (Blume) Miq.
Memorialis hirta (Blume) Wedd.

Pouzolzia quinquenervis Benn.
Premna serratifolia L. (timber trees/medicinal and poisonous plants)
Premna corymbosa Rottl. & Willd.
Premna foetida Reinw. ex Blume
Premna integrifolia L.
Premna obtusifolia R. Br.
Prumnopitys amara (Blume) de Laubenf. (timber trees)
Podocarpus amara Blume
Podocarpus eurhyncha Miq.
Stachycarpus amara (Blume) Gaussen
Sundacarpus amara (Blume) C.N. Page
Prunus arborea (Blume) Kalkman (timber trees)
Pygeum arboreum (Blume) Blume
Pygeum parviflorum Teijsm. & Binnend.
Pygeum stipulaceum King
Prunus beccarii (Ridley) Kalkman (timber trees)
Pteridium aquilinum (L.) Kuhn (cryptogams)
Pteridium esculentum (Forst.) Nakai
Pteris aquilina L.
Pteris esculenta Forst.
Pteris moluccana Blume (cryptogams)
Pterocymbium tinctorium (Blanco) Merr. (timber trees)
Pterocymbium columnare Pierre
Pterocymbium javanicum R. Br.
Pterocymbium viridiflorum Koord.
Pterospermum celebicum Miq. (timber trees)
Pterospermum niveum S. Vidal
Pterospermum diversifolium Blume (timber trees)
Pterospermum acerifolium auct. non (L.) Willd.
Pueraria montana (Lour.) Merr. (medicinal and poisonous plants/plants yielding non-seed carbohydrates)
Dolichos montanus Lour.
Pueraria hirsuta (Thunb.) Matsumura
Pueraria lobata (Willd.) Ohwi
Pueraria thomsonii Bentham
Pueraria thunbergiana (Sieb. & Zucc.) Benth.
Pueraria tonkinensis Gagnepain
Pueraria triloba (Houtt.) Makino
Pueraria phaseoloides (Roxb.) Benth. (forages/auxiliary plants)
Dolichos phaseoloides Roxb.
Pueraria javanica (Benth.) Benth.
Pueraria phaseoloides Roxb. var. *javanica* (Benth.) Baker
Quisqualis indica L. (medicinal and poisonous plants)
Quisqualis glabra Burm.f.
Quisqualis pubescens Burm.f.
Quisqualis spinosa Blanco
Ravenala madagascariensis J.F. Gmelin (ornamental plants)
Rhapis excelsa (Thunberg ex Murray) A. Henry (ornamental plants)
Rhapis flabelliformis L'Héritier ex W. Aiton

Rhynchospora corymbosa (L.) Britton (auxiliary plants)
  Rhynchospora articulata (Roxb.) Roem. & Schultes
  Rhynchospora aurea Vahl
Rourea mimosoides (Vahl) Planchon (medicinal and poisonous plants)
  Santalodes concolor (Blume) O. Kuntze
  Santalodes mimosoides (Vahl) O. Kuntze
  Santalodes simile (Blume) O. Kuntze
Roystonea oleracea (N.J. Jacquin) O.F. Cook (ornamental plants)
Roystonea regia (Kunth) O.F. Cook (ornamental plants)
Saccharum officinarum L. (plants yielding non-seed carbohydrates)
Saccharum spontaneum L. (forages)
Salacca wallichiana C. Martius (edible fruits and nuts)
  Zalacca rumphii Wallich ex Blume
Salacca zalacca (Gaertner) Voss (edible fruits and nuts)
  Salacca edulis Reinw.
Salacia macrophylla Blume (edible fruits and nuts)
  Salacia flavescens Kurz
Sapindus saponaria L. (medicinal and poisonous plants)
  Sapindus microcarpus Jardin
  Sapindus mukorossi Gaertner
  Sapindus vitiensis A. Gray
Scaphium macropodum (Miq.) Beumée ex K. Heyne (timber trees)
  Scaphium affinis (Masters) Pierre
  Scaphium beccarianum Pierre
  Scaphium lychnophorum (Hance) Pierre
Scaphium scaphigerum (Wallich ex G. Don) Guibort & Planchon (timber trees)
  Scaphium wallichii Schott & Endl.
Schefflera heptaphylla (L.) Frodin (medicinal and poisonous plants)
  Schefflera octophylla (Lour.) Harms
  Vitis heptaphylla (L.)
Schima wallichii (DC.) Korth. (timber trees)
  Schima bancana Miq.
  Schima crenata Korth.
  Schima noronhae Reinw. ex Blume
Schizostachyum aciculare Gamble (bamboos)
Schizostachyum brachycladum (Munro) Kurz (bamboos)
Schizostachyum grande Ridley (bamboos)
Schizostachyum hantu S. Dransf. (bamboos)
Schizostachyum latifolium Gamble (bamboos)
  Ochlandra ridleyi Gamble
  Schizostachyum longispiculatum (Kurz ex Munro) Kurz sensu Holttum
  Schizostachyum ridleyi (Gamble) Holttum
Schizostachyum lima (Blanco) Merr. (bamboos)
  Bambusa lima Blanco
  Schizostachyum hallieri Gamble
Schizostachyum lumampao (Blanco) Merr. (bamboos)
  Bambusa lumampao Blanco
Schizostachyum zollingeri Steudel (bamboos)
  Schizostachyum chilianthum Kurz sensu Gamble

Schoutenia ovata Korth. (timber trees)
- *Actinophora fragrans* Wallich ex R. Br.
- *Actinophora hypoleuca* (Pierre) Kuntze
- *Schoutenia hypoleuca* Pierre

Scleria poaeformis Retz. (medicinal and poisonous plants)
- *Scleria oryzoides* Presl

Secale cereale L. (cereals)

Sechium edule (Jacq.) Swartz (vegetables)
- *Chayota edulis* Jacq.
- *Sechium americanum* Poiret
- *Sicyos edulis* Jacq.

Selaginella intermedia (Blume) Spring (cryptogams)
- *Selaginella ascendens* Alderw.
- *Selaginella atroviridis* (Wall.) Spring
- *Selaginella plumea* Spring

Selaginella usteri Hieron. (cryptogams)

Sesbania bispinosa (Jacq.) W.F. Wight (auxiliary plants)
- *Aeschynomene aculeata* Schreb.
- *Aeschynomene bispinosa* Jacq.
- *Sesbania aculeata* (Willd.) Pers.

Sesbania cannabina (Retz.) Poiret (auxiliary plants)
- *Aeschynomene cannabina* Retz.
- *Sesbania australis* F. Mueller

Sesbania grandiflora (L.) Poiret (forages)
- *Aeschynomene grandiflora* (L.) L.
- *Agati grandiflora* (L.) Desv.
- *Robinia grandiflora* L.

Sesbania sericea (Willd.) Link (auxiliary plants)
- *Coronilla sericea* Willd.
- *Sesbania polyphylla* Miq.
- *Sesbania pubescens* DC.

Sesbania sesban (L.) Merrill (forages)
- *Aeschynomene sesban* L.
- *Sesbania aegyptiaca* Poiret

Shorea balangeran (Korth.) Burck (timber trees)
- *Hopea balangeran* Korth.
- *Parashorea balangeran* (Korth.) Merr.

Shorea macroptera Dyer (timber trees)
- *Shorea bailloni* Heim
- *Shorea sandakanenis* Sym.

Shorea ovalis (Korth.) Blume (timber trees)
- *Shorea eximia* (Miq.) R. Scheffer
- *Shorea rigida* Brandis
- *Shorea sericea* Dyer

Sida acuta Burm.f. (medicinal and poisonous plants)
- *Sida carpinifolia* (non L.f.) Mast.

Sida cordifolia L. (medicinal and poisonous plants)

Sida rhombifolia L. (medicinal and poisonous plants)
- *Sida retusa* L.

Sindora siamensis Teijsm. ex Miq. (timber trees)
    Sindora cochinchinensis Baillon
Smilax china L. (medicinal and poisonous plants)
Smilax zeylanica L. (plants yielding non-seed carbohydrates)
    Smilax australis R.Br. sensu Heyne and Burkill
Sonneratia caseolaris (L.) Engl. (vegetables/timber trees)
    Rhizophora caseolaris L.
    Sonneratia acida L.f.
    Sonneratia obovata Blume
Sonneratia ovata Backer (auxiliairy plants)
    Sonneratia alba auct., non J. Smith
Sorghum bicolor (L.) Moench (cereals)
    Andropogon sorghum (L.) Brot.
    Holcus bicolor L.
    Sorghum vulgare Pers.
Sorghum halepense (L.) Pers. (forages)
    Andropogon halepensis Brot.
Spathodea campanulata P. Beauvois (ornamental plants)
Spatholobus ferrugineus (Zoll. & Moritzi) Benth. (medicinal and poisonous plants)
    Butea ferruginea (Zoll. & Moritzi) Blatter
Spathoglottis plicata Blume (ornamental plants)
Spiridens reinwardtii Nees (cryptogams)
    Spiridens longifolius Lindb.
Spondias pinnata (Koenig ex L.f.) Kurz (spices)
    Mangifera pinnata Koenig ex L.f.
    Spondias amara Lamk
    Spondias mangifera Willd.
Stenochlaena palustris Bedd. (cryptogams)
    Acrostichum scandens (Swartz) Hook.
    Polypodium palustre Burm.f.
Sterculia ceramica R.Br. (timber trees)
    Sterculia glabrifolia Merr.
    Sterculia luzonica Warb.
Sterculia comosa Wallich (timber trees)
    Sterculia keyensis K. Schumann
    Sterculia philippinensis Merr.
    Sterculia ramosii Merr.
Sterculia foetida L. (timber trees)
    Sterculia polyphylla R. Br.
Sterculia macrophylla Vent. (timber trees)
    Sterculia crassiramea Merr.
    Sterculia oncinocarpa F. v. Mueller & Forbes
    Sterculia pachyclados K. Schumann
    Sterculia parkinsonii F. v. Mueller
Sterculia oblongata R. Br. (edible fruits and nuts/timber trees)
    Sterculia forbesii Warb.
    Sterculia kunstleri King
    Sterculia spectabilis Miq.
    Sterculia urceolata auct. non J.E. Smith

Streblus asper Lour. (medicinal and poisonous plants/timber trees)
 Diplothorax tonkinensis Gagnep.
 Streblus monoicus Gagnep.
Streptocaulon baumii J. Decne. (medicinal and poisonous plants)
Strychnos minor Dennst. (medicinal and poisonous plants)
 Strychnos colubrina auct. non L.
 Strychnos laurina Wallich ex DC.
 Strychnos multiflora Benth.
Styphelia malayana (Jack) Sprengel (medicinal and poisonous plants)
 Leucopogon malayanus Jack
Styrax tonkinensis (Pierre) Craib ex Hartwich (plants producing exudates)
 Anthostyrax tonkinense Pierre
 Styrax hypoglaucus Perkins
 Styrax macrothyrsus Perkins
Swintonia floribunda Griffith (timber trees)
Syzygium palembanicum Miq. (timber trees)
 Eugenia grandis Wight var. *lepidocarpa* Kurz
 Eugenia lepidocarpa Wallich ex Kurz
 Eugenia palembanica (Miq.) Merr.
Tacca leontopetaloides (L.) Kuntze (plants yielding non-seed carbohydrates)
 Tacca involucrata (Limpr.) Schum. & Thonn.
 Tacca pinnatifida J.R. & G. Forster
 Tacca viridis Hemsley
Talipariti macrophyllum (Roxb. ex Hornem.) Fryxell (timber trees)
 Hibiscus macrophyllus Roxb. ex Hornem.
 Hibiscus spathaceus Nees & Blume
 Hibiscus vestitus Griffith
 Triplochiton spathacea (Nees & Blume) Alefeld
Talipariti tiliaceum (L.) Fryxell (timber trees/medicinal and poisonous plants)
 Hibiscus tiliaceus L.
 Hibiscus celebicus Koord.
 Hibiscus hastatus L.f.
 Hibiscus similis Blume
Terminalia brassii Exell (timber trees)
 Terminalia kajewskii Exell
Terminalia calamansanai (Blanco) Rolfe (timber trees)
 Terminalia blancoi Merr.
 Terminalia latialata C.T. White
 Terminalia pyrifolia (Presl) Kurz
Tetracera indica (Houtt. ex Christm. & Panz.) Merr. (medicinal and poisonous plants)
 Assa indica Houtt. ex Christm. & Panz.
 Tetracera assa DC.
 Tetracera dichotoma Blume
Tetracera sarmentosa (L.) Vahl (medicinal and poisonous plants)
 Delima sarmentosa L.
 Tetracera asiatica (Lour.) Hoogl.
Tetracera scandens (L.) Merr. (medicinal and poisonous plants)
 Tetracera hebecarpa (DC.) Boerl.

Tetracera monocarpa Blanco
Tragia scandens L.
Tetrameles nudiflora R. Br. (timber trees)
Tetrameles grahamiana Wight
Tetrameles horsfieldii Steud.
Tetrastigma harmandii Planchon (edible fruits and nuts)
Thaumatococcus daniellii (Bennet) Benth. (spices)
Donax daniellii (Bennet) Roberty
Monostiche daniellii (Bennet) Horan
Phrynium daniellii Bennet
Themeda gigantea (Cav.) Hackel (forages)
Thespesia populnea (L.) Soland. ex Corrêa (auxiliary plants/timber trees)
Hibiscus bacciferus J.G. Forster
Hibiscus populneoides Roxb.
Hibiscus populneus L.
Malvaviscus populneus (L.) Gaertn.
Thespesia macrophylla Blume
Thrinax argentea Loddiges (ornamental plants)
Thrinax barbadensis Loddiges (ornamental plants)
Thrinax parviflora O. Swartz (ornamental plants)
Thyrsostachys siamensis Gamble (bamboos)
Thyrsostachys regia (Munro) Bennet
Thysanolaena latifolia (Roxb. ex Hornem.) Honda (forages)
Agrostis maxima Roxb.
Melica latifolia Roxb. ex Hornem.
Thysanolaena maxima (Roxb.) Kuntze
Tiliacora triandra (Colebr.) Diels (medicinal and poisonous plants)
Cocculus triandrus Colebr.
Limacia triandra (Colebr.) Hook.f. & Thomson
Trema orientalis (L.) Blume (auxiliary plants)
Celtis orientalis L.
Sponia orientalis (L.) Decne
Trema guineensis (Schumach. & Thonn.) Ficalho
Trichospermum discolor Elmer (timber trees)
Trichospermum mindanaense Merr. ex Elmer
Trichospermum involucratum (Merr.) Elmer (timber trees)
Halconia involucrata Merr.
Trichospermum cuneata Elmer
Trichospermum negrosense (Elmer) Elmer
Triticum aestivum L. (cereals)
Triticum cereale Schrank
Triticum sativum Lamk
Triticum vulgare Vill.
Triumfetta bartramia L. (medicinal and poisonous plants)
Triumfetta rhomboidea Jacq.
Tylophora indica (Burm.f.) Merr. (medicinal and poisonous plants)
Tylophora asthmatica (L.f.) Wight & Arnott ex Wight
Uvaria purpurea Blume (medicinal and poisonous plants/edible fruits and nuts)

Uvaria grandiflora Roxb. ex Wallich
Uvaria littoralis (Blume) Blume (edible fruits and nuts)
Ventilago madraspatana Gaertner (dye and tannin-producing plants/medicinal and poisonous plants)
Vetiveria zizanioides (L.) Nash (essential-oil plants)
Andropogon muricatus Retzius
Andropogon zizanioides (L.) Urban
Phalaris zizanioides L.
Vitex negundo L. (medicinal and poisonous plants)
Vitex incisa Lamk
Vitex leucoxylon Blanco
Vitex paniculata Lamk
Waltheria indica L. (medicinal and poisonous plants)
Waltheria americana L.
Wikstroemia tenuiramis Miquel (essential-oil plants)
Wikstroemia acuminata Merrill
Wikstroemia clementis Merrill
Willughbeia angustifolia (Miquel) Markgraf (plants producing exudates)
Willughbeia apiculata Miq.
Willughbeia elmeri Merr.
Willughbeia rufescens Dyer ex Hook.f.
Xanthosoma nigrum (Vell.) Mansfeld (plants yielding non-seed carbohydrates)
Arum nigrum Vell.
Xanthosoma ianthinum K. Koch
Xanthosoma violaceum Schott
Xylopia ferruginea (Hook.f. & Thomson) Hook.f. & Thomson (timber trees)
Xylopia altissima Boerl.
Xylopia oxyantha Hook.f. & Thomson
Yucca filamentosa L. (ornamental plants)
Zanthoxylum armatum DC. (spices)
Zanthoxylum alatum Roxb.
Zanthoxylum planispinum Sieb. & Zucc.
Zanthoxylum integrifoliolum (Merr.) Merr. (timber trees)
Zea mays L. (cereals)
Zizania latifolia (Griseb.) Turcz. ex Stapf (vegetables)
Hydropyrum latifolium Griseb.
Limnochloa caduciflora Turcz. ex Trinius
Zizania caduciflora (Trinius) Handel-Mazzetti

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Acronyms of organizations

- BJRI: Bangladesh Jute Research Institute (Dhaka, Bangladesh).
- CAAS: Chinese Academy of Agricultural Sciences (Beijing, China).
- CATIE: Centro Agronómico Tropical de Investigación y Enseñanza (Turrialba, Costa Rica).
- CGN: Centrum Genetische Bronnen Nederland (Wageningen, the Netherlands).
- CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement (Paris, France).
- CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora (Lausanne, Switzerland).
- CNPA: Centro Nacional de Pesquisa de Algodão (Campina Grande, Brazil).
- CNSF: Centre National de Semences Forestières (Ouagadougou, Burkina Faso).
- CODA: Cotton Development Authority (Pasig City, the Philippines).
- CRIJAF: Central Research Institute for Jute and Allied Fibres (Barakpur, India).
- CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia).
- DGIS: Directorate-General for International Cooperation of the Netherlands Ministry of Foreign Affairs (Den Haag, the Netherlands).
- EU: European Union (Brussels, Belgium).
- FAL: Bundesforschungsanstalt für Landwirtschaft (Braunschweig, Germany).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- FIDA: Fibre Industry Development Authority (Quezon City, the Philippines).
- FPRDI: Forest Products Research and Development Institute (College, Laguna, the Philippines).
- FRIM: Forest Research Institute Malaysia (Kepong, Malaysia).
- IAC: Instituto Agronômico de Campinas (Campinas, São Paulo, Brazil).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- INRA: Institut National de la Recherche Agronomique (Paris, France).
- IPB: Institute of Plant Breeding, University of the Philippines Los Baños (Los Baños, the Philippines).
- IPGRI (formerly IBPGR): International Plant Genetic Resources Institute (Rome, Italy).
- IPK: Institute for Plant Genetics and Crop Plant Research (Gatersleben, Germany).
- IRD (formerly ORSTOM): Institut de Recherche pour le Développement (Montpellier, France).

- ITOFCRI: Indonesian Tobacco and Fibre Crops Research Institute (formerly RITFC: Research Institute for Tobacco and Fibre Crops) (Malang, Indonesia).
- JARI: Jute Agricultural Research Institute (Barakpur, India).
- LIPI: Lembaga Ilmu Pengetahuan Indonesia [Indonesian Institute of Sciences] (Jakarta, Indonesia).
- MARDI: Malaysian Agricultural Research and Development Institute (Serdang, Malaysia).
- MINT: Malaysian Institute for Nuclear Technology (Kajang, Malaysia).
- NARC: National Abaca Research Centre (Baybay, Leyte, the Philippines).
- NARS: National Agricultural Research System.
- NBPGR: National Bureau of Plant Genetic Resources (New Delhi, India).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PGRC: Plant Gene Resources of Canada (Saskatoon, Canada).
- PICRI: Philippine Industrial Crops Research Institute (Kabacan, North Cotabato, the Philippines).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- PROTA: Plant Resources of Tropical Africa (Wageningen, the Netherlands).
- PTRI: Philippine Textile Research Institute (Taguig, Metro Manila, the Philippines).
- TAPPI: Technical Association of the Pulp and Paper Industry (Norcross, Georgia, United States).
- 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 Los Baños (Los Baños, the Philippines).
- UPM: Universiti Putra Malaysia (Serdang, Malaysia).
- USDA: United States Department of Agriculture (Washington DC, United States).
- USDA/ARS: United States Department of Agriculture, Agricultural Research Service (Beltsville, Maryland, United States).
- VIR: N.I. Vavilov Research Institute of Plant Industry (St Petersburg, Russia).
- WHO: World Health Organization (Geneva, Switzerland).
- WU (formerly WAU): Wageningen University (Wageningen, the Netherlands).
- WUR: Wageningen University and Research Centre (Wageningen, the Netherlands).

Glossary

α-cellulose: the portion of holocellulose that is insoluble in strong (17.5%) sodium hydroxide solution
abaxial: on the side facing away from the axis or stem (dorsal)
abortifacient: causing abortion; an agent that causes abortion
abscess: a swollen, inflamed area in body tissues, in which pus gathers
abscission: the natural detachment of leaves, branches, flowers or fruits
absolute: a highly concentrated, alcohol-soluble liquid, normally obtained by alcoholic extraction of concretes or pomades and considered to reflect most accurately the taste and odour of the original material
acaulescent: lacking a visible stem
accession: in germplasm collections: plant material of a particular collection, usually indicated with a number
accessory buds: those additional to the axillary and normal buds; more than one bud in an axil
accrescent: increasing in size with age
acetate pathway: the biosynthetical route which leads to acetate
achene: a small dry indehiscent one-seeded fruit
actinomorphic: radially symmetrical; applied to flowers which can be bisected in more than one vertical plane
aculeate: furnished with prickles; prickly
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
adaxial: on the side facing the axis (ventral)
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
adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems
aerenchyma: a spongy tissue having large thin-walled cells and large intercellular spaces, serving for aeration or floating tissue
aerial root: any root that grows above the ground
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
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
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 polythene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated
albumen: the nutritive material stored within the seed, and in many cases surrounding the embryo (endosperm)
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
allergenic: acting as an allergen; inducing allergy
allergic: pertaining to, caused by, affected with, or of the nature of allergy
allogamous: from allogamy, cross-fertilization
allopolyploid (alloploid): a polyploid with more than two sets of chromosomes, derived from different species; allotriploid with three sets, allotetraploid with four sets, etc.
allotetraploid: an alloploid produced when a hybrid between two species doubles its chromosome number (also mentioned:amphidiploid)
alternate: leaves, etc., inserted at different levels

along the stem, as distinct from opposite or whorled

amphidiploid (amphiploid): a polyploid with a complete set of chromosomes from each parent, usually produced by doubling the chromosome number in the first generation hybrid

amplexicaul: stem-clasping, when the base of a sessile leaf or a stipule is dilated at the base, and embraces the stem

anaemia: a condition in which the blood is deficient in red blood cells, in haemoglobin, or in total volume

analgesic: relieving pain; not sensitive to pain; an agent alleviating pain without causing loss of consciousness

androecium: the male element; the stamens as a unit of the flower

androgynophore: a column on which stamens and carpels are borne

androphore: a stalk supporting the androecium or stamens

annual: a plant which completes its life cycle in one year

annular: used of any organs disposed in a circle

annulate: ring-shaped

annulus: a ring or a ring-like part

anthelmintic: destructive to worms: a drug or agent that destroys worms

anther: the part of the stamen containing the pollen

antheriferous: bearing anthers

anthesis: the time the flower is expanded, or, more strictly, the time when pollination may take place

anthocyanins: glycosides of the anthocyanidins, often colouring plant parts blue or red

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

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

antihistamine: any of various compounds used for treating allergic reactions and cold symptoms presumably by inactivating histamine (antihistaminic)

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

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

antitussive: preventing or relieving cough; an agent that prevents or relieves cough

antrorse: directed upwards (opposed to retrorse)

aperient: a mild or gentle purgative; also called laxative

apetalous: without petals

apex (plural: apices): the tip or summit of an organ

aphrodisiac: stimulating sexual desire; a drug arousing the sexual instinct

apical: at the apex of any structure

apiculate: ending abruptly in a short point

apomict: an organism reproducing by apomixis

apomixis: reproduction by seed formed without sexual fusion (apomictic)

appendage: a part added to another; attached secondary or subsidiary part, sometimes projecting or hanging

appendix (botany): a name given to appendages of any kind, e.g. in *Araceae* the sterile top part of the spadix

appressed (adpressed): lying flat for the whole length of the organ

arachnoid: like a cobweb

arborescent: attaining the size or character of a tree

architectural model: model describing the branching habit of a tree as determined by the pattern of activity of axes, the pattern including timing, positioning and fate (e.g. terminating in an inflorescence) of active axes

aril: an expansion of the funicle enveloping the seed, arising from the placenta; sometimes occurring as a pulpy cover (arillus)

aristate: awned

armed: bearing some form of spines
article: a segment of a constricted pod or fruit
articulate: jointed, or with places where separation takes place naturally
articulation: a joint, popularly applied to nodes of grasses
ascendent, ascending: curving or sloping upwards
ascites: effusion and accumulation of serous fluid in the abdominal cavity
asexual: sexless; not involving union of gametes
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: an agent or substance causing constriction 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
attar: liquid perfume traditional in India; it carries the scent of an aromatic plant in a base of sandalwood or sesame oil
attenuate: gradually tapering
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
auct.: auctorum (Latin); of authors
auricle: a small lobe or ear
auriculate: eared, having auricles
awn: a bristle-like appendage, especially occurring on the glumes of grasses
axil: the upper angle between the leaf and the stem
axillary: arising from the axil
axis: the main or central line of development of a plant or organ
bamboos: a taxonomic group of plants comprising the tribe *Bambuseae* of the *Bambusoideae*, a subfamily of the *Gramineae*; living plants, or culms (stems) severed from plants of this group
bark: the tissue external to the vascular cambium collectively, being the secondary phloem, cortex and periderm
barkcloth: cloth made from the inner bark of trees such as wild breadfruit (*Artocarpus elasticus* Reinw. ex Blume) or paper mulberry (*Broussonetia papyrifera* (L.) L'Hér. ex Vent.)
basifixed: attached or fixed by the base
basionym: the synonym of a scientific name that supplies the epithet for the correct name
bast: the inner bark (phloem) of dicotyledonous plants
bast fibre: fibre obtained from the inner bark of woody plants
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
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
biennial: a plant which flowers, fruits and dies in its second year or season
bifid: forked, divided in two but not to the base
biliousness: a symptom complex with nausea, abdominal discomfort, headache and constipation, formerly attributed to excessive secretion of bile
binder twine: a single-strand yarn usually 3–4 mm in diameter and sufficiently stiff to perform on mechanical binders
bisexual: having both sexes present and functional in the same flower
blade: the expanded part, e.g. of a leaf or petal
bleaching: treatment of pulp with chemical agents to increase pulp brightness
blight: a general term applied to any of a wide range of unrelated plant diseases
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
bran: the husks or outer coats of ground cereals, separated from the flour by bolting
breaking length: the length at which the material, when hung up, will break under its own weight
breaking load: the weight at which a fibre or assembly of fibres breaks
breeding: the propagation of plants or animals to improve certain characteristics
brightness: the whiteness of pulp or paper on a scale from 0% (black) to 100%
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

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
bulbil: an aerial bulb or bud produced in a leaf axil or replacing the flower, which, on separation, is capable of propagating the plant
bulbous: having bulbs or having the form or function of a bulb
bullate: surface much blistered or puckered
bunch: cluster, growing together
bush: a low thick shrub without a distinct trunk
butt: the base of the trunk from which the roots spring
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
cabbage: of palms, a terminal bud of a palm tree that resembles a head of a cabbage and is eaten as a vegetable
caducous: falling off
calcareous: consisting of or containing chalk (calcium carbonate)
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
cambium (plural: cambia): a layer of nascent tissue between the wood and bark, adding elements to both
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
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
capitate: headed, like the head of a pin in some stigmas, or collected into compact head-like clusters as in some inflorescences
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 carbon dioxide; 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*
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
carding: combing and cleaning with a sharp-toothed instrument to disentangle fibres before spinning
carinate: keeled
carminative: relieving flatulence; an agent relieving flatulence and assuaging pain
carpel: one of the foliar units of a compound pistil or ovary; a simple pistil has only one carpel
cartilaginous: hard and tough
caryopsis: the fruit of a grass, in which the outer layer (testa) of the seed proper is fused to the ovary wall
catarrh: inflammation of the lining tissue of various organs, particularly of the nose, throat, and air passages, and characterized by an outpouring of mucus
caudate: with a tail-like appendage
cauliflorous: with the flowers borne on the trunk
cauline: belonging to the stem or arising from it
cellobiose: a disaccharide, consisting of two glu-

cose moieties in β-(1,4)-linkage, and forming the basic repeating unit of the polysaccharide cellulose; it is obtained by partial hydrolysis of cellulose

cellulose: a carbohydrate, being the material base of the cell wall; the residue when the hemicelluloses are extracted from the holocellulose; often referred to as α-cellulose

chalaza: the basal part of the ovule or seed where it is attached to the funicle and the point at which vascular tissues enter and spread into the ovule

chalcones: a subgroup of the flavonoids

channelled: grooved, hollowed out like a gutter

chartaceous: papery

chipboard: a fibreboard made from depulped wood chips

chlorosis: a disorder, shown by loss of colour

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

cigarette paper: well-formed tissue paper free of pinholes and having relatively high strength, stretchability, opacity and porosity

ciliate: with a fringe of hairs along the edge

ciliolate: fringed with small hairs

cincinnus (plural cincinni): a flower cluster wherein each successive flower arises in the axil of a bracteole borne on the stalk of the previous flower

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

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

coherent: the incorporation of one part with another, as the petals to form a tubular corolla

coiling: a weaving technique which involves sewing; a foundation material is coiled upwards and stitched into place; a pointed tool is used to pierce a hole in each coil; the sewing element is then threaded through the hole and sews that coil down to the coil below it

collar: the boundary between the above- and underground portions of the axis of a plant

collateral: standing side by side

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)

compound: in botany: of two or more similar parts in one organ, as in a compound leaf or compound fruit; in chemistry: a substance consisting of 2 or more elements combined chemically in fixed proportions; in perfumery: a perfume concentrate in which the ingredients of a perfume formula are mixed together

concave: hollow

confluent: blended into one, passing by degrees from one into the other

conical: having the shape of a cone (cone-shaped)

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)

contiguous: touching but not united, directly bordering

contraceptive: reducing the likelihood of or preventing conception; an agent that reduces the likelihood of or prevents conception

convex: having a more or less rounded surface

convolute: rolled, the margins overlapping (e.g. floral envelopes in the bud)

coppice: a small wood which is regularly cut at stated intervals; the new growth arising from the stools

cord: the product formed by twisting together 2 or more yarns

cordage: general term including threads, yarns, twines, cords, ropes and cables

cordate: heart-shaped, as seen at the base of a leaf, etc., which is deeply notched

cordiform: heart-shaped

core: central part; the seeds and integuments of a pome, such as an apple; pith in dicotyledonous plants

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

costa: a rib, when single, the midrib or vein

costapalmate: shaped like the palm of a hand and having a short midrib or costa

cottonization: a process in which fibre strands are cut to a uniform length (38 mm) so that they can be spun using cotton-spinning equipment.

cotyledon: seed-leaf, the primary leaf; dicotylous embryos have two cotyledons and monocotylous embryos have one

coumarins: benzo-'alpha'-pyrone ('alpha'-chromone) derivatives

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

crest: an elevation or ridge upon the summit of an organ

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

cucullate: hooded; hood-shaped

culm: the stem of grasses and sedges

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 be written with an initial capital letter and given single quotation marks (e.g. banana 'Gros Michel') unless preceded by 'cv.' (e.g. cv. 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

cuspidate: abruptly tipped with a sharp rigid point

cuticle: the outermost skin of plants, consisting of a thin continuous fatty film

cutting: a portion of a plant, used for vegetative propagation

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

cystitis: inflammation of the urinary bladder

cytotoxic: pertaining to or exhibiting a destructive effect on certain cells

deciduous: shedding, applied to leaves, petals, etc.

decoction: a medicinal preparation or other substance made by boiling, especially in water

decompound: several times divided or compounded

decortication: the removal of the bark from plant stems by power-operated units that crush and break up the core, and then separate the bark from the broken core

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: the ratio of mass to volume of a substance 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

depressed: sunk down, as if flattened from above

depurative: tending to purify or cleanse

dermatitis: inflammation of the skin

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

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

digestibility: the percentage of a foodstuff taken into the digestive tract that is absorbed into the body

digynous: with 2 pistils or styles

dilated (botany): expanded into a flat structure

dimer: a compound formed by combination of two identical simpler molecules

dimorphic: of two forms, as may occur with branches, etc.

dioecious: with unisexual flowers and with the staminate and pistillate flowers on different plants (dioecy)

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*

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

dissolving pulp: highly-processed pulp with high α-cellulose content used for the production of products such as viscose rayon and cellulose acetate

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

diuretic: tending to increase the flow of urine; an agent that promotes the excretion of urine

diureticum: an agent increasing the urinary discharge

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

drainage: in paper making: the ease of removing water from pulp fibre slurry

drawing: the transformation of fibre into a continuous sliver which by repeated processing becomes longer and thinner

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

dry rot: a decay of seasoned timber caused by certain fungi

dysentery: any of various diseases characterized by inflammation of the intestines, abdominal pain and frequent bloody, mucous faeces

dyspepsia: a condition of disturbed digestion

dysuria: difficult or painful urination

ear: the spike of a grass

ebracteate: without bracts

elasticity: the degree to which material, e.g. fibre, recovers its original length after extension

ellipsoid: a solid which is elliptical in outline

elliptical: oval in outline but widest about the middle

elongation at break: the amount of extension when the fibre breaks, expressed as a percentage of the original length of the fibre

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

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
endemic: exclusively native to a specified or comparatively small region; also used as a noun for a taxon thus distributed
endocarp: the innermost layer of the pericarp or fruit wall
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
energy value: the heat produced by the combustion of a unit weight of a fuel or food (= calorific value)
ensiform: sword-shaped
entire (botany): with an even margin without teeth, lobes, etc.
epicalyx: an involucre of bracts below the flower, resembling an extra calyx
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
epigeal: above the ground; in epigeal germination the cotyledons are raised above the ground
epipetalous: borne upon or placed before the petals
epiphyte: a plant that grows on another plant but without deriving nourishment from it
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
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
exocarp: the outer layer of the pericarp or fruit 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
extract: a concentrated preparation of a vegetal or animal drug obtained by removing the active constituents with a suitable solvent
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
febrifuge: an agent serving to reduce fever
fermentation: a chemical change accompanied by effervescence and suggestive of changes produced in organic materials by yeasts
ferruginous (ferrugineous): rust-coloured
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: an elongate tapering cell that at maturity has a small lumen and no protoplasm content; it is found in many plant organs and is especially well developed in the xylem and phloem of the vascular system; it imparts elasticity, flexibility, and tensile strength to the plant or organ
fibre bundle: the aggregate of fibre strands separated from plant stems after retting
fibre strand: a single length of fibre from a fibre bundle comprised of overlapping ultimate cells bound together by lignin and hemicelluloses
fibreboard: sheet material manufactured under pressure and heat from wood or other plant fibres
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
filiform: slender; threadlike
fimbriate: fringed
fines: small particles other than fibres found in pulps; they originate from different vessel elements, tracheids, parenchyma cells, sclereids and the epidermis
fissured: provided with fissures (cracks of considerable length and depth), e.g. in the bark of some trees
flaccid: withered and limp, flabby
flatulence: the presence of excessive amounts of air or gases in the intestine
flavones: a subgroup of the flavonoids
flavonoid: water-soluble phenolic compound, con-

sisting of 2 aromatic rings joint together with a 3-carbon unit

fleshy: succulent

flexuous, flexuose: zigzag; bent alternately in opposite directions

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

floss: fluffy fibrous material

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 pouch-like depression or cavity, e.g. hair follicle

forage: grassland and fodder plants suitable as feed for herbivores, usually with lower nutrient concentration and digestibility than concentrates such as grain

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

frond: the foliage of ferns and other cryptogams; also used for the leaves of palms

fruit: the ripened ovary with adnate parts

fulvous: yellow, tawny

fungicide: an agent that destroys fungi or inhibits their growth

fungivorous: feeding on fungi

funicle (funiculus): the little cord which attaches the ovule or seed to the placenta

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

gallery forest: fringing forest, forest growing along a water course in an otherwise non-forested area

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

genome: a set of chromosomes as contained within the gamete and corresponding to the haploid chromosome number of the species

genus (plural: genera): the smallest natural group containing distinct species

geotextiles: textile or textile products used in combination with soil, clay etc.

germplasm: the genetic material that provides the physical basis of heredity

girdling: cutting a girdle around the stem to kill the plant by interrupting the circulation of water and nutrients

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

glaucous: pale bluish-green, or with a whitish bloom which rubs off

globose: spherical or nearly so

glucoside: compound that is an acetal derivative of sugars and that on hydrolysis yields glucose

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

glycoside: compound that is an acetal derivative of sugars and that on hydrolysis yields one or more molecules of a sugar and often a non carbohydrate

gonorrhoea: a venereal disease characterized by inflammation of the mucous membrane of the genitourinary tract and a discharge of mucus and pus

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: of wood, the general direction or arrangement of the fibres; texture

grain (botany): a general term for cereals, those grasses cultivated for food; the caryopsis or the fruit of cereals

green manure: green leafy material applied to and mostly worked into the soil to enrich the soil with nutrients and organic matter

gregarious: growing in associated groups or clusters but not matted

gum: a colloidal polysaccharide substance that is gelatinous when moist but hardens on drying; gum is exuded by plants or extracted from them
gynoecium: the female part or pistil of a flower, consisting, when complete, of one or more ovaries with their styles and stigmas
gynophore: a stalk supporting the gynoecium formed by elongation of the receptacle
habit (botany): external appearance or way of growth of a plant
habitat: the kind of locality in which a plant grows
hackling: the process of rough combing to remove residual shives attached to the fibre bundles and to mechanically separate the fibres into long strands
haemorrhage: bleeding; the escape of blood from blood vessels
haemostatic: arresting the flow of blood; an agent that checks the flow of blood
hammer mill: equipment for reducing the size of bulk solid material using pivoted hammers revolving at high speed within a steel casing
hank: a coil or skein of fibre strands, yarns etc.
hapaxanthic: describing plants (e.g. some palms) having a single flowering period after which the plant dies
hardboard: homogenous thin fibreboard having a density of not more than 16 kg/m^3
hardwood: the wood of an angiospermous tree as distinguished from that of a coniferous tree
head: a dense inflorescence of small crowded often stalkless flowers (a capitulum)
heath forest: see kerangas
hemicelluloses: polysaccharides of relatively low weight built up from hexoses, pentoses and uronic acid residues
hepatitis: inflammation of the liver
herb: any vascular plant which is not woody
herbaceous: with the texture, colour and properties of a herb; not woody
hermaphrodite: bisexual; in flowers, with stamens and pistil in the same flower
heterogeneous: lacking in uniformity; exhibiting variability
heterostylous: having styles of two or more distinct forms or of different lengths
heterozygous: the condition in which homologous chromosomes of an individual possess different alleles at corresponding loci
hexagonal: having six angles and six sides
hilum: the scar left on a seed indicating its point of attachment
hirsute: with rather coarse stiff hairs
hirtellous: minutely hirsute
hispid: covered with long rigid hairs or bristles
hispidulous: minutely hispid
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
hoarseness: to be rough or harsh in sound
holocellulose: the total carbohydrate fraction of e.g. plant fibres, comprising cellulose and hemicelluloses
homogeneous: uniform as to kind; showing no variability
homozygous: possessing identical genes at corresponding loci on homologous chromosomes
husk (hull): 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
hydrolysis: a chemical reaction of water in which a bond in the reactant other than water is split and hydrogen and hydroxyl are added
hydrophobic: resistant to or avoiding wetting
hygrophilous: moisture-loving
hygroscopic: susceptible to extending or shrinking on application or removal of water or vapour
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
hypertension: high arterial blood pressure
hypocotyl: the young stem below the cotyledons
hypoderm: the cell layer beneath the epidermis
hypogeal: below ground; in hypogeal germination the cotyledons remain below ground within the testa
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
imparipinnate: of leaves, pinnate with an unpaired terminal leaflet
impotence: lack of power, specifically lack of copulative power in the male due to failure to initiate or maintain an erection
inbreeding: breeding through a succession of parents belonging to the same stock
incised: cut deeply
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
indumentum: a covering, as of hairs, scales, etc.
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
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
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 to promote growth
inoculum: material used for inoculation, e.g. rhizobia in soil to promote the growth of certain *Leguminosae*
insecticidal: destroying or controlling insects
insecticide: an agent that destroys insects
in situ: in the natural environment; in medicine: in the natural or normal place
intercropping: the growing of two or more crops in different but proximate rows
interfloral: between the flowers
interfoliar: borne among the leaves
internode: the portion of the stem (culm) between two nodes
interpetiolar: of stipules placed between the petioles of opposite leaves
intraspecific: occurring within a species or involving members of one species
introrse: turned inward, towards the axis, as the dehiscence of an anther
in vitro: outside the living body and in an artificial environment
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*
isozymes: multiple distinct molecular forms of an enzyme that differ in net electrical charge; important to the investigation of the molecular basis for cellular differentiation and morphogenesis, and increasingly used to clarify genotypic relationships
isthmus: a narrowed connection between two parts
joint; jointed: an articulation, like a node in plants and a place of union of two bones in the human body; articulated
juvenile phase (stage): the period between germination and the first signs of flowering, during which vegetative processes preclude flower initiation even under the most favourable conditions
kappa number: a measure of the lignin content of pulp; the kappa number has a linear relationship with lignin content over a wide range
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
kerangas: heath forest, a type of tropical forest generally consisting of comparatively small trees with thin trunks (pole forest), often overlying a podsolic soil
kernel: the nucellus of an ovule or of a seed, that is, the whole body within the coats
kraft pulp: a chemical pulp obtained by digesting wood chips or other plant material at high temperature and pressure in a solution of sodium hydroxide and sodium sulphate (sulphate pulp)
laciniate: slashed, cut into narrow lobes
LAI (leaf area index): a measure of the photosynthetic area over a given area of ground
lamina: the expanded part, e.g. of a leaf or petal (blade)

laminate, laminated: consisting of plates or layers
lanate: with woolly hairs
lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex
landrace: a locally developed kind of cultivar, without formal recognition, and usually much more variable than an official registered cultivar and from which usually several cultivars can be selected
lateral: on or at the side
latex: a juice, usually white and sometimes sticky, exuding from broken surfaces of some plants
laticiferous: latex-bearing
latrorse: directed towards the sides, as the dehiscence of an anther
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)
leaflet: one part of a compound leaf
leaf sheath: the lower part of the petiole which more or less invests the stem
lemma: the lower of the two glumes which surround each floret in the spikelet of grasses
lenticellate: having lenticels
lenticular: shaped like a double-convex lens
leucorrhoea: a whitish, viscid discharge from the female genitals
liana: a woody climbing vine
lignans: a group of natural products (dimers) derived from condensation of 2 phenylpropane units
lignification: the action or process of being converted into wood or woody tissue
lignified: converted into wood or woody tissue
lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres
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
lobe: any division of an organ or specially rounded division
lobed: divided, but not to the base
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
lodge: (in agronomy) to beat (as a crop) flat to the ground
log: a section cross cut from the stem or a branch of a tree; round log: bark, branches and protuberances removed; squared log: if a log has been sawn to an approximately rectangular cross-section
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
lumen (plural: lumina): the space enclosed by the walls of a cell or organ, such as the central cavity of a cell
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
MDF (Medium Density Fibreboard): a panel product manufactured from lignocellulosic fibres combined with a synthetic resin or suitable binder; the panels are compressed to a density of about 0,40 to 0,80 g/cm^3 in a hot press by a process in which substantially the entire interfibre bond is created by the added binder; other materials may have been added during manufacture to improve certain properties
median: belonging to the middle
membranaceous (membranous): thin and semi-transparent, like a fine membrane
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.
mesocarp: the middle layer of the pericarp or fruit wall which is often fleshy or succulent
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
middle lamella: the lignin-rich cementing layer between cell walls in plants
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
moisture content: the weight of water expressed as a percentage of the dry weight
molluscicidal: destroying molluscs such as snails
monocarp: a plant that flowers and fruits only once during its lifetime; the single carpel of an apocarpous fruit
monocarpic: only flowering and fruiting once (said of an annual or other plant)
monocotyledon: angiosperm having a single cotyledon or seed-leaf
monoecious: with unisexual flowers, but male and female flowers borne on the same plant
monogastric: having a stomach with only one compartment (e.g. swine, chicks)
monomer: the simple unpolymerized form of a chemical compound having relatively low molecular weight
monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches
monoterpene: a terpene of molecular formula $C_{10}H_{16}$, e.g. limonene, myrcene and phellandrene; most monoterpenes are readily oxidized to coarse-smelling products, so essential oils containing them must be carefully preserved to minimize this tendency
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
mucilage: a gelatinous substance that is similar to gum but that swells in water without dissolving and forms a slimy mass
mucilaginous: slimy
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
mutagenic: capable of inducing genetic mutation
myocardium: the middle and thickest layer of the heart wall, composed of cardiac muscle
naturalized: introduced into a new area and established there, giving the impression of wild growth
nectar: a sweet fluid exuded from various parts of the plant (e.g. by the flower to attract pollinators)
nectariferous: containing or exuding nectar
nectarivorous: feeding on nectar
nectary: a group of modified subepidermal cells in flowers or leaves (extrafloral) secreting nectar
nematode: small elongated cylindrical worm-like micro-organism, free-living in soil or water, or parasitic in animals or plants
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 cord-like structure consisting of nerve fibres, which convey impulses between the central nervous system and other body parts
newsprint: machine-finished, unsized paper composed mainly of mechanical pulp for use in newspapers
nocturnal: of flowers, flowering during the night
node: the point on the stem or branch at which a leaf or lateral shoot is borne
nut: a one- to many-seeded indehiscent fruit with a hard dry pericarp or shell
nutlet: a little nut
oblanceolate: reverse of lanceolate
oblique: slanting; of unequal sides
oblong: longer than broad, with the sides parallel or almost so
obovate: reverse of ovate
obovoid: a solid object which is obovate in section
obsolete: wanting or rudimentary; used of an organ which is scarcely apparent or has vanished
obtuse: blunt or rounded at the end
oil gland: a glandular cell which secretes oil
oligotrophic: providing inadequate or with a low supply of nutrition
opacity: the ability of paper to hide or mask a colour or object in the back of the sheet; high opacity results in less transparency and is im-

portant in printing papers
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
orbicular: flat with a more or less circular outline
order (and its extensions, first, etc.): a sequence, as of branching: a first order branch branches to produce a second order branch, etc.
orthotropic: having a more or less vertical direction of growth
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
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 (oval)
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
p.v.: physiological variety (race), pathogens of the same species which are structurally similar, but which differ in physiological and pathological characteristics
palea: the upper of two membranous bracts enclosing the flower in grasses
palmate: of leaflets, leaf-lobes or veins, with the different elements arising from the same point
palmatifid: cut about half way down in a palmate manner (palmately lobed)
palmatilobed: lobed in a palmate matter
palmatipartite: cut nearly to the base in a palmate manner
panelling: to furnish or decorate with panels (rectangular boards)
panicle: an indeterminate branched racemose inflorescence
paniculate: resembling a panicle
pantropical: distributed throughout the tropics
paper: material consisting of a web of pulp fibres originating from wood or other plant materials
papillae: soft superficial glands or protuberances
papillose: covered with minute nipple-like protuberances
parasitic: deriving nourishment from some other organism
parasympathomimetic: producing effects resembling those of stimulation of the parasympathetic nerve supply to a body 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
particle board: board made from bonded particles of wood and/or other ligno-cellulosic material
partite (parted): cleft, but not quite to the base
patent (botany): spreading out widely
pectin: a substance yielding viscous solutions with water and, in combination with acid and sugar, forming a gel constituting the base of fruit jellies
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
peduncular bract: in palms, empty bract on main inflorescence axis (peduncle) between prophyll and the first rachis bract
pedunculate: furnished with a peduncle
peel: the rind or skin of the fruit
peeling: of a log, producing a continuous sheet of veneer by feeding a knife mounted parallel to the axis onto a rotating log
pellucid: translucent
pendent, pendulous: drooping; hanging down from its support
penninerved: pinnately veined, parallel veins arise at an angle from a midvein (as in *Musa*)
pentagonal: with five angles
pentaploid: having five sets of chromosomes ($5n$)
pentosan: any of various polysaccharides that yield monosaccharides containing five carbon atoms (pentoses) on hydrolysis; it functions as inter-fibre bond in paper manufacture
perennial: a plant living for many years and usually flowering each year
perfume: a harmonious composition prepared from natural and/or synthetic aromatic materials having aesthetic appeal alone, or after incorporation in an end-product
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

pericycle: the outermost zone of cells of the stele or central cylinder of vascular tissue in plants

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

petaloid: petal-like

petiolate: having a petiole

petiole: the stalk of a leaf

phalange: bundle, e.g. of stamens (staminate phalange) or carpels (carpellate phalange), often with partly connate parts

pharyngitis: inflammation of the pharynx

phenolics: phenols are compounds which have an aromatic ring with an alcoholic group attached to it

phlegm: a viscid, stringy mucous secretion, like that produced by the mucous membranes of the respiratory tract, as during a cold

phloem: the principal food-conducting tissue of vascular plants; the bast element of a vascular bundle and basically composed of sieve elements, parenchyma cells, fibres and sclereids

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

phthisis: wasting away of (a part of) the body; tuberculosis, especially of the lungs

phyllotaxis: the arrangement of leaves or floral parts on an axis or stem

phytosanitary: of or relating to health or health measures of plants

phytosaprophagous: feeding on living or dead plant material

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

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

pits: recesses in the secondary wall of a cell, often in walls connecting two elements of a vessel (intervessel pits), these can be arranged in ladder-like series (scalariform), in horizontal rows (opposite) or in diagonal rows (alternate)

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

plagiotropic: having an oblique or horizontal direction of growth

plaiting: a weaving technique in which the weft crosses over and under one or more warp at a time

plicate: folded to and fro, like a fan

ploidy: degree or repetition of the basic number of chromosomes

plumose: featherlike with fine hairs

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

pod: a dry fruit composed of a single carpel and dehiscing by sutures, as in legumes; a general term for a dry dehiscent fruit

polish: a smooth and glossy surface produced by a mechanical process, usually by friction

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

polymorphic, polymorphous: with several or various forms; variable as to habit

posticous: on the posterior side

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 counter irritation

praemorse: jaggedly toothed, as if bitten; as though the end were bitten off

prickle: a sharp, relatively stout outgrowth from the outer layers

procumbent: lying along the ground; in wood anatomy also of ray parenchyma cells with their longest dimension in radial direction

progeny: offspring

prolific: fruitful, producing offspring

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
prostrate: lying flat on the ground
protandrous: of flowers, shedding pollen before the stigma is receptive
proteolytic: pertaining to, characterized by, or promoting proteolysis
protogynous, proterogynous: of flowers: the stigma is receptive before the pollen is shed; of inflorescences: the female flowers mature before the male ones
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
pruinose (pruinous): having a waxy powdery secretion on the surface, a bloom
pruning: cutting off the superfluous branches or shoots of a plant for better shape or more fruitful growth
pseudopetiole: a structure resembling a petiole, but not being one
pseudostem: an axis with the appearance of a stem but made up of other organs, e.g. leaf sheaths in *Musa* and *Curcuma*
puberulent: covered with down or fine hairs
puberulous: minutely pubescent
pubescent: covered with soft short hairs
pulp: in paper making: an aggregation of the cellulosic fibres liberated from wood or other plant materials physically and/or chemically so that discrete fibres can be dispersed in water and reformed into a web to form paper or allied products; in botany: the soft fleshy part of the fruit
pulping: the process by which wood or other plant materials are converted into pulp; during pulping, fibre strands or fibre bundles are broken down into their ultimate fibres
pulp yield: the amount of material (% of dry matter) recovered after pulping compared to the amount before the process
pulses: dry edible seeds of legumes
pulvinus (plural pulvinae): a minute gland or swollen petiole base
purgative: causing evacuation of the bowels; an agent causing evacuation of the bowels, especially through stimulating peristaltic action; also called cathartic
pustule: a pimple or blister
pyriform: resembling a pear in shape
quadrangular: four-cornered or four-edged
raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards
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
radical: arising from the root, or its crown
radicle: the first root of an embryo or germinating seed
rain forest: a tropical forest receiving an annual rainfall of at least 1800 mm, characterized by lofty evergreen trees forming a continuous canopy below which terrestrial herbs and shrubs are poorly developed
raspador: decorticating device consisting of open rotating drums with blades or bars on the periphery, into which the leaves are fed manually and end-on.
ratoon: shoots in perennial crops such as the pineapple, left on the plants after harvest to produce the subsequent crop (ratoon crop)
rays: in wood, ribbons of parenchymatous tissue which are seen on a cross-section of timber as lighter coloured lines radiating from the pith outwards, and extending right up to the bark
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
recovery: (of pulping chemicals) a process in which the inorganic chemicals used in pulping are recovered and regenerated for reuse
recurved: bent or curved downward or backward
reduced: subnormal in size; connotes also either a failure to fulfil a normal function, or a diminution of the expected number of parts in a set (of stamens, for example)
reduplicate: of leaflets, inversed V-shaped in cross section
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
reniform: kidney-shaped

resin: solid to soft semisolid amorphous fusible flammable substance obtained as exudate or as an extract of plants
resinous: exuding, made of, or similar to resin
resolvent: promoting resolution or the dissipation of a pathological growth
reticulate: netted, as when the smallest veins of a leaf are connected together like the meshes of a net
retting: a microbiological process in which the joint action of water and microbial enzymes decomposes the non-fibrous material around fibre bundles enabling the fibre bundles to be loosened for extraction
revolute: of leaves with the margins rolled downwards towards the midrib
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
rhizome: an underground stem which is distinguished from a root by the presence of nodes, buds, and leaves or scales (rootstock)
rhomboid (botany): quadrangular, diamond-shaped with the lateral angles obtuse
ribbon: a strip of bark separated from the woody core of the stem of bast fibre crops, which may be removed by hand or by machine
ribboning: stripping of the bark from the stem of bast fibre crops, leaving the woody core unbroken
rootstock: a stock for grafting consisting of a root and part of the main axis; rhizome
root sucker: a shoot originating from adventitious buds on the roots
rosette: a cluster of leaves or other organs in a circular form
rostrate: beaked
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
roving: forming into roves, i.e. strands of loosely-assembled fibres, especially preparatory to spinning
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
Runkel ratio: parameter used by the pulp and paper industry, derived from the fibre cell dimensions: the ratio between twice the fibre cell wall thickness and the lumen diameter (2W/L)
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 fungus 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
sapling: a young tree of more than 1.5 m tall and with a bole of less than 10 cm in diameter
saponin(s): 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
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
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
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
schistosomiasis: infection with flukes of the genus *Schistosoma*; sometimes called bilharzia
schizocarp: a dry fruit formed from a syncarpous ovary which splits into one-seeded portions, mericarps or 'split fruits'
sclerenchymatous: of tissue, composed of thick-walled cells
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
scutching: the mechanical beating of stems or straw to separate the fibre from the woody core and other plant tissues
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
selfing: fertilization of female gametes with male gametes from the same individual
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
septate: divided by one or more partitions
septum (plural: septa): a partition or cross-wall
seral: a temporary or developing vegetation type
seriate: serial, disposed in series of rows
sericeous: silky
serrate: toothed like a saw, with regular pointed teeth pointing forwards
serrulate: serrate with minute teeth
sesquiterpene: a terpene of molecular formula $C_{15}H_{24}$, e.g. caryophyllene and farnesene
sessile: without a stalk
sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses
shell: the hard envelope of a nut
shingles: an acute, infectious skin disease, characterized by neuralgia and eruptions sometimes extending half round the body like a girdle; also called herpes zoster
shiv(e): the small portions of woody core produced during decortication or adhering to fibre strands following fibre extraction from retted stems; in the pulp and paper industry referring to the small fragments causing imperfections in sheets of pulp or paper
sliver: a strip of loose, untwisted textile fibres produced by carding
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
silica body: globular or amorphous conglomerate of siliceous material, generally included in parenchymatous cells
sludge: a muddy or slushy deposit or sediment
soda pulp: a chemical pulp obtained through application of a solution of sodium hydroxide
softwood: the wood of a coniferous tree
sole crop: one crop grown alone in pure stands (also called single crop)
solitary: single stemmed, not clustering
solubility: the weight of a solute required to saturate 100 g of a solvent at a given temperature
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)
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
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
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
spinning: a process whereby twisting is applied to a supply of overlapping fibres to produce a yarn
spiral: as though wound round an axis
spore: in cryptogams a cell which becomes free and capable of direct development into a new bion; the analogue of seed in phanerogams
spring tide: a tide just after a new or full moon, when there is the greatest difference between high and low water
springing: the curvature of a piece of sawn timber in the plane of its wide face
spur (botany): a hollow and slender extension of some part of the flower, usually nectariferous; a small reproductive shoot; in forestry: a buttress-like projection of a tree trunk
stain(ing): 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

staminate: a flower bearing stamens but no pistil
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
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)
steroidal alkaloids: a subgroup of the alkaloids
steroid saponins: a subgroup of the saponins
steroids: a group of modified triterpenes which contain a ring system of three 6-membered and one 5-membered rings
sticks: the intact woody core component of the stems of bast fibre plants
stiffness: (of paper) the degree to which paper resists bending when handled
stigma: the portion of the pistil which receives the pollen
still: an apparatus for distillation
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
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
stone: the hard endocarp of a drupe containing the seed or seeds
straggling: extremely divergent, spreading very far apart; irregular, bushy
strand: a number of yarns twisted together to form one of the component parts of a rope
stratification: a moist, cold treatment of seed to overcome physiological dormancy
striate: marked with fine longitudinal parallel lines, as grooves or ridges
strophiole: an outgrowth of a seed near the hilum (caruncle)
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
subalpine: relating to high upland slopes immediately below the timber line
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
sulcate: grooved or furrowed
sulphate pulp: a chemical pulp obtained by digesting wood chips or other plant material at high temperature and pressure in a solution of sodium hydroxide and sodium sulphate
superior: of an ovary, with the perianth inserted below or around its base, the ovary being attached at its base only
suture: the line of junction of two carpels; the line or mark of splitting open
syconium: a multiple, hollow fruit, like a fig
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
syncarp: a multiple or fleshy aggregate fruit, including fruit produced from a more or less entire inflorescence (as in *Artocarpus, Ananas, Morus*)
syncarpous: of an ovary composed of two or more united carpels
synchronous: happening, existing or arising at the same time
syphilis: a disease usually communicated by sexu-

al 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

tail (botany): any long and slender prolongation

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)

tear: the energy required to propagate an initial tear through several sheets of paper for a fixed distance

tendril: a thread-like climbing organ formed from the whole or part of a stem, leaf or petiole

tensile strength: of fibre or cordage: the weight at which a fibre or assembly of fibres breaks (breaking load) per unit area of cross-section

tepal: a segment of a perianth, applied when no distinction between sepals and petals can be made

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 honey combing or wide channels with dry bore-dust or dust cemented together

ternate: in threes

terrestrial: on or in the ground

tertiary venation: generally the collection of the smallest veins of a leaf blade

tessellate: having a checkered appearance (resembling squared stones)

testa: the outer coat of the seed

tetraploid: having four times ($4n$) the basic number of chromosomes or twice the diploid number ($2n$)

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

thyrse (thyrsus): a compound inflorescence composed of a panicle (indeterminate axis) with the secondary and ultimate axes cymose (determinate)

thyrsiform: shaped like a thyrse

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)

tilth: surface soil prepared for planting or cultivation

timber: any wood other than fuelwood

tissue culture: a body of tissue growing in a culture medium outside the organism

tomentellous: minutely tomentose

tomentose: densely covered with short soft hairs

tomentum: pubescence

tonic(um): 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

tortuous: bent or twisted in different directions

tow: short lengths of fibre removed during fibre extraction

tracheid: an imperforate wood cell with bordered pits to congeneric elements

transverse: straight across; of tertiary veins, connecting the secondary veins, not necessarily in a perpendicular way

trap crop: a crop known to attract a pest and planted near a crop susceptible to that pest to lure the pest away from the desired crop

tree: a perennial woody plant with a single evident trunk

tribe: a taxonomic rank between the family and the genus

trichotomous: three-forked, branching into three divisions

trifoliate: three-leaved

trigonous: three-angled, with plane faces

trigynous: with 3 pistils or styles

triploid: having three times the basic number of chromosomes, usually written $3n$

triquetrous: three-edged, with three salient angles

triterpenes: a subgroup of the isoprenoids, formed by coupling of 6 C_5 units

truncate: cut off more or less squarely at the end

trunk: the main stem of a tree apart from its limbs and roots

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
tuberous: producing tubers or resembling a tuber
tufted: growing in tufts (caespitose)
turbinate: top-shaped
turgid: swollen, but not with air
turning: of wood, shaping, especially in a rounded form, by applying a cutting tool while revolving in a lathe
tussock: a tuft of grass or grass-like plants
twine: a ply yarn made from medium twist single yarn with ply twist in the opposite direction
twining: weaving technique in which two wefts cross over each other between warps; in botany: winding spirally
ulcer: an open sore on an external or internal body surface, usually accompanied by disintegration of tissue and formation of pus
ultimate fibre: the individual cell in a fibre strand or fibre bundle
ultrabasic: of soil, very low in silica and rich in ferromagnesian minerals as in e.g. serpentine soils
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
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
unguiculate: contracted at the base into a claw
unilocular: one-celled
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
utricle: a small bladdery pericarp
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
vein (botany): a strand of vascular tissue in a flat organ, such as a leaf
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
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
verrucose: warty
versatile (botany): turning freely on its support, as anthers on their filaments
vessel (anatomy): a continuous tube formed by superposition of numerous cells whose common walls are perforated or have broken down
viability: ability to live, grow and develop
vicariant: referring to species that occupy similar ecological niches but in geographic isolation from each other
villose (villous): with long weak hairs
viscid: sticky
viscosity: (in pulping) a measure of the average chain length of the cellulose present; a higher viscosity indicates stronger pulp and paper
viscous: glutinous, or very sticky
vulnerary: pertaining to wounds or the healing of wounds; an agent promoting the healing of wounds
warp: the lengthwise yarn over and under which the weft yarns are passed in fabric weaving
wart (in medicine): a small, usually hard and non-malignant, excrescence on the skin
warty: covered with firm roundish excrescences
waterlogged: flooded with water, generally for a period of at least a few weeks
wax: waxes are mixtures of esters of higher alcohols and higher fatty acids; waxes are used as stiffening agents in the manufacture of cosmetics; natural plant waxes are removed from concretes to produce absolutes
weaving: the process of producing articles such as baskets, hats and mats by interlacing relatively

stiff material such as stems, rods and leaves; the process of producing fabric by interlacing one set of yarn with another set at a right angle

weft: the crosswise yarns that are passed over and under the warp yarns in fabric weaving

whorl: arrangement with more than two organs of the same kind arising at the same level

wickerwork: articles made by weaving together twigs, canes etc.; a weaving technique in which fibrous material is woven around a frame that forms the core of the piece

wilt: loss of turgidity, usually in leaves, typically caused by pathogens which colonize the vascular system

wing: any membranous expansion attached to an organ; a lateral petal of a papilionaceous corolla

wood: the hard, compact, fibrous substance between pith and bark

woodfree paper: paper containing at least 90% chemical pulp

woolly: clothed with long and tortuous or matted hairs

xerophytic: relating to a plant structurally adapted for life and growth with a limited water supply

xylem: the main water-conducting tissue in vascular plants which extends throughout the body of the plant and is also involved in transport of minerals, food storage and support; primary xylem is derived from the procambium, secondary xylem (e.g. the wood of trees and shrubs) from the vascular cambium; xylem is composed of tracheary elements: tracheids and (in angiosperms) vessel elements; both are elongated hollow cells, with thickened, usually heavily lignified walls, and lacking protoplasts when mature; they are joined end to end to form a continuous conducting tube

xylophagous: feeding on wood

yarn: an assemblage of fibres or filaments, twisted or laid together to form a continuous strand suitable for use in weaving, knitting or otherwise intertwining

Young's modulus: the ratio of the stress (force per unit area) or applied load to the strain or deformation produced in a material that is elastically deformed; the higher the value, the stiffer the material

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Figure 1. Esau, K., 1977. Anatomy of seed plants. 2nd Edition. John Wiley & Sons, New York, United States. Fig. 4.1, p. 45. Redrawn and adapted by P. Verheij-Hayes.

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Index of scientific plant names

Page numbers printed in bold refer to main treatment.

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 University (WU), 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 4 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.
- Prosea beyond 2000 (Phase 2001–2005): handbook finalization; emphasis on lesser-known useful plants, and making the information services demand-driven.

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.

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In brief, Prosea is

- an international programme, focused on plant resources of South-East Asia;
- interdisciplinary, covering the fields of agriculture, forestry, horticulture and botany;
- a research programme, making knowledge available for education and extension;
- ecologically focused on promoting plant resources for sustainable tropical land-use systems;
- committed to conservation of biodiversity;
- committed to rural development through diversification of resources and application of farmers' knowledge.

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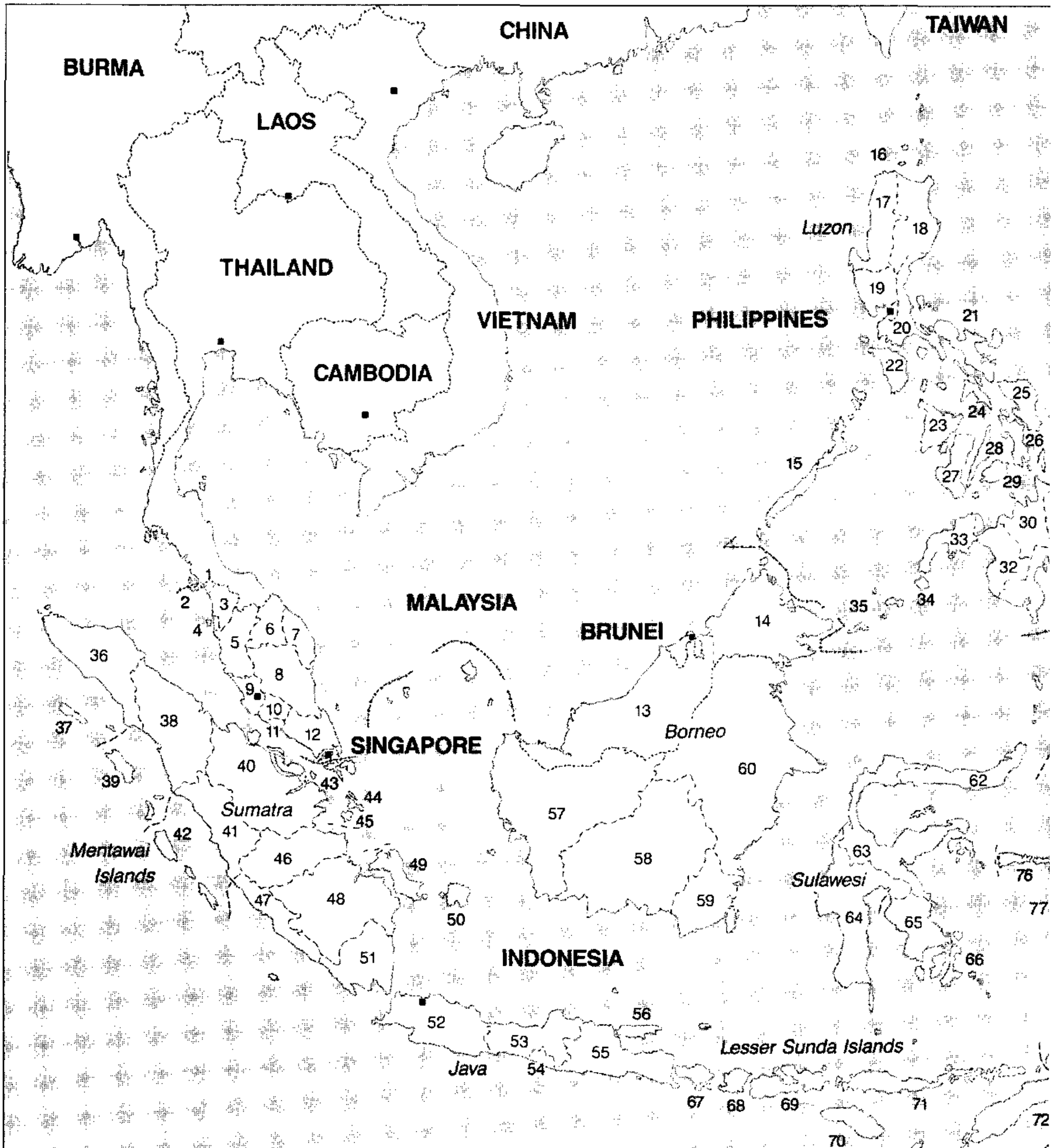

MAP OF SOUTH-EAST ASIA FOR PROSEA

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
Southern Tagalog *r* 20
Southern Mindanao *r* 31
Sulu Archipelago *i* 35
Western Mindanao *r* 33

INDONESIA
Aceh *p* 36
Ambon *i* 79
Aru Islands *i* 82
Bali *i* 67
Bangka *i* 49
Belitung *i* 50
Bengkulu *p* 47
Buru *i* 77
Butung *i* 66
Central Java *p* 53
Central Kalimantan *p* 58
Central Sulawesi *p* 63
East Java *p* 55
East Kalimantan *p* 60
Flores *i* 71
Halmahera *i* 74
Irian Jaya *p* 84
Jambi *p* 46
Kai Islands *i* 83
Lampung *p* 51
Lingga *i* 44
Lombok *i* 68
Madura *i* 56
Morotai *i* 73
Nias *i* 39
North Sulawesi *p* 62
North Sumatra *p* 38
Obi *i* 75
Riau *p* 40
Riau Archipelago *i* 43
Seram *i* 78
Siberut *i* 42
Simeuluë *i* 37
Singkep *i* 45
South-East Sulawesi *p* 65
South Kalimantan *p* 59
South Sulawesi *p* 64
South Sumatra *p* 48
Sula Islands *i* 76
Sumba *i* 70
Sumbawa *i* 69
Talaud Islands *i* 61
Tanimbar Islands *i* 81
Timor *i* 72
West Daya Islands *i* 80
West Java *p* 52
West Kalimantan *p* 57
West Sumatra *p* 41
Yogyakarta *p* 54

PAPUA NEW GUINEA
Bougainville Island *i* 87
D'Entrecasteaux Islands *i* 88
Louisiade Archipelago *i* 89
New Britain *i* 86
Papua *r* 85