Plant Resources of South-East Asia

No 18

Plants producing exudates

E. Boer and A.B. Ella (Editors)

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Foreword

Exudate-producing plants (mainly trees) form a very interesting and diverse group. They have been exploited for centuries, especially in Africa, Australia, and Asia (notably China and South-East Asia). The exudates they yield include resins, latexes and gums, used as ingredients in cosmetics, perfumes and industrial products. Gums are of little importance in South-East Asia.

The most important plant exudate is rubber from *Hevea brasiliensis*. With an annual production of 5 million t, it is the major source of cash income for over a million households in South-East Asia. Other exudate-producing plants in the region are an important source of revenue for local communities. The most valuable resin, pine resin, has an annual world production of about 1 million t. Although the other resins and latexes are suffering from fierce competition from synthetic substitutes, they have retained a reasonable market share.

With the exception of a small portion of rubber and gutta-percha obtained from *Palaquium gutta*, plant exudates are rarely harvested from estates. Though not of comparable value to rubber, it is worth managing other exudate-producing trees, as this may have a positive effect on the sustainable use of natural resources. This has been demonstrated in agroforestry systems using *Shorea javanica*, *Styrax benzoin* and *Styrax paralleloneurum*. Fortunately, there is renewed interest in research on these plants that is aimed at more efficient harvesting techniques, the application of stimulants to increase exudate yield, and improved post-harvest handling and processing. Nevertheless, interest in exudate-producing plants has been confined to a few species to the detriment of others that were traditionally exploited for their exudate.

In some regions of the world, the production of certain commercial plant exudates depends on cheap labour. The usual techniques of tapping trees for exudates are very labour-intensive, especially if the exudates are collected in the natural forests. Mechanical devices for harvesting exudates could enhance the commercial development of these plant resources.

This volume is the result of concerted efforts by experts on non-wood forest products with a particular interest in exudate-producing plants. The existing knowledge on South-East Asian plant exudates has now been compiled, evaluated and published. I am hopeful that the information presented here will encourage all concerned to persevere in the efficient use of this commodity and will form a sound basis for new research and development activities.

Laguna, September 2000

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1 Introduction

1.1 Definition and selection of species

1.1.1 Definitions

When a tree is injured, the fluid that oozes out of the wound is referred to as an exudate. The injury may be deliberate ('tapping') or it may be natural or accidental (e.g. caused by insects, animals, pathogen attack, drought or storm damage). In most cases exudates are harvested from the stem or branches of the tree or shrub, but occasionally they are harvested from the roots. Exudation varies greatly amongst genera, and between species within a genus, and the function of the exudate in the plant is not fully understood. One probable role of resinous exudates is to serve as a defence mechanism: when the tree is wounded or attacked by insects or pathogens, it responds by 'bleeding' and resin flows to the wound, sealing it off from further attack. Some terpenoids present in the resin may be fungitoxic so that in addition to physical protection there is some chemical protection in terms of inhibiting the spread of fungi. Depending on their physical and chemical characteristics, exudates are conveniently classified as resins, oleoresins, balsams, latexes or gums. Exudates are a fairly widely used and traded category of non-wood forest products.

Resin

Resins are solid or semi-solid amorphous materials, usually comprising a complex mixture of organic compounds called terpenes. They are insoluble in water but soluble in certain organic solvents. Oil-soluble resins are soluble in oils and hydrocarbon-type solvents, while spirit-soluble resins are soluble in alcohols and some other solvents. Resins can occur in almost any organ or tissue of the plant and a few, such as lac, are produced from insects. 'Copal' and 'damar' (from *Agathis* Salisb. and *Dipterocarpaceae*, respectively) are two important resins from South-East Asia and these are exported in large quantities, particularly from Indonesia, to many other parts of the world. Other resins, such as dragon's blood (from *Daemonorops* Blume ex Schult.f., also of South-East Asia) and mastic (from *Pistacia lentiscus* L. well-known from the island of Chios and other islands in Greece) are also articles of commerce, but are of much more restricted occurrence and are exported in very much smaller quantities.
Some resins, like copal, are very hard but others such as 'Manila elemi' (from *Canarium luzonicum* (Blume) A.Gray in the Philippines) and pine resin (worldwide) are quite soft, particularly when fresh. Such resins are sometimes called 'oleoresins' and they may be sufficiently fluid to run down the tree to a considerable distance from the point of exudation. Their softness is due to a high con-

tent of essential oil which, like the non-volatile part of the resin, is primarily a mixture of terpenes. When exposed to the air, the resin or oleoresin hardens as the volatile terpenes evaporate or polymerize. The essential oil is often a valuable product in its own right, and in the case of pine oleoresin it is distilled from the crude exudate as an integral part of the post-harvest processing (Espiloy, 1973). The volatile component of pine resin is called 'turpentine' and the non-volatile part 'rosin' (not to be confused with resin). Occasionally the term 'turpentine' is used to describe the liquid resins from some other coniferous species (such as *Abies* Mill.). If the resin or oleoresin is characterized by a high content of benzoic or cinnamic acids and their esters, with a typical 'balsamic' odour, then it is often called a balsam. Examples of balsams are 'benzoin' (from South-East Asian *Styrax* spp.), 'Tolu balsam' and 'Peru balsam' (from *Myroxylon balsamum* (L.) Harms of Central and South America), and 'copaiba' (from certain Amazonian *Copaifera* spp.).

Note that the term 'oleoresin' is also used in another context to describe prepared extracts of spices or other plant materials. It is the soft extract that remains after the solvent used to extract the spice has evaporated. Most such oleoresins are used as food flavours. Another term applied solely in the context of a prepared extract is 'resinoid'. This is the viscous liquid, semi-solid or solid prepared from a natural resin by extraction with a hydrocarbon-type solvent; it contains any essential oils originally present in the resin and is often used for fragrance applications (Coppen, 1995b).

Latex

Latex is the colourless or milky sap of certain plants consisting of tiny droplets of organic matter suspended or dispersed in an aqueous medium. The best-known example is rubber latex, in which the solids content is over 50% of the weight of the latex. Usually, boiling the latex causes the solids to coagulate into a solid mass. The principal components of the coagulum are cis- or trans-polyisoprenes and resinous material. If the polyisoprene is mainly cis, it confers elasticity to the solid and makes it rubber-like; if it is mainly trans the solid is non-elastic and resembles gutta-percha from *Palaquium* spp. Several latexes are used as the natural ingredient of chewing-gums. Other useful latex-derived products are: 'chicle', the coagulated latex obtained from *Manilkara zapota* (L.) P.Royen and produced on a commercial scale in Mexico and certain parts of Central America; 'jelutong', the coagulated gutta-like material obtained from the latex of wild trees of *Dyera* spp. from Indonesia and Malaysia; and 'sorva', the coagulated latex from certain Amazonian *Couma* spp. (Rehm & Espig, 1991). 'Balata', the coagulated latex from trees of certain South American *Manilkara* spp. is an example of a latex coagulum with non-elastic properties.

The natural rubber obtained from the latex of the para rubber tree (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.) is of prime economic importance in South-East Asia and is by far the most important exudate-yielding plant worldwide. The term 'rubber' includes both natural rubber obtained from plant latex and synthetic rubber, but in this book it refers solely to natural rubber.

Gum

Vegetable gums, i.e. those gums obtained from plants, are solids consisting of mixtures of polysaccharides (carbohydrates) that are water-soluble or that absorb water and swell to form a gel or jelly when placed in water. They are insoluble in oils or organic solvents such as hydrocarbons, ether and alcohol.

Exudate gums are usually obtained by tapping the stem of a tree but in a few cases roots are tapped. Seed gums are those isolated from the endosperm of some seeds. Other vegetable gums can be isolated from marine algae (seaweeds) or by microbial synthesis.

The term 'gum resin' is occasionally found in literature, generally used to describe a resinous material which contains some gum. It has no precise meaning, however, and is best avoided. 'Gum rosin' is used to describe the non-volatile product obtained by distilling crude pine resin or oleoresin but here, again, the word 'gum' is used loosely and should not be taken to imply any similarity to gums as properly defined. The coagulum of some commercially important latexes such as 'chicle' and 'jelutong' is often referred to as non-elastic gum or masticatory (chewing) gum, but these are not true gums.

The wide variety of gums with commercial importance include gum arabic, ghatti gum, karaya gum and tragacanth gum. In South-East Asia, however, gums are of little commercial value.

Foremost of the exudate gums is gum arabic. Although the term 'gum arabic' is sometimes used to describe the gum from any *Acacia* species, it is strictly defined by regulatory bodies for food use as the dried exudate obtained from the stems and branches of *Acacia senegal* (L.) Willd. or *A. seyal* Delile. (Note that the explicit inclusion of *A. seyal* in the definition is fairly recent and was adopted by the Codex Alimentarius Commission in 1999). The principal producers of gum arabic are Sudan, Chad and Nigeria. Ghatti gum is obtained from *Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill. & Perr. trees in India. Karaya gum is the dried exudate obtained from *Sterculia* trees, particularly *S. urens* Roxb. from India, and tragacanth gum is obtained by tapping the taproot and branches of certain shrubby *Astragalus* spp., particularly those which occur wild in Iran and Turkey (Coppen, 1995b).

In addition to the exudate or bark gums, there are also gums obtained from seeds, such as guar gum from *Cyamopsis tetragonoloba* (L.) Taub. and locust bean (or carob) gum from *Ceratonia siliqua* L., both obtained from the ground endosperm. Other natural gums are the mucilages produced by algae (e.g. alginates, agar, carrageenan) and by bacteria (dextran, xanthan) (Lawrence, 1976).

1.1.2 Selection of species

Though the prime use of the species discussed in this volume is to provide exudate, the group is diverse and not as clearly distinguishable as, for instance, 'Timber trees' or 'Medicinal plants'. Recently, a global overview of 'Gums, resins and latexes of plant origin' which includes the exudate-producing species of South-East Asia appeared (Coppen, 1995b). 'Vegetable gums and resins' (Howes, 1949) is still much cited and although it gives a useful historical background, and discusses many of the very minor gums and resins, much of the in-

formation is now outdated. The same is true for an overview of gums and resins in the Philippines (West & Brown, 1921).
Whether a species is given an extensive entry in Chapter 2 or a brief entry in Chapter 3 depends on the present or past economic importance of the exudate. For example, *Ficus elastica* Roxb. was important for natural rubber production by the end of the 19th Century, so it has been given an extensive entry in this volume. There are brief entries for species whose exudates are or used to be used locally, or have not generally been commercialized, at least not in South-East Asia. Other plant resources with another primary use but also used for their exudate, are listed in Chapter 4, with a cross-reference to the Prosea volume in which they have been or will be treated in more detail.
Some fairly important exudate-producing plants (e.g. *Agathis* spp., *Palaquium* spp., *Pinus* spp.) are also important timber-producing species. The timber-related aspects of these species were dealt with in detail in the Prosea Handbook volume 5: 'Timber trees'. They include many *Dipterocarpaceae*, the most important timber-yielding family of South-East Asia that also yield exudate ('damar'). However, two genera have been included in this volume; *Dipterocarpus* Gaertn.f. because of its current value as exudate producer, and *Shorea* Roxb. ex Gaertn.f. (mainly *S. javanica* Koord. & Valeton) because of its importance as an exudate producer in agroforestry.

1.2 Role of exudates

1.2.1 History

Many exudates have been used since time immemorial. Amber, a fossilized resin, has been prized since Neolithic times, around 10 000 years ago. The ancient Egyptians are believed to have employed natural resins as varnishes for coffins containing mummies and the Incas of South America used Tolu and Peru balsams as embalming resins. A 9th-Century formula used to prepare an oil-based varnish included galbanum, frankincense, myrrh, mastic, sandarac and several gum exudates among its ingredients. Gum arabic in North Africa has been an article of commerce from at least the 1st Century. Benzoin has a long history, being traded as long ago as the second half of the 8th Century; it is the oldest known export item from Indonesia. In his 'Herbarium Amboinense' (written at the end of the 17th Century but not published until 1741–1747), Rumphius noted the traditional use of the exudates of *Agathis*, *Canarium*, *Dipterocarpaceae* and *Sindora* Miq. Rubber was used to make balls, bottles, crude footwear and for waterproofing fabric well before Columbus reported its use by the end of the 15th Century. Rubber was first brought to Europe in 1736 from South America. Gutta-percha was first taken to Europe in 1665 and again in 1843, when it aroused much more interest (van Romburgh, 1900). Generally, resins have been used for centuries for lighting, caulking boats, as incense in religious ceremonies and to repel mosquitoes as documented in the 15th Century. Some old terminology continues to be used today. The term 'naval stores' to describe those products obtained from the resin of pine trees (especially rosin and turpentine) originates from the days when wooden sailing ships, including naval ships, were waterproofed with pitch and tar and other resinous products from *Pinus* L. Use and international trade in resins increased during the 19th

Century as the technology for producing varnishes and other industrial products improved, as the chemistry of the natural products became better understood and as new applications were discovered. With some notable exceptions, the synthetic materials developed during the 20th Century replaced many natural resins (and latexes) and consumption declined.

Towards the end of the 19th Century various rubber-producing species were introduced into South-East Asia. The many exotic species trialled in the Botanic Gardens in Singapore in 1881–1900 included *Landolphia heudelotii* A.DC., *L. kirkii* Dyer, *L. mannii* Dyer, *L. owariensis* P.Beauv., *L. watsoniana* Vogtherr, *Saba comorensis* (Bojer) Pichon and *S. senegalensis* (A.DC.) Pichon, which are all African lianas from the *Apocynaceae*. *Manihot caerulescens* Pohl emend. D.J.Rogers & Appan ssp. *caerulescens*, *M. dichotoma* Ule, *M. glaziovii* Müll. Arg. and *M. heptaphylla* Ule (*Euphorbiaceae*) were imported, mainly from Brazil. *M. glaziovii*, which yields 'Ceara rubber', was trialled fairly extensively in Central and East Java as it can grow in relatively dry areas. The other three *Manihot* species were trialled later, but without success. In 1899, *Mascarenhasia arborescens* A.DC. (*Apocynaceae*) was introduced from the Mascarene Islands and East Africa into Singapore and Bogor Botanic Gardens (Indonesia), but the trees grew slowly, latex production was low and the quality of the rubber was poor due to its high resin content. The rubber-yielding *Sapium aubletianum* (Müll.Arg.) Huber, *S. jamaicense* Swartz and *S. jenmani* Hemsl. (*Euphorbiaceae*) from tropical America were introduced into the Botanic Garden of Singapore early in the 20th Century. *S. aubletianum* produces poisonous latex, so has no potential for commercial rubber production. In Guyana, the surface of the tapping wounds of *S. jenmani* became too irregular to repeat tapping the same piece of bark; *S. jenmani* and *S. jamaicense* have never been tapped in Singapore (Burkill, 1966; Heyne, 1927).

Among the rubber-yielding species introduced into South-East Asia was *Hevea brasiliensis* which was taken from Sri Lanka to Malaysia in 1882, and then to Singapore and Indonesia. In 1899 it produced the first rubber, which was traded on the world market. Between 1908 and 1912 during the 'rubber boom' rubber plantations expanded rapidly in South-East Asia (Hübner, 1934). It had become apparent that the quality, yield and harvesting of the rubber of this species were far superior to those all other rubber-yielding species. Therefore, the exploitation of South-East Asian plants for rubber that had become important during the second half of the 19th Century, declined rapidly after the rubber boom and the species introduced to assess their value for rubber production were also abandoned, though some were occasionally maintained as ornamentals.

Copernicia prunifera (Mill.) H.E.Moore, the 'carnuaba' or 'wax palm' from eastern Brazil, has also been tested in Malaysia, Singapore and Indonesia, but the leaves have never been exploited for their wax. The 'Chinese lacquer tree' *Rhus verniciflua* Stokes (syn. *Rhus vernicifera* DC.) was introduced into Malaysia, Singapore and Indonesia, but it failed in experimental plantations. *Sideroxylon foetidissimum* Jacq. (*Sapotaceae*), a tree of the West Indies which yields a type of chewing-gum, was also introduced into Malaysia, but with only moderate success (Burkill, 1966; Heyne, 1927).

Two endemic lianas, *Chilocarpus costatus* Miq. and *C. vernicosus* Blume (*Apocynaceae*) have been assessed for their rubber-yielding properties. However,

they can only be tapped when 10 years old and although latex production is abundant it yields only little rubber, of inferior quality. In *C. vernicosus* 74% of the solid material in the latex is resin. *C. denudatus* Blume also contains latex but has never been assessed for its rubber (Burkill, 1966).
Other exotic species that have had some impact as exudate-producing species are discussed in Chapter 3.

1.2.2 Uses

A major problem in the discussion of uses is that it is not always possible to know which ones are current and which ones have long since disappeared and are therefore only of historical interest. The existence of trade statistics for a particular exudate will give some measure of international demand and enable overall trends in usage to be quantified, but the extent (and nature) of local or domestic usage is usually much more difficult to determine.

Resin

Resinous products such as copal, damar and elemi are used extensively in the preparation of paints and varnishes. The benefit of incorporating 'Manila copal', for instance in the manufacture of paints, is much appreciated by manufacturers in South-East Asia. The resin gives a brilliant sheen and a vivid colour to the paint, which is applied on roads and traffic signs. The term 'Manila copal' arose from the time when Manila (the Philippines), was the main port exporting this resin.
Other resins are employed for medicinal purposes, the manufacture of soaps, printing inks, linoleum, plastic and waterproofing materials. Traditionally, rural people used resin as incense in religious ceremonies, against mosquitoes, as torches and for kindling fire. 'Manila elemi' has a very agreeable resinous and balsamic odour and is used at present mainly by perfumeries or the fragrance industry after distillation of the essential oil. It still finds occasional use as an ingredient in lacquers and varnishes, where it gives toughness and elasticity to the dried film. It is used locally for caulking boats and for torches. It is obtained from the trunk of *Canarium luzonicum* and is exported from the Philippines in commercial quantities.
Important natural oleoresins are the crude resins from conifers. Almost one million tonnes of crude resin are produced annually from tapping *Pinus* spp., making it by far the most important natural resin of commerce and second only to rubber of all the exudates in volume terms. On distillation, the crude resin yields turpentine and rosin. Collectively, as noted earlier, turpentine and rosin (and their downstream products) are known as 'naval stores'. More specifically, those products obtained by tapping living pine trees are referred to as 'gum naval stores' to distinguish them from turpentine and rosin obtained as by-products from sulphate pulping of pine chips ('sulphate naval stores') and the products from solvent extracting aged pine stumps ('wood naval stores'). Turpentine and rosin were originally used in unprocessed form in the soap, paper, paint and varnish industries, but today they are used mainly as precursors for the manufacture of a much wider range of products. Most rosin is modified and used in such diverse products as paper size, adhesives, printing inks, rubber

compounds and surface coatings. Turpentine, like rosin, is a very versatile material and is used mainly as a feedstock by the world's chemical industries. The α- and β-pinene constituents of turpentine, in particular, are the starting materials for the synthesis of a wide range of fragrances, flavours, vitamins and polyterpene resins and form the basis of a substantial chemical industry. Synthetic pine oil, widely used in disinfectants with a pine odour, is made from turpentine. Nevertheless, despite the greater use of downstream products the simpler, more traditional uses to which rosin and turpentine can be put can still be of value to the domestic economies of countries which have standing resources of pines, including those in South-East Asia. Such local consumption may be additional to the opportunities offered by exporting the raw materials (Coppen & Hone, 1995).

Latex

Rubber is the most important product obtained from latex. Its elasticity makes it suitable for a wide range of applications, the most important being car tyre manufacture. Car components, engineering components (e.g. mountings, flooring) and consumer products (shoes, sport goods, toys, gloves) are also manufactured from rubber.

The characteristic property of gutta-percha, the coagulated latex of a number of *Sapotaceae* genera, is its thermoplasticity: when heated it can be moulded into any form, which is retained on cooling. Today, its use is restricted to dental surgery, but it has been used widely to insulate submarine electrical cables and in golf ball manufacture. The superior quality of the gutta-percha product obtained from the leaves led to the establishment of a large gutta-percha (*Palaquium gutta* (Hook.f.) Baill.) plantation in Cipetir (West Java, Indonesia) which today is the principal source of high-grade gutta-percha. The processing, which is done at the factory on the plantation, involves chemically or mechanically extracting gutta-percha from leaves.

Before *Hevea* plantations were developed in South-East Asia, 'jelutong' (from *Dyera* spp.) was produced and exported for the manufacture of inferior rubber items, in which elasticity was not a prime consideration. With the advent of large-scale rubber production, exploitation of jelutong declined greatly but later regained importance as a basic ingredient of chewing-gum (Coppen, 1995b). Its properties also make it suitable for bubble gums. It is sometimes used in admixture with 'chicle', the coagulated latex of *Manilkara zapota*, a Central American tree. 'Sorva' is the coagulated latex of *Couma* spp. which serves as an ingredient in chewing-gums.

Gum

Common uses of gums are for cosmetics and soap, as stabilizer or emulsifier in food products (ice-creams, dairy products, sauces, jams and jellies), as paper size, and as anticoagulant compound in medicinal and pharmaceutical preparations and laxatives. Gum arabic is widely used in the manufacture of cola-type drinks and other soft drinks, for flavour encapsulation and in lithography. Gums have been extensively used as adhesives and found useful in increasing the strength of starch pastes. Emulsions of medicinal compounds, insecticides, kerosene, paraffin, neoprene and natural latex can be obtained by the addition of gums. Gum tragacanth is used in preparation of toothpastes, for coating soap chips and powders to prevent dusting and lumping, and also in hairwaving preparations (Mule, 1977). In the Philippines, *Leucaena* Benth. seed gum has been found suitable as paper size and as it is cheaper to obtain than the imported guar gum there is great potential for increased use (Pamplona et al., 1990).

1.2.3 Socio-economic aspects

The collection of non-timber forest products contributes much to local communities. In Palawan, the centre of almaciga resin or copal production in the Philippines, resin collection or tapping is a major income-generating activity of indigenous peoples, local traders and concessionaires. Resin gatherers, estimated to number 500–1000 earned monthly incomes ranging from 1470–2400 Philippine peso (PhP) (US$ 35–60) in 1996–1998. Gathering of almaciga resin is profitable (Garcia et al., 1999).

Tapping of elemi from *Canarium* on the other hand, is an additional source of income to the farmers of Quezon Province. Farmers earn at least 2000 PhP (US$ 50) as additional income per month from tapping elemi, while traders earn an average of 15 000 PhP (US$ 360) from a month's trading of elemi (1996–1998 figures) (Ella et al., 1996).

Tappers have direct links to the trees and thus hold the key to the sustainable management of the forest and the various other non-timber forest products that are collected. To ensure sustainability, tappers should use proper tapping techniques. This will not only prolong the life of trees but will also increase yield and thus the income of tappers.

In North Tapanuli (Sumatra, Indonesia) benzoin production and fruit production associated with the benzoin agroforests are major income-generating activities. Tapping of benzoin trees is a task for men, whereas the women are in charge of food crops and coffee. The same holds true for the damar forests of southern Sumatra, which bring in cash for the farmers, mainly from damar but also from other products of this agroforestry system such as fruits and timber. The exploitation of exudates in agroforestry systems implies that the farmers own the land and have complete control over it. They show responsibility over the resource, which they inherit, and they maintain it. However, if prices of the exudate are low, farmers abandon the tapping, resuming as soon as they judge prices are attractive again. Occasionally, there are disputes with the administration or timber concessionaires over borders of the land occupied by the farmers (Michon & Bompard, 1985; Watanabe et al., 1996).

It is interesting to note that cultivation and exploitation of rubber is mainly in the hands of rural smallholders: 95% in Thailand, 80% in Indonesia and 85% in Malaysia.

1.2.4 Trade and markets

An understanding of trade and markets is of prime importance to anyone contemplating setting up new industries or looking at the opportunities for improving or expanding existing ones. Plant exudates are no different to other commodities in this respect. Domestic markets are important but it is often very difficult to obtain information about them, either about the scale of domestic consumption or about the precise applications for which a particular exudate is used. If official statistics are available, international trade may be easier to assess and it may be possible to gain information on the volume and value of such trade and the destinations or origins of the shipments (according to whether export or import statistics are being examined). However, care needs to be taken in interpreting trade statistics.

Firstly, self-evidently, unofficial trade – exudates which do not pass through customs points – does not appear in trade statistics or other documented sources. Secondly, some exudates are not separately specified in the statistics of the country concerned; they are simply included under an all-embracing heading such as 'Natural gums, resins, gum resins and balsams'. If some major gums and resins *are* specified, then others may be included with 'Natural gums and resins NES' ('not elsewhere specified'). Sometimes, unfortunately, classifications are changed and items that were previously separated are included under a general heading, so making it impossible to carry out any further analysis of the trade into or out of the country concerned. Thus, in 1996, Indonesia subsumed copal, one type of damar, dragon's blood and some other gums – all of which were previously separated – under a general heading 'Gum', while other types of damar (e.g. mata kucing), frankincense and gaharu were subsumed under 'Other resin'; gutta-percha and the various types of jelutong were also put under a general heading. Thirdly, the data are only as good as the customs' returns allow. That is to say, if the exporter chooses not to describe his shipment in precise terms – for whatever reason – then it clearly will not be recorded as such and the official returns will underestimate exports. Occasionally, items are misclassified, which can result in either inflated or deflated figures, or they may be missed by anyone examining the statistics. In pre-1996 Indonesian trade statistics, for example, benzoin is misleadingly described as 'frankincense' and gum turpentine is erroneously recorded within the 'Gums' section. Finally, for those cases where exudates are re-exported from intermediate destinations, additional care must be taken in interpreting the statistics. Recorded exports of Indonesian-origin benzoin from Singapore are far higher in volume terms than the export figures from Indonesia to Singapore would suggest, but this is due to the fact that re-processing occurs in Singapore, which results in a substantial weight gain.

In all systems of customs classification, a numbering hierarchy groups commodities according to type and becomes increasingly more specific as the number of digits increases. If the commodity is a major item then it is usually specified, but otherwise it is included with similar commodities under a general heading. Most countries now use the Harmonized Commodity Description and Coding System (usually known simply as the Harmonized System (HS)) of the Customs Cooperation Council. A few countries still use the older Standard International Trade Classification (SITC) (Revision 3) of the United Nations or show the SITC number alongside the HS number. The classification numbers used by some countries for selected exudates are shown in Table 1.

The South-East Asian exudates all originate from trees. The majority of these trees also yield timber, which is often economically more important. Table 2 compares the trade in timber and exudates for a number of species.

Table 1. Gums and resins: trade classifications and descriptions for some South-East Asian countries.

	HS number	SITC number	Description
Indonesia[1]	130190110	29229110	Copal
	130190120	29229120	Damar
	130190130	29229130	Benjamin[2]
	130190150	29229150	Dragon's blood
	130190210	29229210	Resin of mata kuching[3]
	130190220	29229220	Resin of batu[3]
	130190240	29229240	Resin of pine
	130190250	29229250	Resin of frankincense[4]
	130190260	29229260	Resin of gaharu
	380610000	59814100	Rosin
	400130100	23130100	Gutta percha
	400130210	23130210	Jelutong raw
	400130220	23130220	Jelutong pressed but not refined
	400130230	23130230	Jelutong refined
	400130910	23130910	Jelutong edible
	400130990	23130990	Jelutong in other form
The Philippines	•	2922901	Copal resin (Almaciga)
	•	2922902	Elemi gum
Thailand	1301.900-014	•	Gum damar
	1301.900-034	•	Gambier or catechu
	1301.900-042	•	Gamboge

[1] Since 1996, of those exudates listed here, Indonesia only classifies separately resin of pine and rosin.
[2] Alternative name for benzoin.
[3] Other forms of damar.
[4] Main Indonesian classification for benzoin.
Sources: National trade statistics.

1.3 Properties

Knowledge on the physical and chemical properties of selected plant exudates like resins, latexes and gums is important to optimize their utilization. Understanding the factors causing variation in the quality of exudates may lead to improved utilization and wider industrial application as in the case of resins such as copal, damar or elemi for the manufacture of paints and varnishes.

1.3.1 Physical properties

Resin

Resin is either a hard and brittle solid that breaks with a concoidal fracture or, if it contains more essential oils (oleoresin), it is sticky and highly viscous. Oleoresin eventually hardens through evaporation of the essential oils and/or the process of polymerization. If water from the sap of the tree has been mixed into the resin it is opaque, otherwise it is translucent or transparent. The colour of

Table 2. Value of timber and exudate traded (million US$/year) for the important South-East Asian exudate-producing trees.

Species	Timber	Period	Exudate	Period
Agathis spp.	42.1	1988–1992	1.5	1989–1997
Canarium spp.	1.7	1984–1992	1	1996
Dipterocarpus spp.	205	1989–1992	0.5	1989–1990
Dyera spp.	11.8	1992	2.6	1988–1993
Hevea brasiliensis	333[1]	1988–1992	6000	1998
Palaquium spp.	7.2[2]	1992	0.3	1993
Pinus spp.	·	·	30[4]	1993
Shorea spp.	3800[3]	1989–1992	17	1993
Sindora spp.	4.9	1992	nil	·
Styrax spp.	nil	·	1.4[5]	1995

· No data available.
[1] US$ 318 million from rubberwood furniture.
[2] Nyatoh, of which *Palaquium* constitutes the major part.
[3] US$ 3000 million from plywood with *Shorea* as main constituent.
[4] Gum rosin and gum turpentine from Indonesia.
[5] Only from Indonesia.
Sources: Bureau of Export Trade and Promotion (the Philippines), 1997; Coppen, 1995b, 1999; Coppen & Hone, 1995; Jara, 1999; Soerianegara & Lemmens, 1993.

resin can vary from no tint at all to amber, red, yellow, green or black. Resins are generally soluble in alcohol, ether and essential oils, but usually insoluble in water; only damar is insoluble and Manila elemi only partially soluble in alcohol (Gianno, 1986).

Physico-chemical properties which are generally determined to assess the quality of resins are:

- solubility in 95% ethanol, not used for damar and Manila elemi. A high percentage of solubility indicates a high percentage of resin recovery. It also implies a higher grade or quality due to lesser amount of insolubles. The insolubles may include gummy and gelatinous substances inherent in the resin, and impurities or mixed particles of dirt such as soil and bark. For Manila copal this is the most important basis for commercial resin grading (Tavita & Palanginan, 1999).
- iodine number. This is a measure of the degree of unsaturation of the acids present in the resin. It indicates the presence of double or triple bonds in the acid structure to which oxygen is absorbed to effect drying. Unsaturated acids can absorb oxygen and iodine. The greater the degree of unsaturation, the greater is the amount of iodine absorbed.
- acid number. The acid number is a measure of the acidity of an acidic material. It is measured by the amount (in mg) of KOH required to neutralize one gram of resin. Typical acid numbers are 20–30 for damar mata kucing, about 20 for Manila elemi, 120–140 for copal, 160–170 for most types of rosin obtained from pine resin and 160–200 for Indonesian rosin. Copals are acidic in nature since they consist mostly of resin acids, rendering the resin insoluble in drying oils and incompatible with basic pigments. If copal resin is used for

paint production, it is modified chemically or through thermal processing, which significantly reduces the acid number and converts the resin to an oil-soluble product. On the other hand, resins with high acid number are more suitable for the production of paper sizing agents.

- saponification number. The saponification number is a measure of the total amount of acids and the extent of esterification, a process which renders the resin more soluble in drying oils in the manufacture of paints and varnishes. It is determined by the amount (in mg) of KOH required to saponify one gram of resin. The saponification number is therefore important in testing the purity of the sample. Any unsaponifiable matter may be considered an impurity. The ester number is a measure of the neutral components of the resin and can be calculated by taking the difference between the saponification number and the acid number.
- solubility in organic solvents. Elemis like Manila elemi, and rosin are easily and completely soluble without heating, damar is soluble in aromatic hydrocarbon solvents like benzol and toluol. *Sindora* wood-oil and the essential oil of *Dipterocarpus grandiflorus* (Blanco) Blanco are soluble in common organic solvents except ethanol. Copal is only partly soluble in organic solvents (Tavita & Palanginan, 1999).
- melting/softening point. This is a less common descriptor of resin. When determined, it is usually given as a temperature range and not as a single value, as resin is a mixture of chemical compounds.

The essential oils distilled from resins are characterized by generally accepted physical properties such as relative density, refractive index, optical rotation and miscibility in ethanol (Oyen & Nguyen Xuan Dung, 1999).

Latex

The relevant physical properties of latex are specific gravity, acidity (pH). Also of importance is the rapid coagulation of the latex after it has exuded from the tree. In the case of *Payena leerii* (Teijsm. & Binnend.) Kurz it is the latex that is collected, not the coagulated latex as is the case for many other trees producing gutta-percha. Therefore, it contains much less debris and the colour of the coagulated product is whiter. The acidity influences the stability of the latex: under acid conditions the suspension becomes unstable and the latex starts to coagulate. Fresh *Dyera* Hook.f. latex has a pH of 7, but after standing for 48 hours the pH is 5.0, which triggers coagulation. This is caused by microorganisms and enzymes found in the latex, a phenomenon also encountered in rubber latex.

Gum

Solubility in water is the most important property. Related is the viscosity of the solution of the gum: for gum arabic, for instance, the solution does not become highly viscous even at high concentrations, whereas karaya gum forms a viscous mucilage at low concentrations. The quality of a gum depends on its purity, both in terms of absence of foreign material such as bark or soil particles, as well as the absence of gums of other species.

1.3.2 Chemical properties

Resin

As indicated earlier, most resins are complex mixtures of terpenes. In the case of balsams, a significant proportion of non-terpenoids (benzoic and cinnamic acids) is present. For many resins, the terpene mixture consists of a volatile fraction (primarily containing monoterpenoids and sesquiterpenoids, i.e. C_{10} and C_{15} compounds) and a non-volatile fraction (containing mainly di- or triterpenoids, i.e. C_{20} or C_{30} compounds). For hard resins such as copal and benzoin the amounts of volatile compounds present are negligible or small and no attempt is made to separate them in any post-harvest processing from the much larger quantities of non-volatile compounds. For soft resins or oleoresins such as pine resin and Manila elemi, the volatile fraction (essential oil) forms a significant proportion of the total mass (up to 30% or more) and may be separated by steam distillation from the non-volatile part of the resin. Crude pine resin is always distilled to yield its essential oil (turpentine).

It is not only the proportions of volatile and non-volatile fractions that vary greatly amongst the different resins; the composition of the respective fractions is also very variable, both qualitatively and quantitatively. Within a genus the compositional differences between species may also be considerable. This is particularly true in *Pinus*, where the turpentine is much more variable than the non-volatile fraction. Even within a species, the composition of pine resin can vary markedly according to provenance; *P. merkusii* is a case in point: Indonesian and Thai populations have quite different turpentine compositions to Filipino ones and within the former provenances there are further significant differences. For all these reasons there is little point in trying to detail chemical compositions here, either actual, average or 'typical'; where details are available they are given in Chapter 2.

Latex

Latex can be coagulated by destabilizing the colloidal dispersion which causes the polymeric phase to separate from the liquid phase. Coagulation can be provoked by a number of chemical compounds, called 'coagulants'. The coagulated latex is the 'coagulum', the solid phase after coagulation.

The polymeric substance in rubber latex is predominantly cis-1,4-polyisoprene $(C_5H_8)_n$, whereas that in the latex of species yielding gutta-percha is trans-1,4-polyisoprene. The cis-form of the polyisoprene renders the coagulated latex elastic and rubber-like, whereas coagulum mainly consisting of the trans-form is non-elastic and similar to gutta-percha. When gutta-percha is heated, however, it can be moulded into a shape that is retained upon cooling: it is 'thermoplastic'. In addition to containing rubber and gutta-percha the latexes may contain water, resin and foreign material. The amount of these substances determines the quality of the latex: a high resin content in the latex of *Sapotaceae* decreases the quality of the gutta-percha. Processing of the coagulum is aimed at increasing the rubber or gutta-percha content by removal of the other materials.

Ultracentrifugation of natural rubber latex gives the following fractions:
- light fraction, mainly rubber: 35% (= dry rubber content or DRC),
- a thin yellow layer containing the Frey-Wyssling particles: 2%,
- a watery and clear fraction, called 'C serum' or simply 'serum': 48%,
- a heavy fraction, the 'bottom fraction': 15%.

The polyisoprenes in rubber have a very high molecular weight of 500 000–2 000 000. The particle size ranges from 15 nm to 5.6 μm.

The first main non-rubber particles are the Frey-Wyssling particles, less numerous than lutoids and mainly composed of lipid material. They are yellow or orange due to the presence of carotenoids, a by-product of polyisoprene biosynthesis.

The C serum is essentially aqueous and contains carbohydrates, inositol, nitrogenous compounds, proteins, nucleic acids, inorganic ions and metal ions.

The bottom fraction contains numerous vesicles or vacuoles, 0.5–3 μm in diameter, bounded by a semi-permeable membrane mainly consisting of lipids. The 'lutoids' are the second main non-rubber particles in fresh rubber latex. The liquid content ('B serum') causes coagulation when released from lutoids ruptured by mechanical, osmotic, chemical or electrical activity during and after tapping. This process is still under intensive research and insufficiently understood.

Fresh latex is a dual colloidal system composed of: first, negatively charged particles (mainly rubber and lutoids) dispersed in the neutral C serum containing anionic proteins; and, second, a system within the lutoid membranes comprising the acidic B serum with metallic ions (especially Mg^{++} and Ca^{++}) and some cationic proteins. The two antagonistic systems can only exist as long as they are separated by the intact lutoid membranes; release of the B serum results in interaction between its cationic contents and the anionic surfaces of the rubber particles, causing the formation of floc (Compagnon, 1986; Webster & Baulkwill, 1989).

Gum

Gums are complex mixtures of polysaccharides of high molecular weight, e.g. 240 000 for gum arabic. On hydrolysis, gums yield simple sugars such as arabinose, galactose, mannose and glucuronic acid. Gum quality varies with growing sites, individual trees and seasons, but this is still poorly understood.

1.4 Botany

1.4.1 Taxonomy

Resin

Important resin-yielding families are: *Burseraceae*, *Dipterocarpaceae*, *Leguminosae* (mainly *Caesalpinioideae*), *Styracaceae* and two coniferous families each with one important resin-producing genus, viz. *Araucariaceae* (*Agathis*) and *Pinaceae* (*Pinus*). These families are presented in Table 3 with their estimated annual world production.

Other families of some importance for resin production are listed in Table 4.

Table 3. Important resin-producing species, their origin and average world production (t/year).

Species	Product	Origin	Production
Araucariaceae			
Agathis spp.	(Manila) copal	Indonesia, the Philippines	2200
Burseraceae			
Boswellia spp.	olibanum, frankincense	Iran, Iraq, north-east Africa	3200
Canarium luzonicum (Blume) A.Gray	Manila elemi	the Philippines	350
Commiphora spp.	myrrh, opopanax	north-east Africa, Arabia	1500
Dipterocarpaceae			
Dipterocarpus spp., *Shorea* spp., *Vateria indica* L.	damar, gurjun, balau	India, South-East Asia	15 000
Leguminosae			
Copaifera spp.	copaiba balsam	Central and South America, Africa	100
Hymenaea courbaril L.	West Indian locust	Central and South America	20
Myroxylon balsamum (L.) Harms	Tolu and Peru balsam	Central and South America	10
Pinaceae			
Pinus spp.	rosin, turpentine	Worldwide (including China, Indonesia, Vietnam)	1 000 000
Styracaceae			
Styrax spp.	benzoin	Sumatra (Indonesia), Laos, Vietnam, Thailand	2000[1]

[1] Very approximate figure; could be as high as 4000 t/year.
Sources: Coppen, 1995a, 1995b, 1999; Coppen & Hone, 1995; Jara, 1999; Rehm & Espig, 1991.

Latex

Latex-producing plants are mainly restricted to a relatively small number of families, including *Apocynaceae*, *Euphorbiaceae*, and *Sapotaceae* (Table 5). The *Moraceae* do not figure in Table 5 as the products obtained from their latexes are very limited. The latex from several *Moraceae* is used locally for glues (including birdlime) and to cover and cure wounds (*Calophyllum* spp. and *Ficus* spp.) and is used on arrow tips as it has a strong cardiovascular effect (*Antiaris toxicaria* Lesch. and *Artocarpus* spp.).

Table 4. Less important resin-producing species and their origin.

Species	Product	Origin
Anacardiaceae		
Gluta usitata (Wall.) Ding Hou	Burmese lacquer	Burma (Myanmar), Thailand, Indo-China
Rhus vernicifera Stokes	Chinese or Japanese lacquer	China, Japan
Pistacia lentiscus L.	mastic	Greece (Chios Island)
Cistaceae		
Cistus ladanifer L.	ladanum	Mediterranean
Cupressaceae		
Tetraclinis articulata (Vahl) Mast.	sandarac	Algeria, Morocco
Guttiferae		
Garcinia morella (Gaertn.) Desr.	gamboge	India, Sri Lanka, Thailand, Indo-China
Hamamelidaceae		
Liquidambar spp.	storax, styrax	South-West Asia, Central America
Palmae		
Daemonorops draco (Willd.) Blume	dragon's blood	Sumatra, Borneo
Umbelliferae		
Ferula spp.	asafoetida, galbanum	Iran, Afghanistan
Xanthorrhoeaceae		
Xanthorrhoea hastilis R.Br.	accroides	Australia
Zygophyllaceae		
Guajacum officinale L.	guaiac resin	northern South America

Source: Rehm & Espig, 1991.

Gum

In South-East Asia, there are few plant species producing gums and their economic importance is insignificant. Worldwide, the *Leguminosae* is the most important family, yielding important gums of commerce such as gum arabic (*Acacia* Mill.), tragacanth gum (*Astragalus* L.), locust bean (*Ceratonia siliqua*), guar gum (*Cyamopsis tetragonoloba*, mesquite gum (*Prosopis* L.), tara gum (*Caesalpinia spinosa* (Molina) Kuntze), and tamarind seed gum from *Tamarindus indica* L. Ipil-ipil seed gum from *Leucaena leucocephala* (Lam.) de Wit is gaining importance in South-East Asia. In other families, only karaya gum from *Sterculia* L. (*Sterculiaceae*), ghatti gum from *Anogeissus latifolia* (*Combretaceae*) and kutira gum from *Cochlospermum religiosum* (L.) Alston (*Cochlospermaceae*) are important gums. Gum arabic, tragacanth gum, karaya gum and kutira gum are exudate gums, the others are seed gums. (Coppen, 1995b; Rehm & Espig, 1991)

Table 5. Main latex-producing species, their origin and average world production (t/year).

Species	Product	Origin	Production
Apocynaceae			
Dyera spp.	jelutong	Indonesia, Malaysia	3 600
Couma spp.	sorva	Amazonia	500
Euphorbiaceae			
Hevea brasiliensis (Willd. ex Juss.) Müll.Arg.	rubber	South-East Asia, West Africa	6 280 000
Sapotaceae			
Manilkara bidentata (A.DC.) A.Chev.	balata	northern South America	20
Manilkara elata (Allemao ex Miq.) Monach.	maçaranduba	Brazil	100
Manilkara zapota (L.) P.Royen	chicle	Mexico, Central America	750
Palaquium spp., *Payena leerii* (Teijsm. & Binnend.) Kurz	gutta-percha	South-East Asia	200

Sources: Coppen, 1995b; Rehm & Espig, 1991; paper on *Hevea brasiliensis* in Chapter 2.

1.4.2 Anatomy

Resin and gum ducts

Resin and gum ducts can be a normal feature in plant tissue, for instance the resin ducts in *Pinus* wood and in *Canarium* bark. Production from existing resin ducts is low, however, and exudates are usually formed by secondary resin and gum flow, i.e. by newly formed resin and gum ducts and associated tissues. Their formation is induced by microorganisms, insects, mechanical injury (e.g. tapping), and physiological disturbances. 'Gummosis', as this process is known, is thought to be a result of metamorphosis of the organized cell-wall materials to unorganized amorphous substances such as resins and gums.

Secondary resin flow is generally produced in newly formed wood after injury of the cambium. Its resin acid content is different from resin in unwounded tissue (primary resin). Numerous ducts are formed in one, sometimes more, concentric circles in the wood. These are also known as 'traumatic ducts' or 'traumatic canals' (see Photo 1). After injury, the cambium forms special groups of parenchyma cells instead of normal wood elements. At first, these cells develop schizogenously: they grow intrusively between existing cells. Soon after, the central cells of these parenchymatous groups start to disintegrate and to produce resin and this process proceeds to the periphery. In each cell the disintegration of cell walls starts in the primary wall and then proceeds towards the innermost lamella of the secondary cell wall (lysigenous development). The re-

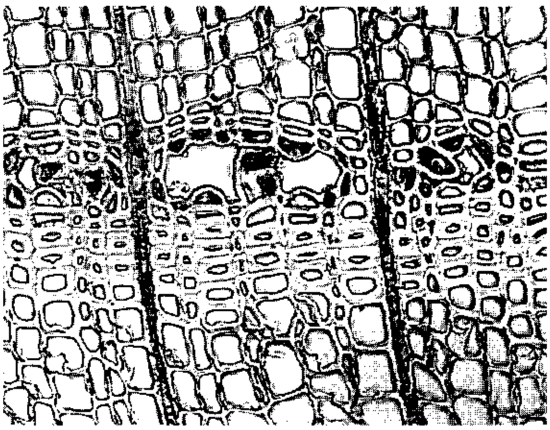


Photo 1. Traumatic resin ducts (*Tsuga sieboldii* Carrière, transverse section ×75).

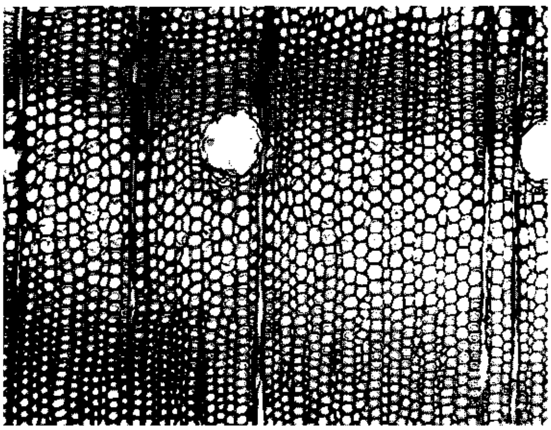


Photo 2. Normal resin ducts (*Pinus merkusii* Jungh. & de Vriese, transverse section ×40).

sulting cavity is filled with resin. As both processes are closely interlinked, this type of resin duct formation is called 'schizo-lysigene' (Tschirch & Stock, 1933).

The resin ducts of *Coniferae* have been extensively studied. In this taxon the traumatic ducts are located in the wood and are lined with epithelial cells. In some genera (e.g. *Abies*, *Tsuga* (Endl.) Carrière) epithelial cells die in the year of formation, whereas in others (e.g. *Pinus*) they remain active for several years. In the tangential plane the resin ducts anastomose extensively to form a network of ducts. They have an open connection to the wound and the resin exudes between the renewed bark and the wood exposed by the wound. More importantly, the wound stress reaches the tissues above the wound, where it induces resin duct formation in the wood for up to several centimetres above the wound. The number of resin ducts formed depends directly on the size of the wound (Hillis, 1987; Tschirch & Stock, 1933).

Normally-formed resin ducts in *Pinus* are elongated structures built of thin-walled epithelial cells surrounding an intercellular space (see Photo 2). The cross-section of this space is round, unlike that of the traumatic ducts, which are much more irregular in shape. On the outer side of the latter there is a sheath of cells of one or more layers with relatively thick walls, very rich in pectic substances. In secondary tissues, both vertical and horizontal ducts occur. The inner end of each radial duct is connected to a vertical duct of the secondary xylem, and the lumina of the two types of ducts are continuous. The vertical ducts have a larger diameter (100–200 µm) than the horizontal ones (30–50 µm) (Hillis, 1987). Radial ducts continue in the phloem, the outer end is enlarged into a cyst-like vesicle. There is no connection between the resin system of the different organs of the primary body (needles, shoots), between them and the duct systems of the xylem and between the separate systems of the xylem itself. This may explain why differences in composition of terpene fractions of resin could be detected at different heights of the trunk and between different organs and tissues. No vertical ducts occur in the phloem of *Pinus* (Fahn, 1979).

Epithelial cells produce the resin which passes into the lumen of the duct where it collects. In *Pinus*, the lipophilic droplets have been observed in the plastids, in the periplastidal and cytoplasmic endoplasmic reticulum, in the mitochondria and in Golgi vesicles of the secretory cells, suggesting that these are the locations of formation of the resin (Fahn, 1978). When the volume of resin in a duct increases it compresses the epithelial cells which, because of the reduction of their size, increases their osmotic potential. This encourages absorption of water and when this occurs cells grow larger and pressure is exerted on the resin in the duct. If the latter is ruptured, the resin is forced out, and the epithelial cells may then produce more resin to refill the duct. Obviously this procedure of emptying and refilling can best be performed in ducts lined by thin-walled cells, as found in pines (Hillis, 1987).

The amount of resin exuded when a duct is ruptured is also influenced by the length of the duct. In pines the ducts are much longer than in the other conifers and can average from about 10 cm in the centre to about 50(–100) cm in the outer sapwood layers. Pines are more sensitive to injuries than other conifers; moreover, this sensitiveness increases with the age of the tree. Many of the injuries made by insects result in greater development of ducts than do purely mechanical wounds of the same size. Wounding, pressure, and the auxins indoleacetic acid (IAA), naphthalene acetic acid (NAA), and 2,4-dichlorophenoxyacetic acid (2,4-D) induce the formation of vertical ducts, but radial resin ducts are formed after a layer of ductless wood has first been laid down (Hillis, 1987).

Gums are formed in this way in the bark of *Acacia senegal* and other *Acacia* spp. Occasionally, gums are formed in the wood, e.g. in the *Prunoideae* (*Rosaceae*), where vessels are frequently filled with gum. Here, the gum production most probably results from secretion from vessel-associated parenchyma cells.

Laticifers

A laticifer is a specialized cell or a row of cells containing latex. Two types of laticifers are distinguished based on their formation. Non-articulated laticifers arise from single initial cells in the embryo or seedling. Articulated laticifers consist of chains of cells whose adjoining walls may sometimes break down, forming tubes or vessels (Metcalfe, 1967). Both types can branch, giving rise to anastomosing laticifers, or to non-anastomosing laticifers.

Non-articulated laticifers are formed in the primary tissues and these cells extend by intrusive apical growth into intercellular air spaces. Successive mitoses which are not followed by the formation of cells make the laticifer a multinucleate cell. In the lower portion of the cell the nuclei soon disappear. Growth of the laticifer occurs only in tissues in which the cells have not lost their ability to divide. In lianas the non-articulated laticifers can become several metres long.

Articulated laticifers are formed by anastomosis of the cells in a chain which are of primary or secondary origin. The laticifers of rubber, for instance, occur in the bark, which is a secondary tissue. The end wall of such cells remains entire or becomes porous or disappears. In the latter case the final result is a large multinucleate structure which cannot be differentiated from the non-articulated laticifers. However, all laticifers of secondary origin formed by the cambium of stem or roots are articulated laticifers (Fahn, 1979).

Laticifers in wood (secondary xylem) usually extend radially in the rays (in

Apocynaceae, *Asclepiadaceae*, *Campanulaceae*, *Caricaceae*, *Euphorbiaceae* and *Moraceae*) or axially (only known in *Moraceae*).

Articulated laticifers are formed in concentric rings in the bark of the stem of *Hevea brasiliensis* and in the phloem of the root of *Taraxacum kok-saghyz* L.E.Rodin. Branching and subsequent anastomosis in these plants only occurs tangentially between laticifers of the same ring.

Non-articulated laticifers are found in the *Apocynaceae*, *Asclepiadaceae*, *Euphorbiaceae* (excluding *Hevea* Aubl. and *Manihot* Mill.) and *Moraceae*, whereas articulated laticifers occur in *Caricaceae*, *Compositae*, *Hevea* and *Manihot* (*Euphorbiaceae*), *Papaveraceae* and *Sapotaceae*.

In *Parthenium argentatum* A.Gray ('guayule', *Compositae*), latex occurs in parenchymatous cells. This is, however, the only example of laticifers that are not morphologically differentiated. In a few species, notably *Guajacum officinale* ('lignum vitae', *Zygophyllaceae*) there is rubber in the xylem.

1.5 Management

1.5.1 Production systems

Exudate-producing plants are managed either in plantations, in agroforestry systems or in natural forests (see Table 6). Apart from rubber, the only exudate for which a plantation has been established is gutta-percha: a plantation of *Palaquium gutta* was established in Cipetir, West Java, in 1885 and is still functional despite the falling demand for the product. Due to the present low demand for gutta-percha, management of the plantation is at a low level, as the plantation is sufficiently large to supply the present annual demand. It is not economically viable to intensify harvesting, which would increase production. For the same reason, old and/or poorly productive trees are not being re-

Table 6. Production systems for exudate-producing plants arranged according to decreasing economic importance.

	Increasing human impact →		
Species	**Natural forest**	**Agroforestry**	**Plantation**
Hevea brasiliensis		x	x
Pinus spp.	x	x	x
Dyera spp.	x		
Styrax spp.		x	
Agathis spp.	x		x
Canarium spp.	x	x	x
Palaquium gutta			x
Shorea javanica		x	
Dipterocarpus spp.	x		
Sindora spp.	x		
other *Palaquium* spp.	x		
Madhuca spp.	x		
Payena leerii	x		

Sources: Papers in Chapter 2.

placed and natural regeneration seems satisfactory in the present situation. Finally, note that in South-East Asia no indigenous exudate-producing plants are currently being managed intensively in plantations, primarily for their exudate.

There are plantations from which exudates are harvested, but which have another primary goal: the production of timber. This is the case of *Pinus* and *Agathis*, although pine resin is of particular economic importance in Indonesia. A century ago both genera were exclusively exploited in natural forest. Since then, exploitation of natural forest has gradually decreased because of dwindling resources and the advent of forest plantations for timber and raw material for pulp and paper manufacture. In these plantations, tapping increasingly proved to be a viable option, especially in the case of tapping *Pinus* trees a few years before felling. There are now fairly large plantations of both *Pinus merkusii* Jungh. & de Vriese and *Agathis dammara* (Lambert) Rich. in Java, where the bulk of pine resin and 'Manila copal' is produced in South-East Asia.

It is interesting to draw a parallel with the developments in rubber cultivation. Here, plantations have always been primarily geared towards latex production. A fairly recent development is that in these plantations, increased attention is being paid to another product: wood. Rubberwood is now a well-known and a well-accepted product in international trade. The parallel between this development and trends in forest plantations of the other exudate-producing trees (*Agathis* and *Pinus*) is that the plantations are becoming more multifunctional, with greater interest being shown in the various products which these trees can yield. Whether this is a general trend in landuse in South-East Asia caused by an increasing pressure on land resources cannot be confirmed here.

The natural forest in South-East Asia is generally owned by the state. In most national legislations it is considered a resource from which non-timber products may be collected by all people living in or near the forest. In the case of the harvesting of exudates, it is customary for those persons who started tapping particular trees to exert use rights over these trees for the period of tapping. Only rarely are use rights exerted over individual exudate-yielding trees which are currently not tapped. The appropriation of the rights to individual trees guarantees the sustainable use of the trees. Towards the end of the 19th Century, when many exudates were rapidly becoming important as an economic commodity, exploitation of natural forest was the rule. At that time, some exudates (e.g. gutta-percha) were harvested by felling the tree whereas others (e.g. jelutong) were tapped in such a destructive way that the trees died. The financial gain from natural forest proved to be more important than the sustainability of exudate collection. Hence the exudate-yielding species in certain tracts of forest, especially those which were easily accessible, were rapidly depleted. This was the case for *Palaquium* trees at the end of the 19th Century. As a result national legislation was endorsed to counteract this depletion. In the Philippines, for instance, exploitation permits specifying the area and the amount of resin which may be collected are mandatory for the tapping of *Agathis philippinensis* Warb. (Callo, 1995).

The case of *Styrax* in the Tapanuli region (Sumatra, Indonesia) is an instance of natural forest that has always been maintained for the collection of benzoin. Instead of natural forest being depleted, there has been a well-managed transition from natural forest to a forest with a larger proportion of *Styrax* trees.

During the transition, there was both natural regeneration and sowing or planting. Most of the production of benzoin from Sumatra currently comes from agroforests in which a number of annuals and perennials, mainly fruit trees such as durian (*Durio zibethinus* Murray), jengkol (*Archidendron jiringa* (Jack) Nielsen), petai (*Parkia speciosa* Hassk.) and kemiri (*Aleurites moluccana* (L.) Willd.) have been planted. The plantation and management of several (perennial) crops reduces the risk for farmers, as benzoin prices fluctuate (Achmad, 1998).
Another interesting case is the damar forests of Lampung Province (Sumatra, Indonesia), which are an agroforestry system producing the resin from *Shorea javanica*. In this region all the damar forests have been planted and there has been no gradual transition from natural forest to agroforest. As seed availability is irregular and seeds cannot be stored, the farmers 'store' the seedlings instead, using them both in existing damar forests as well as for establishing new ones. The management of existing damar forests is aimed at maintaining a minimum level of different development stages of the damar trees, ensuring a more or less continuous production of these individually owned agroforests. Natural regeneration is probably too unpredictable to rely on when managing the damar forests (Michon & Bompard, 1985), so only the natural regeneration of a number of other tree species yielding timber is maintained. Here too, fruit trees, mainly durian and 'duku' (*Lansium domesticum* Correa) are being introduced as a risk-minimizing strategy of the farmers (de Foresta & Michon, 1994).

1.5.2 Harvesting

Resin

Nowadays, resins like copal, damar and elemi which are intended for international markets, are obtained by tapping the tree, rather than collecting fossil resin (in the case of copals) from the ground. To obtain the copal and elemi from the living inner bark of the trunk, the bark of the trunk is incised. Fresh cuts are made at suitable intervals a few days or a week or more, gradually moving up the tree, and the exudate is collected. The size and shape of the cut and its frequency of application vary according to the country or region in which tapping is undertaken, or the tradition of the communities involved. The recommended way of tapping *Agathis* and *Canarium* trees is shown in Figure 1(1), in which a narrow horizontal strip of bark is removed above the panel without damaging the cambium (Ella & Tongacan, 1992; Ella et al., 1998a, 1998b).
Present practice in Indonesia, specifically in Java (the biggest producer and exporter of copal), is for the tapper to return to the tree to make fresh incisions every 3–4 days; up to 4 or more small tin cups may be in place at different points on the tree at any one time, depending on the size of the tree (Coppen, 1995b). In the Philippines, the second biggest producer of copal, research has been conducted on tapping methods very similar to those used in tapping pine trees (involving the use of sulphuric acid as chemical stimulant) but these methods are not yet being used commercially. Experiments have also been done on using Ethrel as a source of ethylene to stimulate resin flow, but these too have not yet been applied commercially (Ella, 2000).

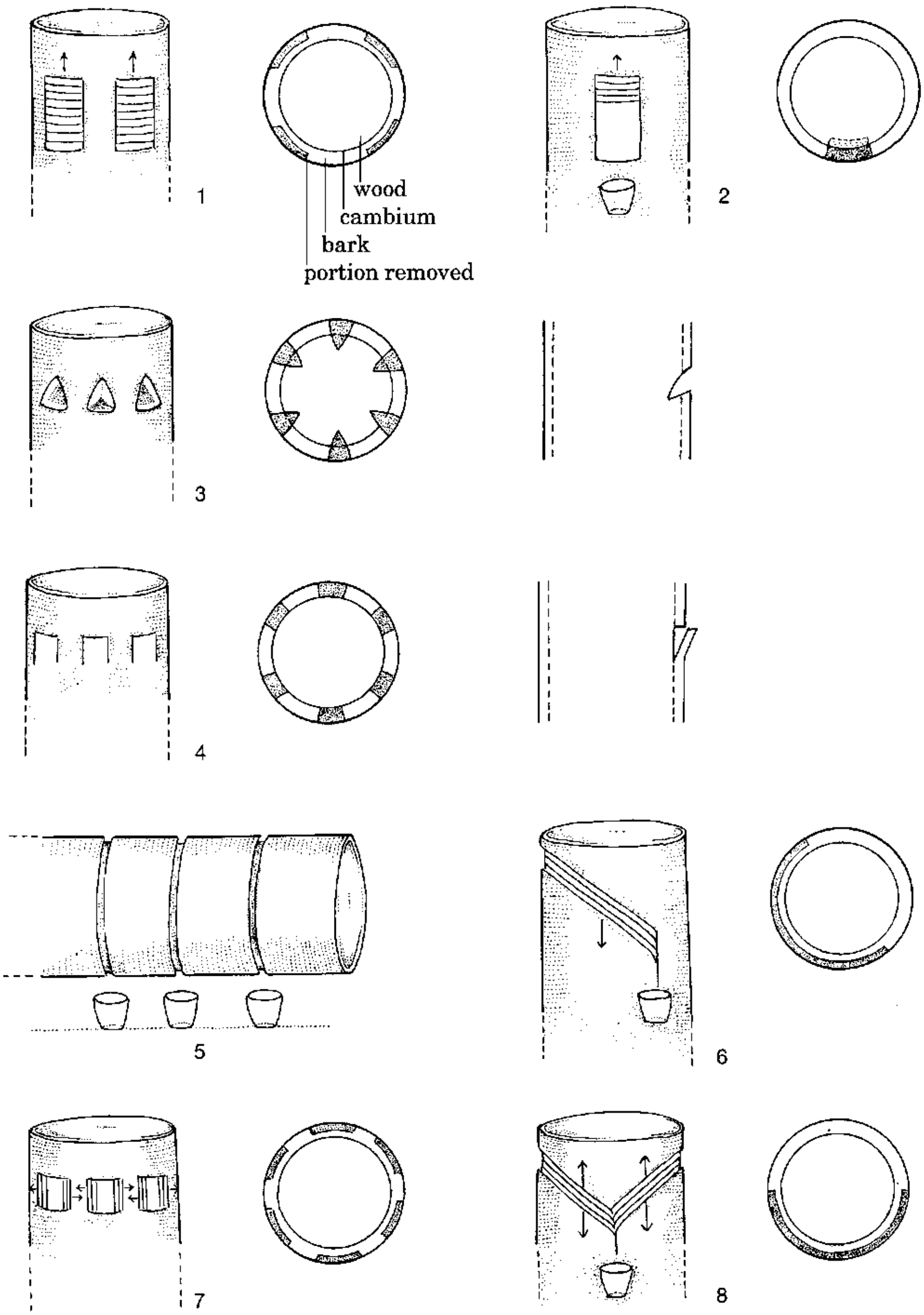


Figure 1. Schematic overview of current techniques for harvesting exudates in South-East Asia. (The small arrow indicates the direction of subsequent tappings) – 1, *Agathis*, *Canarium*; 2, *Pinus*; 3, *Dipterocarpus*, *Shorea*, *Sindora*; 4, *Styrax*; 5, *Madhuca*, *Palaquium*, *Payena*; 6, *Hevea brasiliensis*; 7, *Dyera* (*Ficus elastica*); 8, *Dyera* (*Ficus elastica*).

Crude resin from *Pinus* trees is collected in a variety of ways worldwide. Some traditional methods, as used in Indonesia for example, entail making a shallow cut into the wood every 3–4 days. The panel opened is enlarged at every consecutive tapping by removing a narrow strip of bark and a little sapwood above the panel as indicated in Figure 1(2). In many other countries, 'bark chipping' methods are used, which involve removing a small strip of bark from the stem and applying an acid stimulant, either as a liquid spray or as a paste. The stimulant does not increase the biosynthesis of resin but simply keeps the resin ducts open for longer. In this way the tapper only has to return to the tree to repeat the treatment every 1–2 weeks. In China an alternative method is used in which small channels are cut into the xylem in a V-shape or 'herringbone' pattern, while in India a similar 'rill' method of tapping is used, involving the use of an acid stimulant. In all cases, a small container is fixed to the tree, into which the soft resin runs and accumulates. If carried out correctly none of the tapping methods used, or the use of acid, are damaging to the tree.

Damar is obtained from the wood of *Dipterocarpaceae* (e.g. *Dipterocarpus*, *Shorea*) which are tapped by cutting holes in the stem ('boxing') in which the resin can collect (Figure 1(3)). Once again, the number of holes and the frequency of harvesting, scraping the holes and enlarging them vary with species and region (Torquebiau, 1984). Often, fire is used to stimulate the flow of the resin. *Sindora* wood oil is harvested in the same way.

Figure 1(4) shows the particular way in which *Styrax* is tapped: a small tongue of bark is loosened up to the cambium. The resin exudes from the rays in the wood and collects behind the tongue, which is cut off after the resin has solidified. The same tree can be tapped again by gradually moving upward along the stem.

To counter the detrimental effects of traditional tapping methods, the Forest Products Research and Development Institute (FPRDI) in the Philippines has produced guidelines for the proper tapping of 'almaciga' resin (*Agathis philippinensis*) and elemi (*Canarium* spp.) (Ella et al., 1998a, 1998b). The FPRDI group has already conducted a number of training sessions for resin tappers all over the Philippine archipelago. The tappers learn improved tapping and harvesting techniques to prevent too deep tapping, overtapping by opening too many and/or too large panels, too frequent tapping, and resin contamination with e.g. bark and dirt. The training sessions have been welcomed by both almaciga and *Canarium* resin licensees, and the tappers are keen to learn the improved techniques that enable them to preserve the resin-producing trees which have for so many years been providing them with a source of livelihood.

Latex

The techniques for collecting latex differ according to the plant sources. Most latex-producing species, however, are tapped by making series of cuts around the trunk and removing the bark, as is the case for chicle, jelutong, sorva, and gutta-percha. This practice however, is indiscriminate and inflicts great damage to the trees, especially in the case of gutta-percha. The traditional method of harvesting the gutta-percha latex depicted in Figure 1(5) shows a felled tree with rings cut into the bark and with cups placed underneath to collect the exuding latex. With the threat of extinction of the gutta-percha trees and disappearance of the gutta-percha industry, attention has finally focused on more effective and less destructive methods, such as the one evolved in Singapore, Sumatra, Java, and Borneo which involves extracting gutta-percha from the leaves with a chemical or mechanical process. The superior quality of the product obtained from the leaves led to the establishment of a large gutta-percha plantation in Java, which is now the principal source of high-grade gutta-percha.

The latex of the para rubber tree is harvested by tapping the bark without damaging the cambium. Using a V-shaped tapping knife, grooves are cut at an angle of 30° with the horizontal. At each consecutive tapping a thin slice of bark is removed. The latex runs along the groove into a vertical groove which transports the latex via a metal spout to a cup (Figure 1(6)). After 5–6 years of tapping the panel is 150 cm high; in smallholdings, however, bark consumption is much greater. Stimulants are increasingly being applied in rubber plantations, to decrease the dependency on labour which is in short supply.

The tapping of *Dyera* trees for their latex is shown in Figures 1(7) and 1(8): in both cases only bark is removed, without damage to the cambium. The tapping panel in Figure 1(7) is enlarged horizontally until the edges meet up. The V-groove in Figure 1(8) is enlarged vertically in both directions and a cup is needed to collect the latex.

Ficus and *Madhuca*, *Palaquium* and *Payena* trees are not retapped, because the laticifers are not anastomosing and the latex that is harvested is what drains from the immediate vicinity of the place where the bark has been removed. *Ficus elastica* used to be tapped similar to the techniques indicated in Figure 1(7) and 1(8), but without enlarging the tapping panel.

As can be clearly seen from Figures 1(6),(7),(8), techniques for tapping latex entail removing the bark, but never up to the cambium, thus pathogens do not get easy access to the wood. The undamaged cambium can form new bark tissue which may be tapped again.

The relationship between the tissues tapped and the type of exudate is given in Table 7 for the South-East Asian trees dealt with in this book.

Table 7. Classification of exudate-producing plants according to tissue tapped and type of exudate.

Exudate	Bark	Wood
Resin	*Agathis* *Canarium* *Hymenea courbaril*	*Dipterocarpus* *Pinus* *Shorea javanica* *Sindora* *Styrax*
Latex	*Dyera* *Hevea brasiliensis* *Ficus elastica* *Madhuca* *Palaquium* *Payena*	

Sources: Papers in Chapter 2.

Gum

Exudate gums are usually, but not always, obtained by tapping the trees. In Sudan, *Acacia senegal* (in natural stands or in 'gum gardens') is tapped, but the gum arabic from *A. seyal* is collected from natural exudation. In Sudan, tapping methods have been developed which do not damage the trees and normally begin when the trees are just starting to shed their leaves. Traditional methods of making small incisions into the tree with an axe have largely been replaced by one which uses a specially designed tool, a 'sunki'. This has a metal head fixed to a long wooden handle. The pointed end of the head is pushed tangentially into the stem or branch so as to penetrate just below the bark, and then pulled up so as to strip a small length of bark longitudinally from the wood. Damage to the wood should be minimal. Several branches are treated in a similar manner at one tapping. In subsequent years, the other branches on the opposite side of the previously treated branch are tapped (Coppen, 1995b).
Drops of gum accumulated on the exposed surfaces after tapping are left to dry and harden. It is recommended that hard pieces of gum be picked off by hand and not by knocking them off onto the ground, where they can pick up dirt. Whenever possible, gums should be placed in an open container; the use of plastic bags increases the risk of mould formation.
In the case of *Astragalus*, gum is produced in the taproot and when the root is cut, it exudes rapidly and the exudate hardens into the characteristic ribbons of tragacanth. The process of tapping entails clearing the earth away from the taproot and making one or two cuts into the upper part of the root.
Unlike exudate gums obtained from the trunk of trees, where the sunlight shining on the tree increases gum flow, most exudation of tragacanth occurs at night, under conditions which minimize the drying out of the gum and maintain the outward flow under high osmotic pressure.

1.6 Processing

Resin

The primary processing of collected resin entails a preliminary cleaning (picking over by hand and, less commonly, sieving to remove foreign matter such as pieces of bark). Sorting and grading is common practice and is carried out by hand and/or sieving. When grading benzoin, special care is taken not to break the whole 'tears' of the resin, which are the most highly valued form of benzoin. Crude pine resin cannot be used in its original form and is rarely exported as such. The distillation of crude pine resin to obtain rosin and turpentine can be considered part of 'primary processing'. The oleoresin of *Dipterocarpus* is filtered locally in gunny sacks to clean it and to partially remove the non-volatile fraction which is more viscous and remains behind.
Much of the Sumatra benzoin which enters international trade has undergone secondary processing. 'Block benzoin' consists of pale pieces of damar embedded in a much darker matrix of low quality benzoin. Occasionally, pieces of high-quality benzoin ('almonds') are used instead of damar. The blocks are made according to a well-tried formula that involves cooking the mixture briefly in hot water. After cooling, the mass solidifies and is made into blocks

that are easy to transport and handle. Damar acts as a binder, it improves the burning quality as does the presence of powdered bark, although the scent of damar is inferior (Coppen, 1995b; van de Koppel, 1950).

The value-added processing of resin may consist of purification by ethanol, or hydrocarbon solvent extraction to improve its quality for lacquer and varnish manufacture. Distillation of resin or oleoresin may yield valuable essential oil, as is the case for pine resin and elemi.

In the Philippines, the major application of almaciga resin is in the manufacture of varnish and paint by the cottage industry and small furniture makers. Value-added processing entails the pulverization of the raw almaciga resin, which is then dissolved in 95% ethanol. The solution is filtered to remove impurities and insolubles. The clean resin solution is heated at 60°C for 30 minutes, cooled, and is then ready for packing (Tavita & Palanginan, 1999). Modifying almaciga resin chemically or through thermal processing significantly reduces its acid number, usually by the preparation of copal esters, and renders it oil-soluble (Gonzales et al., 1991).

Value-added processing of 'pagsahingin' (resin from *Canarium asperum* Benth.) for paint production involves heating the raw product with xylene. The solution is screened and filtered to remove impurities. The clean solution is distilled to separate the solvent and the 'modified pagsahingin resin'.

Latex

Primary processing of the latex like gutta-percha entails pressing the partially formed coagulum into blocks after first softening it in hot water and removing larger pieces of foreign matter. The blocks are then transported to the factory for further processing; if they need to be stored for any length of time before transportation they are best kept under water to avoid spoilage by aerial oxidation (van Gelder, 1950; Williams, 1963).

Preparation of purified gutta-percha involves chopping the blocks of crude material into small pieces, removing the resinous (non-gutta) fraction by dissolution in cold petroleum spirit, and then dissolving the remaining, separated gutta fraction in hot petroleum spirit. The hot extract is drained from any insoluble and foreign matter and then allowed to cool, whereupon the purified gutta-percha separates out. After separation and distillation of residual solvent the hot, plasticized gutta is rolled into sheets and stored, either in the dark in well sealed tins, or in water.

Solvent extraction of gutta from harvested leaves follows the same principles as above, but involves pulverized leaf material instead of chopped crude gutta-percha. Bleaching earth is added to the hot mixture to remove unwanted leaf pigments.

An alternative method of processing the leaves involves digesting the leaf pulp in hot water, and collecting the coagulated latex which separates out and pressing it into blocks.

Rubber latex is filtered and bulked on arrival at the factory. Generally, it is coagulated with formic acid in tanks. To produce sheet rubber the coagulated latex is then milled through pairs of rollers, the last pair of which are ribbed. The milled sheets are dried in a smoke house for several days to produce ribbed smoked sheets ('RSS'). If crêpe rubber or air-dried sheets are required, the co-

agulated latex is milled using crêpers to produce a well-knitted thin crêpe. After milling, the crêpe can be dried in hot air rooms.
After being softened by grinding or by dissolving in a suitable solvent, the rubber is compounded with other ingredients. The compounds added are for instance carbon black, a filler to increase wearing resistance, whiting for stiffening, antioxidants, plasticizers (usually oils, waxes, or tars), accelerators and vulcanizing agents. After the compounded rubber has been sheeted, applied as coating or moulded, it is vulcanized.
Most commercial rubbers are diene polymers. These rubbers deform readily when the randomly coiled chains extend due to rotation about C-C bonds in the polymer backbone. However, slippage of chains gives unlimited extension, the sample gets thinner and eventually breaks. Vulcanization involves the formation of chemical crosslinks between neighbouring chains, thereby preventing chain slippage, limiting extension and ensuring that the original dimensions are recovered on removal of the load. Vulcanization is effected by heating the rubber up to 140–170°C with sulphur, one or more organic accelerators, a metal oxide (ZnO) and an organic acid (stearic acid). It comprises a complex sequence of parallel and consecutive reactions. Many different formulations are used, the properties of the product being a function of the particular recipe. Vulcanization can be applied in moulds (e.g. in car tyre manufacture) where the transfer of heat is more favourable than in the case of 'boiler vulcanization' (e.g. with hot air). Non-vulcanized rubber is sticky and rapidly becomes hard and brittle (Compagnon, 1986).
Although the invention of the vulcanization process is ascribed to Charles Goodyear in the year 1839, in Ancient Mesoamerica (by 1600 B.C.) people were already making rubber articles like solid balls, important in religious ball games, and hollow human figures and bindings. They applied the juice of 'morning glory' (*Ipomoea alba* L.) to the latex of *Castilla elastica* Sessé to make rubber articles elastic and tough, but still workable. Morning glory also contains sulphur compounds that are capable of cross-linking the latex polymers and introducing rigid segments into the polymer chains. Today, local communities in Chiapas, Mexico still process rubber using the same methods as recorded by the Spanish observers in the 16th Century, i.e. mixing the latex with the juice of *Ipomoea alba* (Hosler et al., 1999).

Gum

Gums such as gum arabic are often further processed into kibbled and powdered forms after they have been imported into the consumer countries. Kibbling entails passing whole or large lumps of gum through a hammer mill and then screening it to produce smaller granules of more uniform size. These pieces dissolve more easily in water, and under more reproducible conditions, than the raw gum and so are preferred by the end-user.
Powdered gum may be produced kibbled, or by a process known as spray drying. This results in a high-quality, free-flowing powder with even better solubility characteristics than kibbled gum. The gum is dissolved in water, filtered and/or centrifuged to remove impurities and, after pasteurization to remove microbial contamination, the solution is sprayed into a stream of hot air to promote evaporation of the water. By altering atomizing conditions, powder can be

produced with varying particle sizes and bulk densities, according to the end-user's requirements. Spray drying is an energy-intensive process and this, together with the requirements for large quantities of pure water, puts it beyond the reach of most gum arabic producers. The difficulty of handling large volumes of aqueous solution of gum in a producer country – where ambient temperatures are high – without suffering unacceptable increases in the microbiological load aggravates the problem (Coppen, 1995b).

1.7 Genetic resources and breeding

In the past, the large-scale collection of lucrative exudates seriously endangered the tapped species as it often disrupted traditional management systems of the resource, which aimed at a reasonably steady supply. The destructive harvesting of the latex of *Sapotaceae* (*Madhuca*, *Palaquium* and *Payena*) by felling the tree is another example of genetic diversity being reduced by the simple fact that the number of individuals is reduced. Currently, regulations are such that valuable trees as those yielding exudates are protected and their felling is often prohibited. As many exudates are collected from trees in natural forest, their genetic diversity depends on this ecosystem. If forest is selectively logged or cleared for activities such as agriculture, industrial development or mining, the genetic resource base of the trees yielding exudates is considerably narrowed or completely eliminated.

Ex situ conservation is important for those species managed in plantations or in agroforestry systems. In the case of *Styrax*, because the trees are planted or deliberately maintained in a forest, there is some degree of selection of better-yielding individuals. However, the extent of selection is difficult to assess. The resin-yielding *Agathis* and *Pinus* species have been included in international provenance trials with the intention of improving timber production. Areas of particular interest to any of these species have been identified and the conservation of these sites has been recommended. In Indonesia seed orchards of *Pinus merkusii* have been established (Soerianegara & Lemmens, 1993).

Around 1910, at the time of the 'rubber boom' in South-East Asia, breeding activities were started to improve rubber latex production. The first step was clonal propagation by budding, as it was realized that the yield per tree was very variable. Today, there are many clones that yield 6 times what the first plantation trees in South-East Asia yielded. It is increasingly being recognized that rubber breeding should focus not only on yield but also on other desirable characteristics, such as vigour, quality of virgin and renewed bark, colour and stability of latex, resistance to leaf and bark diseases and to wind damage and timber volume produced (Webster & Baulkwill, 1989).

Breeding programmes have also been initiated for *Agathis*. The 3 main objectives of a programme in Indonesia are: improving wood quality and production, improving copal quality and production, and improving resistance to diseases and pests.

1.8 Research and development

The main organizations conducting research and development on exudate-producing plants are:

Indonesia

- Research and Development Centres, Forestry Research and Development Agency (FORDA), Ministry of Agriculture and Forestry, Bogor
  - research on propagation, diseases and pests, ecology and post-harvest handling of *Pinus merkusii*
  - propagation of *Agathis dammara*
  - ecology of *Shorea javanica*
  - post-harvest handling of *Dyera*
- Indonesian Rubber Research Institute, Medan
  - agronomy, soil research, breeding, diseases and pests, processing and socio-economic aspects of *Hevea brasiliensis*
  - latex properties of *Ficus elastica*
- Faculties of Agriculture and Forestry, Bogor Agricultural University, Bogor
  - ecology, seed viability, management, diseases and pests, tapping of *Pinus merkusii*
  - propagation and properties of *Dyera*
  - diseases and pests and resin purification of *Shorea javanica*
  - conservation of *Sindora sumatrana* Miq.
- SEAMEO Regional Centre for Tropical Biology, Bogor
  - seed dormancy and natural regeneration of *Agathis*
  - seed technology, diseases and pests, genetics and silviculture of *Shorea javanica*
- Research Unit for Plantation Crops Biotechnology, Agency for Agricultural Research and Development (AARD), Ministry of Agriculture and Forestry, Bogor
  - biotechnology of *Hevea brasiliensis*
- Other universities and research institutes
  - diseases and pests, ecology, progeny tests, tapping, resin technology of *Pinus merkusii*
  - site requirements of *Shorea javanica*
  - post-harvest technology, growth of *Dyera*
  - seed viability of *Agathis labillardieri* Warb.
- Center for International Forestry Research (CIFOR), Bogor
  - research projects on *Shorea javanica* and *Styrax*
- Perum Perhutani, Jakarta
  - responsible for production of copal (from *Agathis*) and pine resin (from *Pinus merkusii*)
  - tapping methods for *Pinus merkusii*

Malaysia

- Forest Research Institute Malaysia (FRIM), Kepong
  - utilization and properties of *Dipterocarpus* wood-oil
  - utilization of jelutong (*Dyera*)

- Malaysian Rubber Board, Kuala Lumpur
  - all aspects of rubber cultivation, processing and utilization, especially new applications of rubber
- Universiti Putra Malaysia (UPM), Serdang, Selangor
  - properties of wood-oil from *Dipterocarpus*
  - rubber utilization
  - new applications of pine resin, rosin and turpentine (*Pinus*)
- Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor
  - rubber utilization

The Philippines

- Forest Products Research and Development Institute (FPRDI), Department of Science and Technology, College, Laguna
  - improved tapping systems for *Agathis philippinensis*, *Canarium luzonicum*, *Pinus* and *Dipterocarpus*
  - stimulant use in tapping, resin properties and application of *Agathis philippinensis* resin in end products
  - application of *Canarium luzonicum* oleoresin in end products
  - use of natural resin in paper size, and in rubber-based adhesives
- University of the Philippines at Los Baños, College of Forestry and Natural Resources, Department of Forest Products and Paper Science, College, Laguna
  - establishment of a plant for semi-commercial production of *Agathis philippinensis* resin varnish
  - physico-chemical properties of resin, rosin and essential oils use of *Canarium luzonicum* oleoresin in paints
- Philippine Industrial Crops Research Institute, Philippine Rubber Testing Centre, University of Southern Mindanao, North Cotabato the following aspects of *Hevea brasiliensis*:
  - propagation
  - nursery techniques and management
  - tapping technology and yield
  - diseases and pest control
  - latex processing and equipment
  - germplasm collection, evaluation and breeding
- Regional Research Centres of the Department of Agriculture
  - all agricultural aspects of *Hevea brasiliensis* cultivation
  - propagation of *Pinus*, *Shorea*, and *Canarium*

Thailand

- Rubber Research Institute Thailand
  - *Hevea brasiliensis*
- Rubber Estate Organization, Nabon Station, Nakhon Si Thammarat
  - rubber processing
- Office of the Rubber Replanting Aid Foundation, Bangkok
  - introduction of high-yielding varieties of *Hevea brasiliensis*
- Songkla Rubber Research Center, Songkla
  - rubber processing

- Faculty of Natural Resource, Department of Plant Science, Prince of Songkhla University, Songkhla
  - genetic modification of *Hevea brasiliensis*
- Faculty of Forestry, Kasetsart University, Bangkok
  - rubberwood production

Cambodia

- General Directorate of Rubber Plantation, Phnom Penh
  - *Hevea brasiliensis*

Vietnam

- Rubber Research Institute of Vietnam
  the following aspects of *Hevea brasiliensis*:
  - soil research and classification
  - plantation establishment
  - diseases and pests control
  - post-harvest handling
  - processing
  - germplasm collection
  - extension in agronomy and rubber quality

In the other countries, research is being done, mostly on *Hevea brasiliensis*. In Laos, provenance trials aimed at identifying superior resin-yielding trees of *Styrax tonkinensis* and tapping trials aimed at optimizing harvesting methods, established in 1997 with FAO assistance, are continuing to be monitored and evaluated with EU support.

1.9 Prospects

It has already been pointed out that in the last 100 years the use of many of the species that were once important sources of resins, latexes and gums in South-East Asia has declined. Most of the decline is attributable to the availability of cheaper, technically superior synthetic alternatives. The production of synthetics is not constrained by the vagaries of the weather or the uncertain productivity of the natural resource. The quality, too, is more consistent and can be varied at will according to the requirements of the end-user. However, it would be wrong to be over-pessimistic about future prospects; there is some cause for optimism. The two most important exudates (rubber and pine resin) continue to be produced from natural sources and this will remain so for the foreseeable future. Other exudates such as copal, damar and benzoin, retain substantial markets and the fact that several major projects involving them have been undertaken in the region in recent years demonstrates the importance that is attached to them by governments and international organizations. For those exudates (such as gum arabic and the chewing-'gums') which have a food or pharmaceutical use, the 'naturalness' of the natural material is a powerful selling point.

Rubber is a very large export commodity for Malaysia, Indonesia, Thailand and

Vietnam and its prospects are promising: demand is expected to rise. Moreover, the added revenues from rubberwood will strengthen the economic viability of rubber cultivation. Demand for gum turpentine and rosin, the primary products of crude pine resin, is also buoyant, although it is influenced by factors other than those related to the use of synthetics, namely the availability of supplies from China (the leading producer of gum naval stores) and the supply of sulphate turpentine and tall oil rosin as by-products from pulping (sulphate naval stores). Demand and economic circumstances permitting, Indonesia has the potential to increase its production of turpentine and rosin if it chooses to tap larger numbers of pine trees.

With the exception of rubber, the exudates produced in agroforestry systems are of minor importance to the national economies in South-East Asia, but in some areas they are very important to the local communities. In recent decades the price fluctuations of exudates produced in agroforestry systems such as damar and benzoin gardens have had direct influence on the intensity of exudate collection. When exudates command low prices or are temporarily not traded at all due to periods of political unrest or war, farmers shift their attention to other components of their gardens, such as fruit trees. It is precisely this flexibility that sustains the production system from which exudates can be collected.

2 Alphabetical treatment of genera and species

Agathis Salisb.

Trans. Linn. Soc., London 8: 311, t. 15 (1807).
ARAUCARIACEAE
x = unknown; *A. borneensis*: $2n = 26$

Major species and synonyms

- *Agathis borneensis* Warb., Monsunia 1: 184, t. 80 (1900), synonyms: *A. beccarii* Warb. (1900), *A. alba* Foxw. (1909), *A. latifolia* Meijer Drees (1940).
- *Agathis dammara* (Lambert) Rich., Comm. bot. Conif. Cycad.: 83, t. 19 (1826), synonyms: *A. loranthifolia* Salisb. (1807), *A. celebica* (Koord.) Warb. (1900), *A. hamii* Meijer Drees (1940).
- *Agathis labillardieri* Warb., Monsunia 1: 183 (1900).
- *Agathis philippinensis* Warb., Monsunia 1: 185, t. 8E (1900), synonyms: *A. regia* Warb. (1900), *A. dammara* auct. non (Lambert) Rich.

Vernacular names General: kauri, kauri pine (En). Pin de kauri (Fr). Brunei: bindang, tulong. Indonesia: damar (Java), damar sigi (Sumatra), damar bindang (Kalimantan). Malaysia: damar minyak (general), mengilan (Sabah), bindang (Sarawak). Papua New Guinea: kauri pine. Philippines: almaciga (general), bidiangao (Negros), bagtik (Palawan). Thailand: son-khaomao (Bangkok).

- *A. borneensis*: Brunei: bindang. Indonesia: bembueng (south-eastern Kalimantan), damar pilau (Dayak, Kalimantan), hedje (Sumatra). Malaysia: damar minyak (general), bindang (Sarawak), tambunan (Sabah).
- *A. dammara*: Indonesia: damar raja (general), kisi (Buru), salo (Ternate). Philippines: dayungon (Samar).
- *A. labillardieri*: Indonesia: kayu damar putih (general), kessi, fuko (Irian Jaya). Papua New Guinea: New Guinea kauri.
- *A. philippinensis*: Indonesia: goga, solo (Sulawesi). Philippines: almaciga (general).

Origin and geographic distribution *Agathis* is the most tropical genus of the *Coniferae* and the number of species varies with the species concept: the narrow concept recognizes 21 species, the wider concept only 13. Its natural distribution is from Peninsular Malaysia, Sumatra, Borneo, Sulawesi, the Moluccas, the Philippines, New Guinea and New Britain towards western Australia, the Solomon Islands, New Caledonia, Vanuatu, Fiji and northern New Zealand. It has been hypothesized that *Agathis* invaded the Malesian Archipelago and the Melanesian Islands from two Gondwanic centres, northern Queensland and New Caledonia, and that speciation has since occurred. If a narrow species concept is adopted, a third centre can be recognized in Borneo. The oldest fossil records date from the Upper Cretaceous of New Zealand and the Jurassic of Australia. *Agathis* is cultivated as a plantation tree and used in enrichment planting and reforestation in various areas within its natural range, especially in Irian Jaya. *A. borneensis* occurs in Peninsular Malaysia, Sumatra and Borneo. *A. dammara* occurs naturally in the Philippines (Palawan and Samar), Sulawesi and the Moluccas and is planted on a fairly large scale in Java. *A. labillardieri* occurs naturally and planted in western and central New Guinea. *A. philippinensis* occurs naturally in the Philippines, Sulawesi and the northern Moluccas.
Outside its natural range, *Agathis* has been planted in Java, India, Mauritius, tropical Africa, South Africa and Central America.

Uses The inner bark of *Agathis* exudes a translucent or clear white resin which is called 'copal' or 'Manila copal'; 'almaciga resin' is the copal from *A. philippinensis*. Manila was once the most important port of export, hence the name Manila copal. This resin used to be very important as a raw material for varnish as it has good storing quality, and the varnish film is very lustrous, elastic, and has good weathering properties. It has been used in oil and spirit varnishes, lacquers, paper size, paint driers, linoleum, oilcloth, waterproofing compounds, printing inks, adhesives, floor polish, shoe polish and for fluxes. Today, its major use is as a varnish for wood and paper. It is still used in road-marking reflector paints. Local applications of the resin are as varnish, incense, fuel for lamps and torches, sealing wax, as a liniment, as an unguent to deter leeches, smudges against mosquitoes, and in the manufacture of patent leather.
There are several identified uses of *Agathis* wood such as in the manufacture of veneer and plywood, sawn timber, furniture, panelling, musical instruments, pencil slats, carvings, toys, engineering instruments, household utensils, artificial limbs, and prostheses.

Production and international trade Indonesia is by far the biggest producer and exporter of Manila copal. In 1926 the world production of Manila copal was 18 000 t, 88% of which came from Indonesia, 7% from the Philippines and 5% from Sabah. In 1987 the export of Manila copal from Indonesia was still 2650 t (with a value of US$ 1.7 million), but over the period 1989–1993 exports fell to a remarkably constant level of about 1850 t. Exports in 1995 amounted to 1528 t. In 1982 Sarawak exported just over 50 t. Since then, Malaysia has exported only very small quantities. Production from natural stands and plantations of *A. labillardieri* in Irian Jaya amounts to several hundred tonnes of copal annually; the average annual export from Irian Jaya in 1954–1958 was 587–748 t. In 1977 the Philippines exported a total of 778 t of Manila copal worth US$ 325 000, in 1984 522 t worth US$ 237 000, in the period 1993–1997 the average annual export was 360 t worth US$ 261 000, and in 1998 355 t were exported with a value of US$ 254 000. The area planted with *A. dammara* in Java is estimated to be about 8500 ha.

Most Indonesian copal and some from the Philippines is shipped via Singapore. Germany (which also imports directly from Indonesia) is the major onward destination in Europe. India and Japan import modest quantities directly from Indonesia, whereas Taiwan is the largest importer of copal from the Philippines.

Copal from *Leguminosae* has also been exported from Africa (from *Copaifera* spp., *Hymenaea verrucosa* Gaertn. and South America (*Hymenaea* spp., notably *H. courbaril* L.).

Properties Manila copal is a translucent or clear white resin, slowly hardening on exposure to a white or yellow to dark brown, hard, ultimately brittle mass. *A. labillardieri*, however, also yields a copal which remains soft ('papeda' or 'Papua syrup').

Generally, three types of Manila copal are distinguished:

- 'bua': a very hard, fossil or semi-fossil resin dug from the ground, probably originating from the roots, or collected from forks in the trees;
- 'loba': a readily hardening copal obtained by tapping;
- 'melengket': a copal remaining somewhat soft with a hard exterior, obtained by tapping.

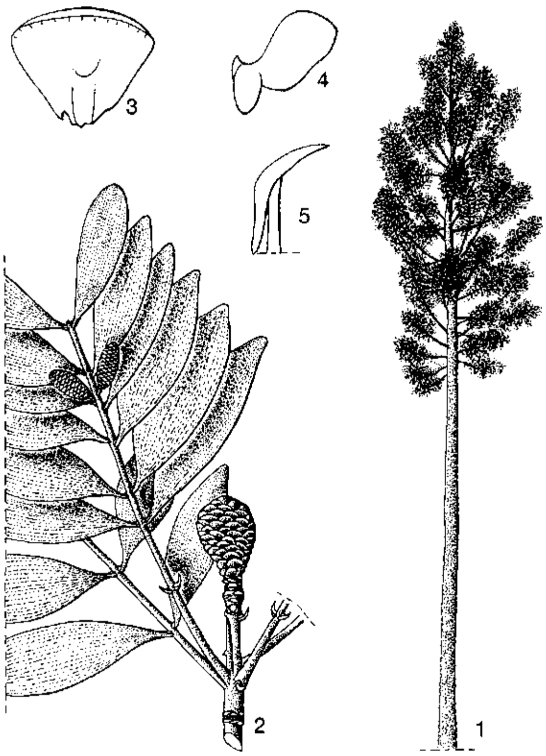
Whether a tree yields 'loba' or 'melengket' copal depends on the species and not on the time between tapping and harvesting. The hardening of the resin is caused by evaporation of the essential oils in the resin and oxidation of other compounds. The oxidation process is accelerated when the copal is exposed to light. It is also a measure of the extent of polymerization. One authority states that the copal should be allowed to harden on the tree, as when it is not left on the tree the resin hardens less and yields another product. This phenomenon has not yet been explained.

The resin is a complex mixture of monoterpenes, sesquiterpenes and diterpenes and contains dammaric acid and dammaran. The following monoterpenes have been demonstrated: limonene in *A. labillardieri* copal and the unstable myrcene in *A. borneensis* copal. The monoterpenes α-pinene, β-pinene and limonene are found in almaciga resin. The diterpenes in Manila copal are agathal acid, agathol acid and agathis-dicarbon acid; they are present in amounts of 13.5% in hard copal and 6.8% in soft copal. Recent resin and young fossil resin contain 1–11% turpentine. The resin is soluble in ethanol and acetone, but partly soluble in petrol, benzene, terpuntine, and chloroform. The compounds found in the ethanol-soluble fraction are 9% sandaracopimaric acid, 8% acetoxyagathol acid and 38% agathal acid. 'Melengket' dissolves easily in ethanol, whereas 'loba' dissolves only partly. The solubility in alcohol does not depend on the period between exudation of the resin and harvesting but on the type of copal. Philippine samples from *A. philippinensis* were 67–97% soluble in 95% ethanol, regardless of their acid and saponification numbers. The melting point of the hardening copal of *A. labillardieri* is about 100°C and 70–80°C for its soft copal. For other *Agathis* species the melting point is between 115–135°C and increases with increasing hardness of the samples.

The acid number is an indication of the amount of free acids present per gram of the resin. Resins with high acid numbers are disadvantageous when used for paints and varnishes because of livering or stiffening when combined with basic pigments. They are more suitable for the preparation of paper sizes. The acid number is about 140 for the hardening resin from *A. labillardieri* and about 120 for its soft resin. *A. philippinensis* resin samples show a large variation in acid number: 81–170. The saponification number is 147–204 for *A. philippinensis* samples. Darker specimens of resin gave higher acid and saponification numbers than did lighter-coloured ones. When stored the acid number decreases but the saponification number increases, probably through oxidation. Manila copal is often chemically or thermally modified before it is applied in varnishes and paints. Thermal processing at 315–360°C for 2 hours makes the resin soluble in oils for application in oil varnishes. Esterification with glycerol neutralizes the natural acidity and renders the resin more soluble in drying oils for its use in paints and varnishes. The quality of the copal used for varnish is assessed differently due to different ways of varnish manufacture. Chemical

modification of 'almaciga resin' by formic acid yielded a product which compared favourably with the sizing performance of commercial rosin size.
Physical properties of the essential oil are: refractive index (20°C) 1.4714 and specific gravity (25°C) 0.8361.
The softer copals have the tendency to 'block' when packed and during transport, i.e. the pieces of resin stick together and eventually become one hard block.

Description Medium to very large monoecious but strongly dichogamous trees of up to 65 m tall; bole straight and cylindrical, up to 200(–400) cm in diameter, without buttresses but often with swollen superficial roots at base; bark surface at first quite smooth and light grey to reddish-brown, peeling with large, irregular roundish thick flakes leaving a pitted somewhat rough black or purplish-brown to fawn surface with an orange hue on larger trees; crown monopodial, usually eventually sympodial, that of young trees conical, but globular or umbrella-shaped in older ones, large branches often irregularly upturned.



Agathis dammara (Lambert) Rich. – 1, tree habit; 2, twig with female and male cones; 3, seed scale; 4, seed; 5, microsporophyll.

Foliage buds globular, covered with several pairs of tightly overlapping scales; leaves subopposite to opposite, very shortly petioled, entire, ovate to lanceolate, with a considerable variation in shape even along a single shoot, leathery, with many parallel veins that converge no more than slightly towards the apex, resin canals alternating with the veins. Male inflorescences consisting of pollen cones in or slightly above the leaf axils or seldom terminal, sessile or nearly so, more or less cylindrical, subtended by several pairs of scales forming a basal cupule, made up of numerous small spirally placed and narrowly stalked microsporophylls having a more or less peltate head bearing up to 12 pollen sacs. Female inflorescences consisting of terminal seed cones, massive, ovoid to spherical, woody; bracts spirally placed, their thickened apical margin blunt or in some species with a projecting flattened 'beak', the lateral margins thin and broadly expanded but not membranous; seed scale complex fused with the bract, flat, with a single ovule. Seed attached along the base of the seed scale, more or less flattened and oval-shaped, the margin on one side greatly expanded from the basal part into an oval membranous wing, the other margin blunt or more often with a rudimentary and often acute wing. Seedling with epigeal germination; cotyledons two, opposite, broad and lanceolate with an acute apex, the first leaves are triangular scales, first normal leaves on lateral shoots.

- *A. borneensis*. A very large tree of up to 55 m tall; adult leaves ovate, 6–12 cm × 2–3.5 cm, with a more or less acute apex, resin canals paired; mature pollen cones cylindrical, 4–7 cm × 2–2.5 cm, subtended by a 2–10 mm long peduncle, microsporophylls with a spoon-shaped, slightly acute apical part of 5.5–6.5 mm × 4–5 mm, the apex a broad semicircle; mature seed cones ovoid, 6–8.5 cm × 5.5–6.5 cm, seed bracts roughly obtriangular with rounded upper edges and a strongly hooked projection on one side only; seed blunt on one upper corner and with a wing on the other corner.
- *A. dammara*. A very large tree of up to 65 m tall; adult leaves elliptical, 6–8 cm × 2–3 cm, tapering towards the rounded apex, with solitary resin canals; mature pollen cones ellipsoidal, 4–6 cm × 1.2–1.4 cm, subtended by a peduncle about 3 mm long, microsporophylls with a spoon-shaped apical part of about 2 mm × 2.5 mm, slightly angled at the apex; mature seed cones ovoid, 9–10.5 cm × 7.5–9.5 cm, seed bracts roughly obtriangular with a small projection near the base

on one side; seed with a short acute projection on one upper corner and a wing on the other.

- *A. labillardieri*. A very large tree of up to 60 m tall; adult leaves ovate to ovate-lanceolate, 6–9 cm × 2–2.4 cm, acute, on a petiole 5–7 mm long; mature pollen cones ellipsoidal, 2.5–3.5 cm × 1–1.5 cm, subtended by a peduncle 2–6 mm long, apical part of the microsporophylls prismatic with a series of lateral sides and a flat hexagonal upper face 1–1.5 mm wide and long, the dorsal part sharply angled; seed cones not shattering on maturity, ovoid, 8.5–10 cm × 7.5–9 cm, seed bracts roughly obtriangular with nearly straight lateral margins and a distinct projection on one side and an indistinct one on the other; seed with a small and short, broadly acute projection on one upper corner and a wing on the other.
- *A. philippinensis*. A very large tree of up to 60 m tall; adult leaves ovate, 4.5–6 cm × 1.5–2 cm, tapering at base into a 5–8 mm long petiole, slightly to distinctly acute at the apex; mature pollen cones 2.5–4.5 cm × 1.0–1.1 cm, microsporophylls with a helmet-shaped and very slightly angled apex of 2–2.5 mm × 1.5–2 mm; seed cones ovoid, 7–9 cm × 12 cm, seed bracts obtriangular-ovate with broadly rounded upper corners and a small projection at the base on one side; seed with a broadly acute projection on one upper corner and a wing on the other.

Growth and development Seedlings of *Agathis* need shade and show slow growth during the first years. Afterwards, when released from competition with herbs, growth is rapid. For *A. labillardieri*, height growth of trees amounts to 0.5–1.5 m annually, depending on soil characteristics and competition. Diameter increment can easily exceed 1 cm annually. Maximum age is unknown, but may be several hundred years.

Young trees have a cone-shaped taproot and thin horizontal lateral roots. In older trees most of the laterals grow vertically from the taproot and sometimes reach a depth of 12 m. Horizontal laterals grow just below the soil surface and may cover an extensive area.

In plantations in Java *A. dammara* starts to produce cones at the age of 15 years, but viable seeds are usually not produced before 25 years. Viable seeds can be collected from February to April and from August to October. In New Guinea ripe cones of *A. labillardieri* appear regularly in November and December, probably with more than 18 months between emergence and disintegration of female cones. Mature trees may produce 200–300 cones and approximately 1 kg of seed per year.

Many *Agathis* species produce seed cones well before pollen cones appear, promoting cross-fertilization. The seed cones usually shatter on the tree at maturity. Seeds are usually carried for only short distances by wind, and they often germinate in large numbers near the parent tree. Pollination is by wind.

Resin is produced and secreted by epithelial cells surrounding the resin ducts of the leaves. The resin formed in the epithelial cell is directly secreted into the resin ducts. A resin duct is a hollow tube that extends from the leaves to the bark of the stems and the roots.

Other botanical information The taxonomy of *Agathis* is still controversial. The naming adopted in the Flora Malesiana treatment has been followed here, but the name *Agathis dammara* has been reinstated because the proposal to reject this name was not accepted by the Committee for Spermatophyte Nomenclature.

Species can best be distinguished by the shape and size of the microsporophyll and to some extent by the male cone. Both of these must be studied in their mature stage. *A. dammara* is sometimes regarded as conspecific with *A. philippinensis*. *A. labillardieri* belongs to a group of species formerly known as *Dammara alba* Lam. or *Agathis alba* Foxw.

Ecology *Agathis* is the conifer genus par excellence of lowland tropical rain forest. Within the Malesian region *Agathis* occurs in lowland or lower montane tropical rain forest except for some populations in Peninsular Malaysia which thrive in upper montane rain forest. It occurs from sea-level up to 2000(–2500) m altitude. In Malesia, *Agathis* is confined to areas with an annual rainfall between 2000 and 4000 mm which is well distributed over the year. On Palawan (the Philippines) several small populations thrive in a climate with a more marked dry period. *Agathis* grows naturally in almost all of the Philippine mountain ranges on well-drained slopes or at altitudes of 200–2000 m above sea-level. It occurs on a diversity of soils and in many habitats. It has been found in places as divergent as heath forest, on ultrabasics, limestone and in peat-swamp forest. *Agathis* occurs as a solitary tree as well as a dominant and main or even sole canopy tree. In Malesia large stands are restricted to azonal soils. *Agathis* is generally least successful in species-rich forest and as a rule does not tolerate waterlogging. *A. borneensis* occurs scattered in upland rain forest up to 1200 m altitude in Peninsular

Malaysia and Sumatra but in Borneo it is often found in pure stands on sandy peat soils at low elevation. *A. dammara* is scattered but locally common in lowland rain forest up to 1200 m altitude. *A. labillardieri* is locally common and seems to prefer slightly oligotrophic soils which are often podzolized, but it occurs on a wide variation of soil types from sea-level up to 1700(–2500) m altitude. *A. philippinensis* occurs scattered and often as an emergent tree in upland rain forest at (250–) 1200–2200 m altitude. Generally, *Agathis* is best adapted to grow in rocky soil.

Propagation and planting *Agathis* can be propagated by seed or by cuttings. Seeds of *Agathis* are difficult to store for a longer period as they lose their viability within a few weeks. Moreover, it is very difficult and thus expensive to collect seed from these large trees, as their cones disintegrate and it is not recommended to collect fallen seeds. *A. borneensis* has 4000 seeds/kg and *A. dammara* 4800–5200 seeds/kg. Seed of *A. dammara* stored in sealed containers for 6 months at 8°C showed 31% germination. After soaking for 24 hours, seeds are sown in seed-beds and lightly covered with soil. Seed of *A. dammara* germinates in 5–30 days. *A. labillardieri* seedlings are ready for planting out in the field when 1–1.5 years old and 25–60 cm tall. Mycorrhizal associations are easily formed with the ubiquitous soil fungus *Endogone*. Vegetative propagation, to overcome lack of seed, has proven successful, e.g. by root suckers from seedlings in the nursery, and by stem and leaf cuttings assisted by auxin applications. Stem cuttings should preferably be taken from young plants or low branches of young trees. Cuttings taken from plagiotropic branches can only be used for seed-orchard trees, as the resulting trees maintain their plagiotropic growth. Root suckers can be produced several times from potted seedlings and are considered to be the most successful material for vegetative propagation. *A. borneensis* cuttings 15–20 cm long with leaves left attached to the upper part were successful from coppice shoots but not from the branches of mature trees. Naturally established seedlings in plantations can also be used as planting stock. When *A. labillardieri* is planted in open terrain, e.g. under taungya systems, with food crops between them for 1–2 years, a shade plant, e.g. *Leucaena leucocephala* (Lam.) de Wit, should be sown in advance to provide the necessary shade. Planting during the dormant stage of terminal buds is preferable, and transpiration is reduced by clipping branches. Trees for tapping are planted at a wide spacing of about 10 m × 5 m.

Management Manila copal is collected in natural tracts of forest and, increasingly from planted trees. *Agathis* plantations, mainly *A. dammara*, are established for the production of timber or raw material for pulp and paper production. In Irian Jaya it has been reported that the local population has been planting *Agathis* trees in groups in the forest and collects wildlings to be planted in the villages.

Diseases and pests The fungus *Aecidium fragiforme* causing rust disease in *A. dammara* has been observed in Ambon, Kalimantan and Java. In Java it is a serious disease on seedlings in areas with over 3000 mm annual rain. In *A. philippinensis* the following diseases have been observed: seedling dieback caused by *Colletotrichum gloeosporoides*, leaf blight by *Phoma* sp. and butt- and heart rot by *Fomes pinicola*. In Papua New Guinea a seed-eating moth (*Agathiphaga*) is widespread and may severely damage seeds. Stem rot caused by cutting tapping wounds into the sapwood may result in the tree dying because the stem breaks at the height of earlier tapping.

Harvesting Most of the resin of *Agathis* produced nowadays is obtained by tapping rather than by collecting fossilized resin from the ground. Overtapping and incorrect tapping techniques have caused many *Agathis* trees to die and stands to be depleted in several areas, e.g. in the Philippines, Sabah and Sulawesi. In the Philippines recommendations for tapping without impairing the productivity or killing the tree (*A. philippinensis*) are as follows. Only trees at least 40 cm in diameter at breast height should be tapped. The bark is then scraped to remove loose material. The first tapping should be at a height no more than 30 cm from the ground. A horizontal cut 30 cm long and 2 cm wide is made; the distance between the cuts should be 60 cm or twice the length of the cut. When cutting, great care must be taken to avoid damaging the cambium, as the resin ducts are only found in the bark. Damage to the cambium and the sapwood first results in attacks by termites, after which wood-rotting fungi further attack the tree. Only if the cambium has not been damaged will the bark regrow and the wound heal. It is recommended to spray 50% sulphuric acid on the cut stem portion, to stimulate resin flow by dissolving the hardened copal on the surface. After 1–2 weeks the resin flow has hardened and a new cut 0.4–1 cm wide is made just above the first one. Be sure to always use a sharp-bladed knife to cut the bark to minimize damaging the cambium. In Indonesia harvesting is still done without the application of acid. Experiments using a 15% hydrochloric acid (HCl) solution increased the resin yield however, whereas higher concentrations changed the colour of the collected resin from transparent yellow to reddish-brown. In Java new incisions in the stems of *A. dammara* are made every 3–4 days. The resin of *Agathis* from South Sulawesi usually takes about 1 month to harden. Resin production is more abundant during dry months and can be increased by covering the wound with black polythene sheet. In Kalimantan a special tapping technique has been used for the production of high grade copal ('Pontianak copal'). The technique consists of severing the ends of branches from which the resin exudes. In the Philippines tappers need a licence defining the area and the amount of resin which may be collected.

Yield Large *Agathis* trees have a higher resin production than smaller ones; however, trees over 1.3 m in diameter become less productive again. Thick-barked trees also yield considerably more than thin-barked ones. Yield also increases after the first few tappings up to one year; sometimes the resin from the first three tappings is not collected at all. The average annual yield of copal from *A. philippinensis* at several sites in the Philippines ranged from 0.6–5.6 kg/tree, with a maximum of 16 kg for very productive trees. In *A. dammara* treatment with 15% HCl solution increased the average yield per tree from 15 g to 25 g per collection every 6 days, i.e. from 0.9 kg to 1.5 kg annually. However, the annual yield of large trees can be as much as 10–20 kg. In Papua New Guinea a productive tree yields 20 kg of resin per year. In a survey in Palawan (the Philippines) in 1980, copal collecting raised about US$ 2.3 per man per day, which was considerably more than the agricultural wage rate at that time.

Handling after harvest Grading Manila copal is important, because the different grades show fairly large differences in quality with regard to the intended use. The solubility in 95% ethanol is an important grade criterion. Other factors determinig the grade are the amount of impurities (e.g. pieces of bark, soil), and the colour and size of the resin particles. In the Philippines, 8 standard grades have been developed, based on these criteria. The grades formerly used in Indonesia represent three large groups with decreasing ethanol solubility: soft ('melengket'), semi-hard ('loba') and hard (including 'bua'). Further grading takes into account the amount of impurities, and the colour and size of the resin particles. Recent Indonesian grades are 'clean scraped chips', 'medium scraped chips' and 'small chips', with indicative prices per t in 1995 of respectively US$ 1500, 1000 and 900. Ethanol extraction and heating under pressure results in a hard and brittle, purified resin which can be formed into blocks. A similar treatment is given to 'papeda' resin, yielding a 'non-blocking' copal with a higher melting point and higher viscosity, but with a darker colour.

Genetic resources Natural *Agathis* populations have been seriously depleted. The once huge stands of *A. borneensis* in South Kalimantan for instance, with a volume of standing timber of 100–400 m³/ha, have been heavily exploited for timber. *A. dammara* populations have been depleted in the Moluccas and *A. philippinensis* is declining in the Philippines because of unscrupulous tapping for resin, illegal cutting and deforestation. Some protected areas contain important gene pools of *Agathis*, e.g. Badas Forest Reserve in Brunei, Gunung Palung Nature Reserve in Kalimantan, Bukit Barisan Selatan National Park in Sumatra, and Taman Negara National Park in Peninsular Malaysia for *A. borneensis*. Mount Apo and St. Paul Subterranean River National Parks (the Philippines) have important stands of *A. philippinensis*. Ex situ conservation is important for *A. dammara*, which is planted on a fairly large scale in Java.

Breeding To improve the resin production of poorly productive stands of *A. dammara* V-grafting has been applied. It appeared that 2-year-old seedlings can best be used as grafting stock. Breeding of *Agathis* trees has been included in the national forest tree improvement programme in Indonesia which has 3 aims: improving wood quality and production, improving copal quality and production and improving resistance to diseases and pests.

Prospects Although synthetic resins have largely replaced natural ones, Manila copal still retains a sizable market share. In the Philippines recent research has shown its importance for the national economy. Quality control is essential, as mixed grades of Manila copal are hardly accepted by commerce. Although timber from *Agathis* is a much more important commodity, more attention should be given to resin production in timber plantations.

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A.B. Ella

Canarium L.

Amoen. Acad. 4: 143 (1759).
BURSERACEAE
x = unknown; *C. ovatum*: $2n = 46$

Major species and synonyms

- *Canarium asperum* Benth., Journ. Bot., Lond. 2: 215 (1843), synonyms: *C. legitimum* Miq. (1859), *C. villosum* Benth. & Hook.f. ex Fern.-Vill. (1880), *C. zollingeri* Engl. (1883).
- *Canarium hirsutum* Willd., Sp. pl. 4(2): 760 (1806), synonyms: *C. hispidum* Blume (1823), *C. multipinnatum* Llanos (1851), *C. subcordatum* Ridl. (1920).
- *Canarium indicum* L., Amoen. Acad. 4: 143 (1759), synonyms: *C. mehenbethene* Gaertn. (1791), *C. zephyrinum* Duchesne (1836), *C. moluccanum* Blume (1850), *C. amboinense* Hochr. (1904).
- *Canarium luzonicum* (Blume) A.Gray, U.S. Expl. Exped., Phan.: 374 (1854), synonyms: *C. carapifolium* Perkins (1904), *C. polyanthum* Perkins (1904), *C. oliganthum* Merr. (1915).
- *Canarium ovatum* Engl., in: A.DC., Monogr. Phan. 4: 110 (1883), synonyms: *C. pachyphyllum* Perkins (1904), *C. melioides* Elmer (1911).
- *Canarium vulgare* Leenh., Bull. Bish. Mus. 216: 31, fig. 13 (1955), synonym: *C. commune* L. (1767) p.p.

Vernacular names

- *C. asperum*: Indonesia: damar jahat (Sulawesi), damar itam (Ambon), kessi (Sumbawa). Philippines: pagsahingin (Filipino), sulusalungan (Bisaya), anteng (Iloko).
- *C. hirsutum*: Indonesia: ki bonteng (West Java), kanari jaki (northern Sulawesi), mede-mede (Moluccas). Malaysia: kedondong (general), damar degun (Peninsular), kambayau burong (Sabah). Philippines: dulit (general), bakayan (Panay Bisaya), hagushus (Bikol).
- *C. indicum*: Indonesia: kanari ambon (Sundanese), kanari ternate (northern Sulawesi), kanari bagea (Moluccas). Papua New Guinea: red canarium (general), galip (Pidgin), lawele (New Britain).
- *C. luzonicum*: Philippines: piling-liitan (Filipino), belis (Tagalog), malapili (Bikol).
- *C. ovatum*: Pilinut (En). Philippines: pili, pilaui (general), liputi (Tagalog).
- *C. vulgare*: Java almond (En). Amande de Java (Fr). Indonesia: kanari (general), ki tuwak (Java), jal (Ambon). Malaysia: pokok kenari, rata kukana (Peninsular).

Origin and geographic distribution *Canarium* consists of about 80 species and is distributed in the Old World tropics, from tropical Africa to tropical Asia, northern Australia and the Pacific. The main centre of diversity lies in the Malesian area. *C. asperum* is found in the Philippines, Borneo, the Lesser Sunda Islands, Sulawesi, the Moluccas, New Guinea and the Solomon Islands. *C. hirsutum* occurs in Peninsular Malaysia, the Philippines, Sumatra, Java, Borneo, Sulawesi, the Moluccas, New Guinea, the Caroline Islands (Palau) and the Solomon Islands. *C. indicum* is found in Sulawesi, the Moluccas, New Guinea, Vanuatu, the Solomon Islands and the Santa Cruz Islands, while *C. luzonicum* and *C. ovatum* are both restricted to the Philippines (where the latter is often cultivated for its nuts). *C. vulgare* occurs naturally in the Kangean and Bawean Islands, the Lesser Sunda Islands, Sulawesi, the Moluccas and New Guinea and is planted throughout the tropics for its fruits.

Uses 'Manila elemi', also known under the name 'brea branca' meaning white pitch, is the oleoresin which exudes from the bark of *Canarium* trees when they are tapped or wounded. *C. luzonicum* is by far the most important species for commercial production of Manila elemi. In commerce the essential oil distilled from Manila elemi is mainly used for fragrance applications (such as soap and perfumes) and as a base for liniment. Manila elemi still finds occasional use as an ingredient in lacquers and varnishes, where it gives toughness and elasticity to the dried film. Moreover, it is applied in medicinal plasters and in ointments where a slight stimulant and antiseptic is required. It has also been used for the manufacture of printing inks, surface coatings for textiles and paper, incense, linoleum, oilcloth, waterproofing compositions and as an insect repellent in cabinets. Locally it is used in torches, as a firelighter, to caulk boats and to dress transmission belts and conveyors. In China it has been applied for the manufacture of transparent paper for window panes. Manila elemi has also been used for fixing iron tools in their wooden handles and it is used medicinally as stimulant, rubefacient and anti-rheumatic and for the treatment of respiratory ailments.

In Peninsular Malaysia, the dark brown resin, known locally as 'damar sengai' is most probably from *C. hirsutum* and has been found to be suitable in spirit varnish. This hard resin is likely to be confused with resins from *Dipterocarpaceae*, the 'damars'. Torches used to be prepared by kneading the very sticky resin on the ground until enough dirt has been incorporated to make it stiff, and then rolling it into shape.

Several *Canarium* species (e.g. *C. indicum*, *C. luzonicum*, *C. ovatum*) are known for their edible kernels and the edible pulp of their fruits and provide valuable fat and protein in the diets of many people. Sometimes oil is extracted from the fruit pulp or the kernels and used for cooking and lighting; young shoots (e.g. of *C. ovatum*) are occasionally eaten as a salad. The hard and thick shell enclosing the seeds makes an excellent fuel for cooking. *Canarium* trees make an excellent windbreak and are well suited as ornamentals. Their wood falls within the 'kedondong' timber trade group and is used for indoor construction and as a firewood.

Production and international trade Manila elemi is the only elemi traded internationally nowadays. Annual exports from the Philippines were somewhat erratic for the period 1988–1993, but the average is almost 300 t. In the three years 1996–1998, 353 t, 162 t and 221 t of Manila elemi were exported. France is the largest importer, accounting for 75% of the total exported from the Philippines. Germany is the second biggest market, followed by Japan. The market for Manila elemi can probably sustain levels of around 200–300 t annually. Prices for Manila elemi fluctuate more than those for other resins. The free-on-board (FOB) export prices were US$ 1.67–2.08 per kg for the period 1990–1993. By mid-1995, London-based importers reported a doubling of the price compared with the previous year and quoted prices of US$ 4.20–4.50 per kg. The FOB export price in 1996 was US$ 2.68/kg.

Properties When fresh, Manila elemi is oily and pale yellow or greenish, resembling crystallized honey in consistency, but on exposure to air it loses some of the volatile constituents and hardens. It has a balsamic odour and a spicy, rather bitter taste. Soft and hard elemi are distinguished. 'Soft elemi' is aromatic and soft and is produced by *C. luzonicum*, *C. asperum*, *C. indicum*, *C. ovatum* and *C. vulgare*. The 'hard elemis' are only slightly aromatic and are darker in colour (e.g. *C. hirsutum*). Manila elemi is completely soluble in alcohol and ether. The crude oleoresin contains 25–30% essential oil, which can be obtained by steam distillation. The scent of the oil of *C. luzonicum* resembles that of fennel (*Foeniculum vulgare* Mill.) and mace (*Myristica fragrans* Houtt.). The scent of the essential oil from *C. indicum* and *C. vulgare* resembles eugenol, the major component of the essential oil of clove (*Syzygium aromaticum* (L.) Merr. & L.M.Perry). Manila elemi consists primarily of resenes together with some resin acids and volatile terpenes; its approximate composition is 0.4–1% insoluble matter, 17–25% volatile terpenes, 1–2% non-volatile terpenes, 56–61% resenes, 15–18% resin acids and 1–3% moisture. The saponification number is 28.5, the acid number 18.5 and the ester number is 10.0. The chemical composition of Manila elemi oil is approximately: 56% limonene, 18% α-phellandrene, 6% elemol, 6% sabinene, 3% terpinolene, 2% elemicin and 3% β-phellandrene, but the composition can vary a great deal and α-pinene, β-pinene, myrcene, Δ-carene, σ-terpinene and geraniol have also been demonstrated in the oil. It has the following properties: specific gravity 0.952, optical rotation (α_D^{30}) −2°, refractive index (n_D^{30}) 1.497. The essential oil from *C. indicum* oleoresin also contains phellandrene. On an experimental scale Manila elemi oil at 5% concentration has proved to be capable of eliminating a number of wood-destroying fungi. At 20% it caused 88% mortality in drywood termites (*Cryptotermes* spp.) and 25% mortality in powder post beetles (*Lyctus* spp.). It shows significant antibacterial activities against *Escherichia coli* and *Staphylococcus aureus*.

The exudate from *C. asperum*, known as 'sahing' in the Philippines, contains 11% essential oil with p-cymol as principal constituent.

Damar sengai (from *C. hirsutum*) forms stalactite-like masses which are uniformly free from dirt. The surface of the very hard resin has a vitreous appearance; it has a melting range of 120–135°C. It is almost non-acid (has an acid number of 0.9) and has a very low saponification number of 8. The resin dissolves completely in benzene, chloroform, kerosene, petroleum ether and turpentine and 25% soluble in alcohol, 39% soluble in acetone and 44% soluble in ether. It is the only hard resin completely soluble in petroleum ether.

Description Dioecious, evergreen trees up to 35(–60) m tall, rarely shrubs; bole up to 120(–200) cm in diameter, with or without buttresses; bark surface smooth to flaky, scaly or dippled, often greyish, inner bark sometimes laminated, pinkish or reddish-brown, with strong resinous odour and clear sticky or oily exudate; pith of twigs usually containing vascular strands. Leaves arranged spirally, imparipinnate, with (1–)3–17(–27) opposite and often toothed leaflets; base of petiole and of petiolules often swollen; stipules usually present, entire to fimbriate. Inflorescence terminal or

Canarium luzonicum (Blume) A.Gray – 1, leaf with inflorescence; 2, branch with leaves, flower buds and fruits.

sometimes axillary, paniculate or sometimes reduced to a raceme or a spike; flowers actinomorphic, 3-merous, functionally unisexual but vestiges of the opposite sex present; calyx cupular with deltoid lobes, nearly always densely hairy inside; petals free, usually imbricate, creamy white, with inflexed tips; stamens 6, or rarely 3, free to entirely connate; disk intrastaminal, 6-lobed, often pilose; ovary superior, 3-celled, each cell with 2 axillary ovules, stigma sessile or short-stalked. Fruit a cylindrical drupe, seated on a persistent enlarged calyx, hairy or glabrous, ripening blue-black, glaucous at first, very wrinkled when dry; endocarp stony (pyrene), with 1–2 cells slightly to nearly entirely reduced. Seed with palmatifid to 3-foliolate and variously folded cotyledons. Seedling with epigeal germination; first 2 leaves simple and opposite, entire or toothed, subsequent leaves alternate and eventually arranged spirally and imparipinnate.

- *C. asperum*. A tree up to 35 m tall, bole 100 cm in diameter, buttresses prominent; stipules subpersistent to caducous, narrow; leaves with 1–13 leaflets; leaflets ovate to elliptical, 4–30 cm × 2–10 cm, apex tapering to acute or bluntly acuminate, margin entire but serrulate to dentate in young plants, glabrous to pilose on the midrib above and the veins below, with (7–)12–15(–20) pairs of secondary veins; inflorescence very variable, spicate to narrowly paniculate; flowers 3–7 mm long, stamens 6; fruit ovoid to subglobose, circular to slightly trigonous in cross-section, 9–14 mm × 4–11 mm, glabrous. This is a highly variable species.

- *C. hirsutum*. A tree up to 32(–48) m tall, bole 60(–200) cm in diameter, buttresses usually absent or very small; stipules absent or present, inserted at the base of the petiole, narrow; leaves with 9–27 leaflets, rachis thick with sharp edges; leaflets ovate to lanceolate, 5–45 cm × 2–15 cm, apex gradually to rather abruptly short-acuminate, margin entire, variably pubescent to glabrous, with 12–30 pairs of secondary veins; inflorescence axillary, male one paniculate, female one subracemose; flowers 10–13 mm long, stamens 6; fruit ovoid, circular in cross-section, 20–63 mm × 17–45 mm, usually with irritating reddish-brown hairs. This is also a highly polymorphic species.
- *C. indicum*. A tree up to 40 m tall, bole 100 cm in diameter, buttresses up to 1 m tall; stipules persistent, rarely inserted on the petiole, ovate to oblong, large and prominently dentate; leaves with 7–15 leaflets; leaflets oblong to lanceolate, 5–28 cm × 2–11 cm, apex gradually to distinctly acuminate, margin entire, glabrous, with (8–)10–15(–20) pairs of secondary veins which are slightly sunken above and prominent below; inflorescence terminal, broadly paniculate; male flowers about 10 mm long, female ones up to 15 mm long, stamens 6; fruit ovoid, circular to slightly triangular in cross-section, 35–60 mm × 15–30 mm, glabrous.
- *C. luzonicum*. A tree up to 35 m tall, bole 100 cm in diameter; stipules caducous to subpersistent, inserted on the base of the petiole, orbicular; leaves with 7–11 leaflets; leaflets lanceolate to oblong, 6–25 cm × 2–11 cm, apex gradually and long blunt-acuminate, margin entire, glabrous, with 14–18 pairs of secondary veins; inflorescence axillary, paniculate; male flowers 2.5–4 mm long, female ones 6–8 mm long, stamens 3–6 in the male and 6 in the female flower; fruit broadly ovoid to ellipsoidal, circular to bluntly triangular in cross-section, 25–38 mm × 15–20 mm, glabrous.
- *C. ovatum*. A tree up to 35 m tall, bole 100 cm in diameter, without buttresses; stipules persistent, inserted on the petiole, deltoid to lingulate; leaves with 5–9 leaflets; leaflets ovate to elliptical, 4–24 cm × 2–12 cm, apex distinctly acuminate, margin entire, glabrous, with 8–12 pairs of secondary veins; inflorescence axillary, narrowly paniculate to nearly racemose; flowers up to 13 mm long, stamens 6; fruit ovoid to ellipsoidal, triangular in cross-section, 35–63 mm × 20–28 mm, glabrous.
- *C. vulgare*. A tree up to 45 m tall, bole often gnarled in cultivated specimens, up to 70 cm in diameter, buttresses up to 3 m tall; stipules caducous, inserted at the leaf axil, oblong; leaves with (5–)9–11 leaflets; leaflets ovate to oblong, 5–16 cm × 2–10 cm, apex gradually to distinctly long-acuminate, margin entire, glabrous, with 12–15 pairs of secondary veins which are slightly prominent below; inflorescence terminal, broadly paniculate; male flowers 5 mm long, female ones 6–7(–12) mm long, stamens 6; fruit ovoid, circular to slightly trigonous in cross-section, 35–50 mm × 15–30 mm, glabrous.

Growth and development *Canarium* trees flower mainly in the dry season and fruit during the wet season, although many species do not have definite flowering or fruiting seasons. *C. vulgare* flowers and fruits throughout the year in West Java and fruits are ripe in February–March and October. *C. ovatum* flowers in March–June in the Philippines. In both male and female trees the order of blooming of the flowers in an inflorescence is basipetal, that is blossoming proceeds from the top downwards. Anthesis in both male and female flowers takes place between 4 and 6 p.m. At anthesis the flowers emit a fragrant odour; this suggests that they are principally pollinated by insects. Fruit set in flowers pollinated at anthesis averages almost 90% but no fruits develop in flowers pollinated 24 h after anthesis. The fruits are dispersed by fruit-eating pigeons and monkeys, and are occasionally eaten and dispersed by bats.

Other botanical information *C. asperum* and *C. hirsutum* are widespread in Malesia and their variability is large – several subspecies and varieties have been distinguished. *C. indicum* and *C. vulgare* are closely related – for a long time they were distinguished as separate species. *C. luzonicum* and *C. ovatum* are also closely related. Other *Canarium* species from which the exudate has been used, mainly in traditional applications such as torches, for caulking boats and for fixing tools in handles are: *C. balsamiferum* Willd., *C. de-*

cumanum Gaertn., *C. copaliferum* A.Chev., *C. littorale* Blume, *C. oleosum* (Lam.) Engl., *C. pseudodecumanum* Hochr. and *C. sylvestre* Gaertn.

Ecology *Canarium* occurs in primary and secondary rain forest, generally up to 500 m altitude, but occasionally up to 1800 m. *C. vulgare* occurs locally and gregariously in rather dry primary rain forest on limestone, up to 1200 m altitude; other *Canarium* species usually occur scattered.

Propagation and planting *Canarium* trees are usually planted for fruit production and for ornamental purposes, but not for resin or oleoresin. *Canarium* can be propagated by seed, and seedlings may be prepared as stumps before planting. Vegetative methods of propagation are practised for the fruit species, e.g. budding and grafting techniques are used for *C. ovatum*. There are 200–1350 seeds of *C. ovatum* per kg and about 145 dry stones (each stone containing 1–2 seeds) of *C. vulgare* per kg. Without temperature control air-dry *C. vulgare* seeds can be stored for several months to 1.5 years.

Management Tapping of *Canarium* trees provides a livelihood for people in parts of the Philippines where these trees are common, namely Bicol Peninsula (Luzon Island), Quezon Province, Marinduque, Masbate (Ticao and Burias Islands), Romblon (Sibuyan Island) and parts of Samar. In Quezon Province many subsist by tapping *Canarium* trees. Apart from the actual tapping, the wild trees are not managed.

Diseases and pests It has been suggested that because of the resinous material it contains *Canarium* is relatively free from diseases and pests. Anthracnose of young seedlings has been observed in *C. ovatum*, but this is easily controlled by fungicides.

Harvesting *C. luzonicum* trees are tapped by making horizontal incisions (2 cm high and 30 cm long) in the bark with a sharp bush knife and a wooden mallet. The diameter of the trees tapped is 20–60 cm. Subsequent strips about 1 cm high are removed above the previous cuts. This 'rechipping' is done at intervals of 2–7 days. Tapping is continued upwards, as high as a person can reach. A second face may be opened, provided that at least one third of the circumference of the tree is left intact. An improved tapping method is now advocated in the Philippines. This consists of cleaning and scraping the bark which is to be tapped. The first horizontal incision should not be more than 60 cm from the ground, 2 cm high and 15 cm long. It is important to control the depth of cutting precisely, using a wooden mallet so as not to damage the cambium and hence impair the vigour of the tree. A plastic receptacle should be fixed to the tree and the portion tapped, and the receptacle should be covered by a polythene sheet to prevent contamination with water, insects and debris. The exudate is collected every week and rechippings of 3–5 mm wide are made immediately above the previous incision. A second tapping panel should be at least twice the length of the incision (30 cm) apart. Trees under 30 cm in diameter should not be tapped at all. Tapping is strictly prohibited from April to June as trees shed their leaves and as a consequence resin production is insufficient. Mortality of trees often occurs 5 years after the first tapping, due to very deep incisions, overtapping and too frequent rechipping. In trials new rechippings were sprayed with 15–45% sulphuric acid, but the yield did not significantly increase. In Indonesia, resin exuded spontaneously from *C. indicum* and *C. vulgare* (presumably to be due to reduced vigour of the tree) used to be collected. It was not collected by tapping the lower part of the stem or the roots, as this reduced fruit yield.

Tapping to obtain damar sengai has never been reported.

Yield In Quezon province in the Philippines, an annual yield of resin of 1–4 kg/tree is obtained, but estimates go up to 12 kg of 'uncleaned resin' per tree.

Handling after harvest Three classes of Manila elemi exist for the domestic Philippine market and for export trade, although the designations are not always adhered to. Class 1 is the palest material, with two grades: clean (grade A) and non-clean (grade B). Class 2 is the more yellowish material; it also has grades A and B for clean and non-clean material. Class 3 is a mixture of classes 1 and 2. The softer Manila elemi is of higher quality, reflecting its higher essential oil content compared with the harder elemi's. The essential oil can be obtained by steam distillation. As the freshly distilled oil is liable to resinify and polymerize on standing, distillation is normally carried out in the importing country, where the oil can be formulated soon after preparation. A resinoid is also sometimes prepared by solvent extraction of the crude elemi. Resin for export is packed in polythene bags, to prevent seepage or evaporation of the Manila elemi oil. The bags are then packed in wooden crates which weigh about 25 kg when full. Formerly, Manila elemi used to be purified by solution in benzene, filtering off impurities such as bark and dirt, and distilling the filtrate to yield a white resin of leafy appearance.

Genetic resources Natural populations of *Canarium* (particularly *C. luzonicum*) should be screened to determine the provenance and tree-to-tree variation in oleoresin yield and composition. It is recommended to start a germplasm collection.

Breeding There has already been development of improved varieties of *Canarium* for fruit and nut production. Research on resin production should be complementary to research on fruit and nut production, as the latter is the main purpose of cultivation.

Prospects *C. ovatum* and other exudate-producing *Canarium* species are already grown as sources of fruits and nuts; integration with resin tapping would be a welcome development, provided resin production does not adversely affect fruit production.

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E.C. Fernandez

Dipterocarpus Gaertn.f.

Fruct. 3: 50 (1805).

DIPTEROCARPACEAE

$x = 10, 11$; *D. alatus*: $2n = 20, 22$

Major species and synonyms

- *Dipterocarpus alatus* Roxb. ex G.Don, Gen. Syst. 1: 813 (1831), synonym: *D. philippinensis* Foxw. (1911).
- *Dipterocarpus gracilis* Blume, Bijdr. fl. Ned. Ind. 5: 224 (1825), synonyms: *D. pilosus* Roxb. (1832), *D. marginatus* Korth. (1841), *D. vernicifluus* (Blanco) Blanco (1845).
- *Dipterocarpus grandiflorus* (Blanco) Blanco, Fl. Filip., ed. 2: 314 (1845), synonyms: *D. griffithii* Miq. (1864), *D. pterygocalyx* Scheff. (1870).
- *Dipterocarpus kerrii* King, Journ. As. Soc. Beng. 62(2): 93 (1893), synonyms: *D. obconicus* Foxw. (1913), *D. cuneatus* Foxw. (1918), *D. perturbinatus* Foxw. (1918).

Vernacular names Keruing (general timber trade group of *Dipterocarpus*).

- *D. alatus*: Philippines: hairy-leaved apitong (general), apinau (Tagalog), ayamban (Iloko). Burma (Myanmar): kanyin-byu. Cambodia: chhë: ti:ël bângku:ëy, chhë: ti:ël ba:y, chhë: ti:ël tük. Laos: (maiz) nha:ng, nha:ng kha:w. Thailand: yang-na. Vietnam: d[aaf]u r[as]i.
- *D. gracilis*: Brunei: keruing kesat. Indonesia: keruing keladan (general), wuluk bulan (Java), damar kacawai (southern Sumatra). Malaysia: keruing kesat (general), keruing kesugoi (Sabah). Philippines: panau (general), agan-an (Bikol), lalian (Tagalog). Burma (Myanmar): kanyin, kanyin-ni. Thailand: yang-sian (general), yang-daeng (south-eastern), yung-hua-waen (peninsular).
- *D. grandiflorus*: Indonesia: aput (South Kalimantan), tempudau tunden (East Kalimantan), lagan beras (Sumatra). Malaysia: keruing belimbing (Peninsular, Sabah), keruing pekat (Peninsular). Philippines: apitong (general), dauen (Ibanag), hapitong (Tagalog). Burma (Myanmar): kanyin-byan. Thailand: yang-yung (gener-

al), yang-tang, yung-krabueang (peninsular). Vietnam: d[aaf]u d[oj]t t[is]m.

- *D. kerrii*: Indonesia: lagan beras (northern Sumatra). Malaysia: keruing gondol (Peninsular, Sabah), keruing chair, damar minyak (Peninsular). Philippines: malapanau (general), panalsalan (Bikol). Burma (Myanmar): see-bin. Thailand: yang-manmu, yang-man-khon, yang-wat (peninsular).

Origin and geographic distribution *Dipterocarpus* consists of some 70 species and is distributed from Sri Lanka, India and Burma (Myanmar), through Indo-China, southern China and Thailand towards western Malesia. It does not cross the Wallace line (an important biogeographical barrier) between Borneo and Sulawesi, except between Bali and Sumbawa. The oldest fossil records are from the Miocene.

D. alatus occurs naturally in Burma (Myanmar), Thailand, Laos, Cambodia, Vietnam and the Philippines (Luzon) and *D. gracilis* in Bangladesh, Burma (Myanmar), Thailand, Peninsular Malaysia, Sumatra, West Java, Borneo and the Philippines. *D. grandiflorus* is found in the Andaman Islands, Burma (Myanmar), Thailand, Vietnam, Peninsular Malaysia, Sumatra, Borneo and the Philippines and *D. kerrii* in the Andaman Islands, peninsular Burma (Myanmar), peninsular Thailand, Peninsular Malaysia, northern Sumatra, Sabah and the Philippines.

Uses The oleoresin ('wood-oil') obtained from the sapwood of *Dipterocarpus* is known as 'minyak keruing', 'damar minyak', 'minyak lagan' or 'balau'. The essential oil obtained from the oleoresin is the well-known 'gurjun balsam'. This is not a balsam in the strict sense, as it does not contain any cinnamic or benzoic acid. It is used as a fixative in perfumery, particularly soap perfumes. It is a cheaper substitute for 'patchouli oil' obtained from *Pogostemon cablin* (Blanco) Benth. The oleoresin is still traditionally used for illumination, to caulk boats, to make baskets watertight and to treat timber which is exposed to the weather. It is now used for interior varnishing, and in medicine as disinfectant, laxative, diuretic, mild stimulant, and in analgesic liniments.

Keruing timber from *Dipterocarpus* spp. is an important export commodity. It is a lightweight to heavy timber used for general, medium and heavy construction, especially railway sleepers. The timber of the major exudate-yielding species is usually too heavy and often too oily for first class sawmill and peeler logs.

In Thailand, *D. alatus* is planted as a roadside tree.

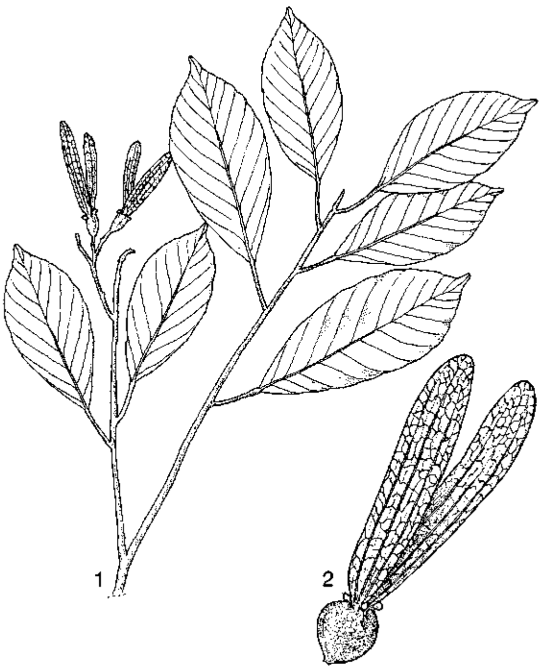
Production and international trade *D. gracilis* and *D. grandiflorus* are the 2 principal sources of 'balau' in the Philippines, but exact export figures are wanting. In the 1920s southern Vietnam produced about 1 000 t of oleoresin annually, all obtained from *D. alatus*. In Peninsular Malaysia the price for *D. kerrii* oleoresin rose significantly during the 1970s from M$7 to M$50 per 15 litre tin. The demand for and the value of *Dipterocarpus* oleoresins fluctuate with the availability and price of the preferred patchouli oil. In Samar, the Philippines, tappers sell 15 litre tins of balau at US$ 6, i.e. US$ 0.4/litre. In 1998, tappers in Laos earned US$ 0.28/litre *D. alatus* oleoresin whereas the export company sold the filtered oleoresin at US$ 1–1.40/litre. The price is probably lower than that of *D. kerrii* oil.

Properties The oleoresin exuded by *D. gracilis* and *D. grandiflorus* is a white sticky fluid when fresh, darkening upon exposure. When freshly collected oleoresin from *D. grandiflorus* is distilled with water it yields 38–40% of a yellowish essential oil. Fresh exudate from *D. gracilis* contains 35% essential oil, 25% water and 40% solid residue. Direct distillation at 255°C of the oleoresin of *D. alatus* yields 70% reddish essential oil and 30% resin. Water distillation of the oleoresin of *D. kerrii* yields 80% essential oil with a pleasantly 'balsamic' odour. The essential oils from *Dipterocarpus* are composed almost exclusively of sesquiterpene hydrocarbons. As such they resemble 'copaiva balsam' from South American *Copaifera* spp. and have been known as 'East Indian copaiva balsam' as well.

The essential oil from the oleoresin from *D. kerrii* harvested by the 'bark chipping' method contains the following compounds: 79% α-gurjunene, 5.3% allo-aromadendrene, 1.1% β-caryophyllene, 0.8% β-gurjunene, 0.3% α-humulene and 3.7% other non-identified sesquiterpenes. The essential oil from traditionally harvested oleoresin contain 58% α-gurjunene and 4.1% allo-aromadendrene. The essential oil of *D. grandiflorus* is soluble in common solvents except ethanol. It has the following properties: specific gravity d^{30}_{30} 0.9228, refractive index n^{30}_{D} 1.493, congealing point −3°C, acid value 0.8, saponification value 16.4, and iodine value 200. The oil contains 50–95% allo-aromadendrene, 3–20% α-gurjunene, 0–10% β-gurjunene, 0.34% β-elemene, trace–4% caryophyllene, trace–20% α-humulene, 0.14% copaene, 0.67% germacrene D and 0.43% γ-gurjunene. The oil from *D. gracilis* is composed of 75% β-caryophyllene and 25% α-humulene. The compounds α-gur-

junene, allo-aromadendrene, humulene and caryophyllene have termiticidal properties. *D. kerrii* oil also has fungicidal properties, but these have not been attributed to any particular compound.
The resinous fraction of the oleoresin contains 10–40% dipterocarpol, a triterpenoid. As a natural varnish it produces a brilliant, tough, and durable coating, but it is slow-drying and becomes brittle over time.

Description Medium-sized to large, resinous trees up to 65 m tall and up to 180 cm in diameter, usually with small and concave or sometimes tall and straight, stout buttresses; bark surface orange-brown to greyish, usually scaly and warty-lenticelled, rarely fissured or scaly-fissured, outer bark dark rust-brown, inner bark pale yellow-brown to dark rust-brown, homogeneous; resin produced on freshly cut wood surfaces; crown usually relatively narrow, even or irregular (not cauliflower-shaped), dome-shaped, frequently rather flat, open, with a few large, strongly ascending, twisted branches; twigs variable in tomentum and appearance, with distinct, usually swollen and pale, amplexicaul stipule scars; buds prominent in dormant stage and specifically diagnostic, not much broader than the twigs. Leaves alternate, simple, leathery, rarely thin; stipules paired, large, hastate to lorate, obtuse, reasonably succulent, caducous, characteristically carpeting the forest floor in the growing season; petiole geniculate at the joint with the lamina, stout or slender; blade very variable in size and tomentum, pinnately veined, with a sinuate or straight margin, plicate in bud and corrugated on opening; secondary veins prominent beneath, straight, curved only near the margins. Inflorescence simple or branched, racemose, short, stout, zig-zag, few-flowered; bracts as the stipules but smaller, fugaceous; flowers large, actinomorphic, bisexual, scented, nodding; calyx persistent, 5-merous, united round the ovary into a tube, but not fused to it, with valvate lobes, two of them long, oblong to spatulate, more or less distinctly 3-veined, and 3 short, (rarely, all 5 short); petals large, oblong to narrowly oblong, strongly contorted, loosely cohering at base after shedding, cream-white with a prominent pink, red or purple stripe down the centre; stamens 15–40, persistent at first in a ring round the ovary after the petals fall, filaments of variable length, broad, compressed, connate at base, tapering apically, connective prolonged into a short, sharp or blunt point or a long awn; ovary 3-celled with 2(–3) ovules in each locule, the base enclosed in the calyx tube, the apex ovoid to conical, shortly tomentose, stylopodium present, shortly tomentose, narrowed gradually into a filiform glabrous style, stigma small, simple. Fruit a nut, surrounded by the calyx, comparatively large; fruit calyx tube woody, becoming more or less distinctly constricted into a distal neck as the nut expands, smooth, pustulate, tubercled, ridged, winged or plicate, fruiting calyx lobes developed into 2 large wings and 3 ear-shaped lobes or rarely vestigial; nut ovoid, with a woody pericarp, tomentose, with a short acute apical style remnant. Seedling with epigeal (cryptocotylar) germination; first two leaves opposite, subsequent leaves arranged spirally.



Dipterocarpus kerrii King – 1, fruiting branch; 2, fruit.

- *D. alatus*: leaf bud lanceolate, yellow pubescent; stipules greyish-yellow pubescent; petiole 2.5–4.5 cm long; blade narrowly ovate to ovate to elliptical-oblong, 9–25 cm × 3.5–15 cm, base cuneate to rounded, apex acute or shortly indistinctly acuminate, secondary veins 11–18(–20) pairs, sparsely pubescent above, beneath densely persistently pubescent; fruit calyx tube glabrous, subglobose, with 5 wings to 8 mm broad, 2 larger fruit calyx lobes up to 14 cm × 3 cm, 3 shorter ones up to 12 mm × 14 mm.
- *D. gracilis*: leaf bud narrowly conical, scabrid rufous tomentose; stipules narrowly lanceolate,

outside persistently rufous tomentose; petiole 2–2.5 cm long; blade elliptical to ovate, 8–15 cm × 4–10 cm, base obtuse, apex shortly acuminate, with 12–20 pairs of secondary veins; stamens about 30; fruit calyx tube spherical, glabrous, smooth, 2 larger fruit calyx lobes up to 14 cm × 2.5 cm, 3 shorter ones up to 2 cm × 1 cm.

- *D. grandiflorus*: leaf bud ovoid, pale buff pubescent; stipules oblong-lanceolate, subacute, outside densely buff pubescent; petiole 3–9 cm long; blade ovate, 10–18 cm × 5–12 cm, base obtuse or subcordate, acumen up to 1 cm long, secondary veins 15–17 pairs, glabrous; stamens 30; fruit calyx tube ellipsoidal, glabrous, with 5 prominent wings continuous from base to apex, 2 larger fruit calyx lobes up to 22 cm × 3 cm, 3 shorter ones up to 2 cm × 1.5 cm.
- *D. kerrii*: leaf bud lanceolate-falcate, glabrous; stipules linear-lanceolate, subacute, inside silky tomentose; petiole 2–3 cm long; blade broadly elliptical, 8–13 cm × 3.3–7 cm, base cuneate, acumen up to 5 mm long, secondary veins (7–)9–11 pairs, ascending, glabrous; stamens about 30; fruit calyx tube globose to subturbinate, smooth, 2 larger fruit calyx lobes up to 14 cm × 3 cm, 3 shorter ones up to 1 cm × 1 cm.

Growth and development In natural forest in Thailand *D. alatus* flowers early in December and fruits are mature in mid-February. Viable *Dipterocarpus* fruits start to germinate a few days to a few weeks after they have fallen on the ground. Twigs and petioles of seedlings are usually hairier than those of the mature trees, leaves are considerably larger, frequently more prominently acuminate and have proportionately shorter petioles. *Dipterocarpus* seedlings need shade for optimal growth. In experiments in Java, *D. grandiflorus* had an average annual increment of 58 cm in height and 0.9 cm in diameter. A comparatively large average height increment of 160 cm/year was reported for *D. gracilis* in Java. In a 40-year-old plantation maximum diameters of 74 cm for *D. kerrii* and 58 cm for *D. grandiflorus* have been observed. *Dipterocarpus* probably needs mycorrhizae for optimal growth. In experiments conducted in Thailand ectomycorrhizae have been observed in *D. alatus* seedlings. These seedlings developed best in association with *Russula* spp.

Other botanical information *Dipterocarpus* is characterized by its bark with warty lenticels, its generally amplexicaul stipule scars, its prominent dormant buds, the leathery, plicate, corrugated leaves with swollen petioles at their base, and its type of venation. It belongs to the tribe *Dipterocarpeae* which is characterized by the fruit calyx lobes being valvate at the base, and a basic chromosome number of 11. Within the tribe *Dipterocarpeae* the genus is most closely related to *Anisoptera* Korth.

In 1993 it was discovered that *D. alatus* and *D. philippinensis* are conspecific. Another important species yielding gurjun balsam is *D. tuberculatus* Roxb. from Bangladesh, Burma (Myanmar), Indo-China and Thailand. Many other *Dipterocarpus* spp. are known to yield an oleoresin, but at present these are only exploited on a local scale.

Ecology *D. alatus* occurs gregariously along rivers in Indo-China and Thailand up to 500 m altitude. It is a rapid colonizer of alluvial soils where it is often found in relatively pure populations. In the Philippines it is rare, occurring in mixed dipterocarp forest in seasonal areas at low and medium altitudes. *D. gracilis* is widespread, often occurring gregariously in seasonal semi-evergreen or evergreen dipterocarp forest on red soils, becoming scattered, rare, and confined to fertile red soils in the humid zones, up to 800 m altitude. *D. grandiflorus* is common and sometimes semi-gregarious on clay-rich soils and grows in primary semi-evergreen or evergreen forest up to 600 m altitude. *D. kerrii* is locally common in semi-evergreen and evergreen lowland dipterocarp forest and occurs near the coast or less frequently inland on flat land or hills up to 400 m altitude.

Propagation and planting Seeds of dipterocarps are generally collected from the ground because of the difficulty of climbing the tall trees and picking the fruits from the branches. Normally, a mature or fully developed fruit has dried greenish-yellow to brownish wings and the endosperm is full and firm. Viability of the seed is short and it is generally recommended to sow seeds within a week after collection. Seeds of *D. grandiflorus* can be stored at 8°C if treated with fungicides and maintain a germination rate of 28% or even 48% for some weeks; after 50 days of storage, however, viability is lost completely. Tests in the Philippines using fresh seed showed a germination rate for *D. grandiflorus* of 56%; the comparable figures for *D. gracilis* are 16% and 6%. In a test in South Kalimantan, however, *D. grandiflorus* had a germination rate of only 13%. Seeds are sown directly in polybags and put under shade. The apex of the dewinged fruits should point downward which facilitates the radicle to establish as soon as it emerges. For optimal development, seedlings raised in nurseries probably need to be infected with mycorrhizae, either in the nursery or in the field by the presence of mature trees. After one year the seedlings have reached 50 cm in height on average, and can be planted out in the field. Wildlings can also be used as planting stock. In the Philippines air layering of *D. grandiflorus* resulted in only 10% of the branches developing roots. Cuttings from 2-month old coppice did not develop any roots, even with different rooting hormone treatments.

Management *Dipterocarpus* seedlings and saplings can persist in the forest for years under heavy shade. In the first 2 years, major openings in the canopy are not tolerated, but after the seedlings are well established (about 120 cm tall) the canopy can be opened up, to speed up growth. Many species regenerate well only in primary forest. When *Dipterocarpus* seedlings are planted in open areas shade trees are used, such as *Acacia auriculiformis* Cunn. ex Benth. and *Paraserianthes falcataria* (L.) Nielsen.

Diseases and pests Diseases reported for *D. grandiflorus* in the Philippines are 'wildling blight' caused by *Botryodiplodia theobromae* and 'apitong wilt' for which the most frequently associated organism is a *Polyporus* sp. A serious attack of bark beetles (*Dryocoetiops laevis*) killed many *D. grandiflorus* trees in central Luzon in 1993–1994. In Peninsular Malaysia the fungus *Cylindrocladium scoparium* is pathogenic to seedlings of *D. grandiflorus*. In the Philippines sooty mould caused by *Asterinella dipterocarpi* affects *D. gracilis* seedlings.

Harvesting The technique for harvesting of the oleoresin from *Dipterocarpus* is similar throughout South-East Asia and has not evolved much in the last 100 years. Tapping involves cutting a hole in the stem, with its base sloping down towards the centre of the stem. This process is known as 'boxing'. Occasionally a scaffold is constructed to be able to reach above the buttresses of large trees. *D. alatus* trees are only tapped when their diameter is over 50 cm, as smaller trees are not sufficiently productive. The hole is usually triangular and may extend halfway through the stem. It is made on the side of the trunk where the canopy has the largest concentration of branches and leaves. Boxing is confined to the lower 2–3 m of the stem and a tree with a diameter of 75 cm usually has 2(–3) holes. Generally, the oleoresin starts to flow within an hour and collects inside the hole. It is removed once every 7–8 days. After collection, the remaining hardened coat of oleoresin is set on fire to prevent clogging and to stimulate further flow. The burning takes 20 seconds to 2 minutes, exceptionally up to 20 minutes. After the fire has been extinguished the burnt resin is scraped off the inner wall of the hole and the oleoresin is left to flow again. When a hole becomes unproductive it is abandoned. The use of ethrel instead of firing to stimulate oleoresin exudation has been investigated, but did not prove to be much more efficient or less damaging to the tree. Tapping is done throughout the year, and although the oleoresin flow is more abundant in the rainy season, the availability of labour then limits harvesting frequency. In Peninsular Malaysia, *D. kerrii* is not tapped in the months November–January due to abundant rain. When trees are carefully tapped, especially with regard to the burning of the holes, they may be tapped for 25 years. Laotian tappers claim that *D. alatus* trees are productive for 50–80 years. Tappers exert user rights over individual trees and these rights are inherited. Gregariously growing trees usually have a single owner. Once the tapping of a tree is abandoned, the tapper loses his rights over that tree.

In Peninsular Malaysia a refined technique has been developed which gives a somewhat better product with a higher essential oil content. The 'bark chipping' method involves removing the outer bark, after which a strip of inner bark 2.5 cm wide is removed to expose the wood. This streak is about 1 m long and directed upward at an angle of 30° to the horizontal. An apron and gutter system is fixed just below the streak and a cup is installed at its bottom. Sulphuric acid is sprayed on the exposed wood; in 4 experimental trees a concentration of 10% proved best, giving a daily yield of 78–320 g. A polythene sheet is fixed to cover the apron and gutter system and prevent rain and dirt from contaminating the exuding oleoresin. Without the application of a stimulant, oleoresin production is negligible. It is doubtful whether this technique will replace the traditional tapping technique, as it involves much extra work for little extra gain.

Yield The annual production of *D. alatus* trees in Laos is estimated at 22.5–31 l/tree. In Peninsular Malaysia, the weekly harvest of *D. kerrii* oleoresin is (10–)150–280(–800) ml/tree, which implies an annual harvest (9 months harvesting) of (0.4–)6–11(–31) l/tree.

Handling after harvest In Peninsular Malaysia the harvested oleoresin of *Dipterocarpus* is filtered by means of gunny sacks and flour sacks, which are firmly fixed to wooden frames. The essential oil fraction drips through, while the more viscous fraction settles inside the sacks. During this process, some of the essential oil evaporates and probably not all essential oil is separated from the resinous fraction. Distillation with water gives a higher essential oil yield.

Genetic resources and breeding Like other dipterocarp species *D. kerrii* in Peninsular Malaysia has fast dwindled due to logging. Several natural hybrids are known, like the one between *D. gracilis* and *D. costatus* Gaertn.f. (Thailand, Peninsular Malaysia) and between *D. grandiflorus* and *D. baudii* Korth. (Burma (Myanmar)). There are no germplasm collections or breeding programmes for *Dipterocarpus* exudates.

Prospects Although oleoresins from *Dipterocarpus* are undoubtedly of great economic importance, the prospects for commercial tapping of their exudates are not promising. At present there are only very few large and mature individuals that can be tapped because dipterocarp forest areas have been reduced in size tremendously. Only saplings and small individuals are now a common sight in most regenerating forest, especially in the Philippines. Scientific research on tapping techniques that could sustain supply of the oleoresin and prolong the life of tapped trees should be promoted.

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Dyera Hook.f.

Journ. Linn. Soc., Bot. 19: 293 (1882).
APOCYNACEAE
x = unknown; $2n$ = unknown

Major species and synonyms

- *Dyera costulata* (Miq.) Hook.f. Journ. Linn. Soc., Bot. 19: 293 (1882), synonyms: *Alstonia costulata* Miq. (1861), *Dyera laxiflora* Hook.f. (1882).
- *Dyera polyphylla* (Miq.) Steenis, Blumea 14: 316 (1966), synonyms: *Alstonia polyphylla* Miq. (1861), *Dyera lowii* Hook.f. (1882), *D. borneensis* Baill. (1898).

Vernacular names General: jelutong (En). Indonesia: jelutung.

- *D. costulata*: Hill jelutong (En). Indonesia: jelutung bukit (general), melabuai (Sumatra), pantung gunung (Kalimantan). Malaysia: jelutong bukit (general), jelutong pipit, jelutong daun lebar (Peninsular). Thailand: teen-pet daeng, yeluu-tong, luu-tong (peninsular).
- *D. polyphylla*: Swamp jelutong (En). Indonesia: jelutung paya (general), gapuk (Sumatra), pantung (Kalimantan). Malaysia: jelutong paya (Sabah, Sarawak).

Origin and geographic distribution *Dyera* consists of only 2 species, namely, *D. costulata* which is found in peninsular Thailand, Peninsular Malaysia, Singapore, Sumatra and Borneo, and *D. polyphylla* which occurs in Sumatra and Borneo.

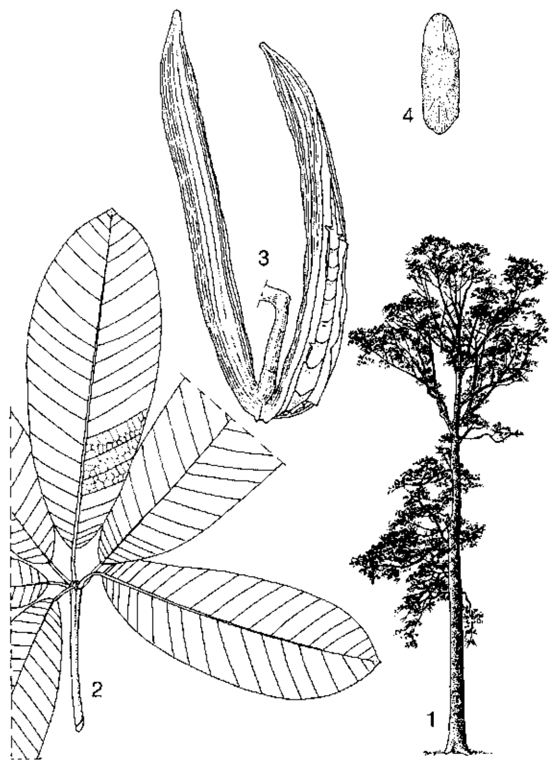
Uses Early in the 20th Century jelutong (or

'Pontianac' or 'dead Borneo'), the coagulated latex of the inner bark of *Dyera*, was used for the manufacture of inferior rubber intended for uses where elasticity was not of prime importance. Up to the 1920s production declined due to the higher-yielding para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.). In 1922, however, demand from the United States sharply increased again for use in the manufacture of chewing gum because supply of the coagulated latex of *Manilkara zapota* (L.) P.Royen ('chicle') was dwindling and jelutong was found to be a suitable substitute due to its tastelessness and consistency. Today, the use of its latex in chewing gum is still the main application. *Dyera* is more important as a timber tree.

Production and international trade Export of jelutong from Indonesia averaged 3600 t annually over the period 1988–1993, but annual exports fluctuated widely, between 1200–6500 t. Kalimantan has always been the main area of supply. Around 1910 annual export from Indonesia was estimated to be 35 000 t; thereafter annual world production fell sharply, to 2700 t in 1922. When jelutong was found to be suitable in the manufacture of chewing gum, exports rose again. Imports by the United States averaged 7500 t annually between 1926–1930. The average annual export from 1973–1983 from Indonesia was 3550 t valued at US$ 3 million. The average free-on-board (FOB) export values for raw, pressed and refined Indonesian jelutong were down to US$ 720–750/t in 1993, from a high of US$ 980–1060/t in 1991. The processed Indonesian jelutong is exported 'pressed', 'refined' or 'other' to Singapore from where it is re-exported, mainly to the United States.

Properties Jelutong contains about 20% of thermoplastic polyisoprene and about 80% resin on a moisture-free basis. A very low concentration of soluble iron (1/20 000) in the latex causes the jelutong to oxidize completely in about 3 months, making it brittle, which is undesirable. Fresh *Dyera* latex has a specific gravity of 1.012–1.015 at 28°C, the pH is 7 and when left standing the pH falls to 5.5 after 24 hours and to 5.0 after 48 hours. *D. costulata* appears to produce a better quality latex than *D. polyphylla*. Latex traces are commonly present in the wood; they are lens-shaped in tangential surface and up to 1 cm high. The compound dimethylmyoinositol isolated from the latex of *D. costulata* is reported to inhibit allergic passive cutaneous anaphylaxis reactions in guinea pigs.

Description Large to very large deciduous trees, up to 50(–65) m tall; bole straight, columnar, branchless for up to 30 m, up to 250 cm in diameter, without buttresses, sometimes with pneumatophores; bark surface smooth, with small squarish scales leaving dippled patches, inner bark mottled, pale brown to whitish, with copious latex; crown monopodial at first, with whorled branches; branchlets 5–8-angled. Leaves verticillate, (5–)7(–8) in a whorl, glabrous. Flowers in a slender axillary panicle, 5-merous, small, fragrant; calyx lobes rounded, margin frilled, with glands at the base inside; corolla with a short slightly angled tube, with a ring of hairs inside, white, fragrant, the lobes overlapping to the right; stamens inserted on the tube above the ring of hairs, the connective prolonged into a fleshy appendage; ovary semi-inferior, pubescent, style single, short. Fruit a pair of large woody spreading follicles, dehiscing along a dorsal suture. Seeds 12–24 in each follicle, flat, ellipsoidal, glabrous, surrounded by a membranous wing. Seedling with epigeal germination, cotyledons leafy, hypocotyl elongated; first few pairs of leaves opposite, later leaves whorled.



Dyera costulata (Miq.) Hook.f. – 1, tree habit; 2, twig with leaves; 3, fruit; 4, seed.

- *D. costulata*: Tree up to 65 m tall, bole branchless for up to 30 m, up to 250 cm in diameter, bark blackish; leaves elliptical to obovate or narrowly so, rounded to subcordate at base, short acuminate to rounded at apex, secondary veins well-spaced.
- *D. polyphylla*: Tree up to 35 m tall, bole straight, columnar, up to 95 cm in diameter, bark whitish; leaves spatulate-elliptical, cuneate at base and decurrent on the petiole, rounded to slightly emarginate at apex, secondary veins close-set.

Growth and development Early growth of *Dyera* is rather slow, but after the establishment of a well developed root system growth becomes more vigorous. Annual diameter increment of *D. costulata* in plantations may be 1.5 cm, whereas that of trees in an unmanaged plantation is about 1 cm. The average diameter of planted *D. polyphylla* 17 years after planting is about 19 cm.

In Peninsular Malaysia *D. costulata* trees are usually deciduous once a year. They are leafless for a few days and all the trees in a certain area tend to change their leaves at the same time. Flowering occurs from July to December, whereas flowers start to develop simultaneously with the young leaves. They open during the night or early in the morning and the corollas are shed before 9 a.m. Fruits ripen in 8–9 months after anthesis. The flat winged seeds are distributed by wind.

Other botanical information *Dyera* is closely related to *Alstonia* R.Br. ('pulai') and may be confused with it. *Dyera* can be recognized by its massive columnar bole, its massive spreading follicles containing seeds with a membranous wing all around, and the short style. *Alstonia* species have a fluted or buttressed bole, slender, drooping follicles with comose or ciliate seeds, and a longer slender style.

Ecology Both *Dyera* species are scattered emergent trees of primary (often dipterocarp) evergreen rain forest, but favour different habitats. *D. costulata* occurs in primary lowland or hill forest in well-drained locations, up to 300 m altitude, whereas *D. polyphylla* is found in swamp forest, peat-swamp forest, and on podzols in kerangas, at low altitudes.

Propagation and planting *Dyera* may be propagated by seed or by stumps made from 2–3 year-old wildlings. Seed weight varies greatly, with 7500–20 000 seeds of *D. costulata* per kg. Fruits should be collected from the tree when they are just beginning to split, as they do not drop until all seeds have been released. Because the trees are so tall, however, it is difficult to judge when the fruits are ready for collection, and the trees are hard to climb.

About 90% of the fresh seed of *D. costulata* germinates in 14–28 days, although a period of up to 4 months has also been reported. The viability of seed stored for 8 months at 22–24°C and a relative humidity of 60% (in an air-conditioned room) is still 70%. Storage temperatures below 10°C are detrimental. Seed of *D. polyphylla* germinates in 5–12 days.

Seeds are sown flat and should be pressed into the soil in nursery beds. To enhance germination, they should be soaked in water for about 2 hours. When the seed has germinated and the seedling has emerged, it should not be allowed to dry out and harden, because then the cotyledons and the plumule risk becoming trapped inside the seedcoat. Seedlings should be grown under shade, as full sunlight adversely affects their growth. Optimal development of seedlings was obtained under experimental conditions with about 33% relative light intensity. Seedlings of *D. polyphylla* are ready for planting in the field when they are 1 year old.

Management Natural regeneration of *Dyera* is generally fairly abundant, but sometimes it is noticeably absent in secondary forest. Growth is vigorous when light is abundant. *D. costulata* demands plenty of light and once a young tree has established well in full light, it tends to spread its crown and develop into a pronounced 'wolf tree'. Rapid opening of the canopy encourages it to outcompete other tree species.

D. costulata coppices readily, is extremely resistant to girdling and tapping panels readily recover when the cambium has not been cut.

Diseases and pests In Peninsular Malaysia, a large longhorn beetle (*Batocera rufomaculata*) is a secondary parasite of *D. costulata*. It is a wound parasite of the latex-tapping panels, but in old and weak trees infestation may extend over the entire stem. Eggs are laid on dead bark or where the bark has been completely removed; if they were to attack living bark, the larvae would be trapped by the copious stream of latex. Two small ambrosia beetles (*Diapus pusillimus* and *D. quinquespinatus*) are other wound parasites, often occurring in association with *Batocera rufomaculata*. They cause degrade of the timber by producing numerous 'pinholes' and associated stain. Another ambrosia beetle (*Platypus vethi*) occurs frequently in fallen trees of *D. costulata* or in trees injured or weakened by unskilled tapping or by *Batocera rufomaculata*. In a survey of tapped *D.*

costulata trees in Peninsular Malaysia, the following *Coleoptera* were found: *Batocera rufomaculata* in 86% of the trees, *Platypus vethi* in 44%, *Schizotrachelus cameratus* in 20% and *Acicnemis vehemens* in 15%.

Harvesting *D. costulata* trees should have a diameter of at least 60–80 cm, whereas the somewhat smaller *D. polyphylla* should reach 50 cm diameter before tapping can start. Tapping of plantation-grown *D. polyphylla* may start 30–35 years after planting, when trees reach a diameter of about 35 cm. Generally, tapping of smaller trees is uneconomic. In Borneo, tapping of *Dyera* is traditionally done by making 4–6 vertical tapping panels of about 10 cm wide which are widened every 8 days by some 3 cm on either side until the panels touch each other. Horizontal tapping panels which are enlarged by cutting 3–5 cm of the bark on the upper side of the panel have also been used. The latex is collected on the same day by scraping it off with a wooden spatula. A more sophisticated way of tapping, the herring-bone method, is generally applied in Peninsular Malaysia. With this method a V shape is cut in the bark at 1.5 m height with its legs at an angle of about 45° with the vertical and covering about half of the circumference of the tree. From the base of the V cut a channel is made to a bamboo receptacle in which the latex is collected. The tapping panel is enlarged every 2–3 days by cutting a narrow strip of bark on both sides of the V. At first a turbid, watery fluid exudes, but soon turns into a chalky-white latex, gradually acquiring a fairly viscid consistency with a tendency to congeal in the channel. In all cases only the bark should be cut, with the cambium and the sapwood remaining intact to promote bark recovery and to prevent attack of wood-boring insects. Tapped panels may be retapped after a resting period of 2 years, as bark recovery is generally good. Many *D. costulata* trees in Peninsular Malaysia, however, have reportedly produced lumps and burs on the old tapping panels, which renders retapping impossible. To prevent the latex becoming contaminated with iron salts, rusty tapping knives, gouges or latex receptacles should never be used.

Tapping is restricted to several months per year, in the case of *D. polyphylla* this is because the swamp forest is inaccessible in certain seasons. In Sarawak in the 1950s, there were restrictions on the felling of *D. costulata* and *D. polyphylla* because of the value of the latex. Prolonged tapping of the latex invariably leads to the death of the trees, but careful tapping of *D. polyphylla* may continue for 12 years.

Yield A single *Dyera* tree may yield up to 30(–50) l of latex per year, but high yields generally kill the trees rapidly. However, during the tapping season average monthly yield for large trees is 12 l of latex, which results in about 3.6 kg jelutong. The latex yield from *D. costulata* is higher than that of *D. polyphylla*.

Handling after harvest The daily tapped latex of *Dyera* is processed on the day of collection, in the temporary settlement in the forest. The fresh latex is first strained through a fine-mesh sieve, which should not be made of copper or iron. Formerly all kinds of coagulants were used (kerosine, sago flour, sap of *Ixonanthes icosandra* Jack, methylated spirit, alum, creosote, sulphuric acid, urine), but today acetic acid and phosphoric acid are used for this purpose. Phosphoric acid is preferred, because any iron in the latex will precipitate as iron phosphate and very small quantities of iron make the jelutong brittle. With the 'cold method' a 10% solution of phosphoric acid or acetic acid is added to the latex at 5 ml/l and the latex completely coagulates in 3 days. During this process it is important not to break the surface film, as anaerobic conditions improve the yield of the coagulum. The coagulum after cold coagulation still contains about 80% moisture, which is reduced to 35–45% by subsequent pressing and moulding. By the 'hot method' acid is added at a rate of only 1 ml/l latex, the mixture is heated, stirred and after 2–3 minutes of boiling the latex coagulates. The hot method not only needs much less coagulant and gives a higher yield but the resulting coagulum is also less susceptible to drying out and is therefore preferred. The moisture content of the coagulum after hot coagulation is about 35%. The coagulum subsequently needs refinement, which is sometimes done in the forest but more generally in a factory. Refining the coagulum consists of repeated boiling in clean water to remove all soluble acids and sugars. If this process is not carefully performed the product is susceptible to oxidation, rendering the jelutong brittle and promoting development of brownish-black moulds. The product is then kneaded, pressed into blocks and stored in running water before shipment.

Genetic resources *Dyera* occurs scattered and there is a risk of over-exploitation for timber and latex. However, it often regenerates readily in logged-over forest and grows fast, which may reduce this risk. Although the production of jelutong from Peninsular Malaysia fell to zero in the 1930s, possibly due to poor tapping techniques, trees have not been killed as the timber export from this area is still considerable.

Breeding Judging from differences in growth rates it seems that genetic variation in *Dyera* is large. Breeding for higher latex yield, however, is not economically feasible.

Prospects With the advent of synthetic products it is unlikely that the use of jelutong will increase. At present, *Dyera* is much more important for timber production.

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E. Boer

Ficus elastica Roxb.

Hort. Bengal.: 65 (1814).
MORACEAE
$2n = 26$

Synonyms *Visiania elastica* (Roxb.) Gasp. (1844), *Urostigma elasticum* (Roxb.) Miq. (1847).

Vernacular names India rubber tree (En). Arbre à caoutchouc (Fr). Indonesia: rambung (eastern Sumatra), kajai (Padang), (ki) karet (Sundanese). Malaysia: bunoh seteroh (Kelantan). Burma (Myanmar): bedi. Thailand: yaang lop, yaang india (central), lung (northern). Vietnam: c[aa]y [dd]a.

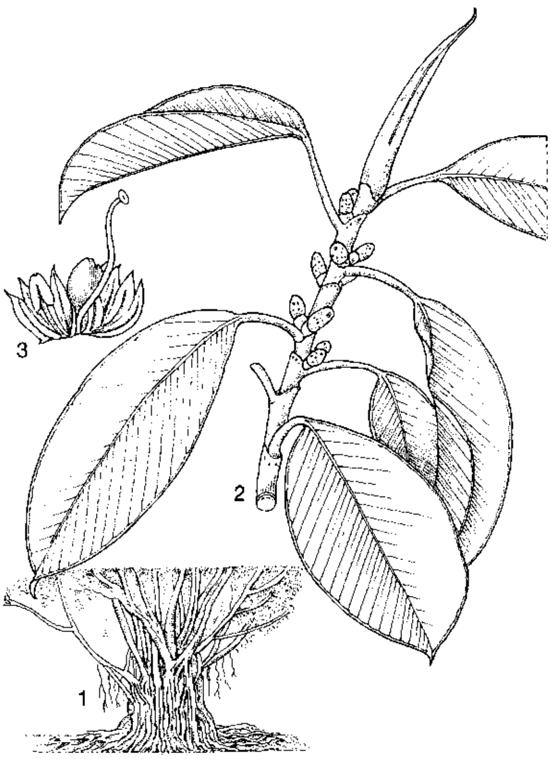
Origin and geographic distribution *F. elastica* is found naturally in north-eastern India (Sikkim, Assam), Burma (Myanmar), northern Peninsular Malaysia, and in Indonesia (Sumatra, Java). It is cultivated and introduced worldwide; outside the tropics it is grown indoors and in greenhouses.

Uses The latex from the bark of the stem and larger branches of *F. elastica* contains rubber, which can be used for all applications of natural rubber, such as tyres, rubber components for cars and machines and consumer products such as footwear, sport goods, toys and gloves. Centuries ago, the latex was used to line baskets of split rattan, to make them watertight. In the late 19th and early 20th Centuries plantations were established, mainly in Sumatra, Java and Peninsular Malaysia, but India rubber was soon eclipsed by para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg. *F. elastica* is presently a very common ornamental or shade tree which is also cultivated as a foliage pot plant.
The very young leaf tips have been eaten as a vegetable in Java. The fibrous bark has been used for the manufacture of clothes and ropes. The wood is of poor quality and occasionally applied for boards, posts, boats and fuel.

Production and international trade In West Java, the latex of *F. elastica* became a trade commodity by 1850, when prices rose for a product that had previously only been used locally. In the period 1873–1896 the mean annual exports were: 393 t from Bangladesh, 187 t from Burma (Myanmar), 189 t from Assam (India), 30 t from Singapore, 28 t from Sumatra and 17 t from Java. After this period trade declined, ceasing in about 1920.

Properties The latex has a specific gravity of 0.96–1.00 and contains (10–)30–40(–58)% rubber with relatively large rubber particles in the latex compared with other latexes. The resin content of the latex varies widely, with estimates ranging from 3% to 25%. Latex from older trees contains less resin, as does the older tissue in a plant: the latex from the top of a plant 2.3 m tall contained 25% resin while latex collected from its base contained 18% resin. The resin content of the latex of trees grown at higher altitudes is higher: latex from trees grown at 45 m altitude contained 3% resin and that from trees growing at 750 m altitude 22% resin. The rubber made from *F. elastica* contains 4–20% resin, which hardens over time and decreases the rubber's elasticity. The rubber has relatively short chains of polyisoprenes of low molecular weight: 78 000. It is soluble in cajeput oil (*Melaleuca cajuputi* Powell). The rubber is hypoallergenic to individuals allergic to the proteins found in *Hevea brasiliensis* rubber products. The latex showed toxicity to the juveniles of the nematode *Meloidogyne javanica*.

Description A large, evergreen, strangling tree, up to 55 m tall with abundant aerial roots from the trunk and the main branches which do not thicken to form 'pillar roots', bark surface smooth, inner bark pale pink producing white latex; twigs glabrous. Leaves arranged spirally, simple; stipules lanceolate and flaccid, connate into an accrescent, narrow, membranous, bright red, long-acuminate cap, 7–35 cm long, largest on lower branches; petiole 2–5 cm long, red when young; blade oblong to elliptical, usually 10–15 cm × 4–7.5 cm, up to 40 cm × 22 cm on lower branches and in saplings, dark green, glabrous, leathery, base cuneate to almost rounded, margin entire, apex shortly acuminate, up to 25 mm long on lower branches, primary vein red when young, with 13–26 pairs of well-developed parallel secondary veins, with intramarginal veins, upper leaf surface with abundant cystoliths, stomata deeply sunken. Inflorescence a fig (syconium), axillary, in pairs, sometimes solitary; peduncle 1–3 mm long, finely puberulous; basal bracts 3, 3 mm long, falling off very early with the stipules and leaving an annular scar; flowers unisexual; male flowers dispersed, with short pedicel, tepals (3–)4, free, eventually spreading, stamen 1, anther 4-celled, dehiscing longitudinally; gall flowers sessile or with short pedicel; female flowers sessile, tepals 4, free, ovary unilocular, emergent, with a single ovule, style single, subterminal, stigma simple, subcapitate. Infructescence a fig, shortly ellipsoidal, 9–12 mm × 8–9 mm, yellow when ripe; individual fruit a drupelet. Seedling with epigeal germination; cotyledons emergent, cotyledons and first pair of leaves appear simultaneously; hypocotyl elongated; first pair of leaves with coarsely-crenate margin with fine punctuations which disappear in older leaves, all leaves arranged spirally.



Ficus elastica Roxb. – 1, stembase of old tree; 2, branch with leaves and twigs; 3, central female flower with 2 lateral male flowers.

Growth and development The symbiotic relation of *Ficus* spp. with specialized wasps is well-known. Figs can only be pollinated by female agaonid wasps (*Hymenoptera*, *Chalcidoidea*, *Agaonidae*). These wasps are highly species-specific; the fig-wasp associated with *F. elastica* is *Blastophaga clavigera*, known from India. In *F. elastica* the wasps arrive when female flowers are receptive. They enter the fig via the osteole, a bract-covered apical pore. Once inside they pollinate the female flowers and deposit their eggs in the ovaries. As style length varies greatly within these figs and because the wasp can only reach the ovary of short-styled flowers, only some of the flowers obtain an egg, while in others the seed develops. Male and female wasps emerge after a few weeks, and mate within the fig. The females then emerge from the fig and, in so doing pick up pollen from the newly mature anthers of male flowers. Figs on a single tree mature at the same time, while different trees of the same species flower out of synchrony, thus inducing cross-pollination. *F. elastica* seedlings develop root nodules containing 95% water, which act as a water reservoir. This most probably helps the seedlings to survive the initial epiphytic phase. During this phase the plant sends down thin aerial roots which only thicken after they have reached the ground. In Java, *F. elastica* flowers throughout the year. In Luzon, the Philippines, it flowers in January–March. Young specimens in Java are reported to be epiphytic. The root system of *F. elastica* is shallow and dense, making mixed plantation or intercropping systems impossible. Roots may anastomose over a distance of 40 m, as reported for India.

Other botanical information Roxburgh's publication of the name *F. elastica* in 1814 in the catalogue of the Hortus Bengalensis is often considered as a nomen nudem which was validated 5 years later by Hornemann. The publication of the name in 1814 is, however, not a nomen nudem because Roxburgh added 'LT', a code for 'Large Tree', 'HS', a code for flowering in the 'Hot Season', 'RS', a code for fruiting in the 'Rainy Season' and he states that the fruit is solitary or paired, that the tree abounds in rubber, that its Bengal name is 'kusmeer' and that the tree arrived in the garden in 1810, brought by a Mr. M.R. Smith.

Because *F. elastica* is easily propagated by cuttings, it often escapes from cultivation. Its true wild status in Malesia is questioned, because fertile seed and the wasp have never been found there. Based on colour, size and odour numerous subclassifications have been made without much practical value. Many cultivars have been developed for ornamental indoor plants.

More than ten cultivars of *F. elastica* are distinguished, all used as foliage pot plants. The best known are: 'Decora' with thick, hard and shiny green leaves, 'Doescheri' with pinkish petioles, grey-green and creamy yellow leaves with green margins, 'Belgaplant' with variegated leaves, 'Robusta' with large rounded leaves to 45 cm long, 'Tricolor' with yellowish to cream-coloured leaves, and 'Variegata' with yellow markings and a yellow margin.

Ecology *F. elastica* occurs naturally in areas with temperatures of 8–33°C and an annual precipitation of 1750–3750 mm without a marked dry season. It does not tolerate waterlogging. It is found scattered in the lowland rain forest of southern West Java and in hill forest, particularly on cliffs and limestone hills. Plantations need full light for optimal development.

Propagation and planting *F. elastica* can be propagated by seed, cuttings and air layering. Seed viability is 20–50% and apparently does not decrease over the first three months of storage. After the seeds have been cleaned from the surrounding pulp they are sown under shade; the first seedlings appear 2 weeks later. Seeds taken from bird or bat excrement are reported to germinate more readily. After the first 2 pairs of leaves have developed, the seedlings are pricked out and placed in trays under shade. The seedlings are transferred to beds when they are several cm tall at a spacing of 25–40 cm. Once they are well established the shade is gradually removed and eventually the seedlings are in full sunlight. Seedlings can be planted out in the field when they are 35–40 cm tall, which is only after about one year, as initial growth is slow. In India, it was common practice to plant out when 3 m tall. For vegetative propagation the highest-yielding mother trees are chosen, which is important as there is a large individual difference in latex yield. Branches cut at a slant can be planted directly, provided the wood of the cutting is not too young. Initially, planted cuttings need support, to prevent root damage from wind rock. Air layering is also very successful; layers can be severed from the mother plant after only 40 days. In the heyday of *F. elastica* plantation establishment, wildlings were collected and traded in Sumatra. The recommendations for the spacing in *F. elastica* plantations varied widely, from 2 to 12 m apart. A spacing of 10 m seemed favoured in Indonesia, provided weeds could be controlled. Rooted air-layers have also been 'planted' on trees in the forks of branches, but this practice has never been common. Experimentally, *F. elastica* has been propagated by inserting in-vitro shoots directly into non-sterile sand to induce rooting, thus eliminating the in-vitro rooting step. Plants from unrooted tissue culture are used for pot plant production.

Husbandry In plantations common management practices such as weed control and protection from livestock were practised. Moreover, the thin aerial roots were regularly trimmed, so that the stem could easily be reached for tapping. Plantations where initial spacing had been dense (e.g. 4 m × 4 m) to reduce weed growth were subsequently thinned.

Diseases and pests A common disease of *F. elastica* pot plants is anthracnose caused by the fungus *Glomerella cingulata*. Anthracnose develops pale rose-coloured pustules, usually scattered along the veins. Any wound or breaking of leaves or accumulation of water on the leaves for considerable periods will favour infection. Twig blight and canker caused by *Fusarium lateritium* are other diseases of *F. elastica* pot plants.

Harvesting As the latex of *F. elastica* is not harvested at present, the harvesting techniques described here are those used a century ago. The latex of wild as well as planted trees is collected by tapping the bark, generally only of the stem and larger branches, though root bark may also be tapped. It is best to harvest when the air humidity is high, as drier conditions cause the latex to coagulate too fast and rain reduces the rubber content of the exudate. Traditionally the bark was cut with a knife or small axe, later incisions were made with a gouge to better control the depth of cutting and to limit the wounding of the cambium. In the bark the laticifers are found closest to the cambium in a fibrous tissue which is difficult to cut. If the incision is not deep enough, the tissue containing most laticifers is not tapped and yield is low. A deep incision damages the cambium and hence influences the vitality of the tree. A V-shaped gouge can also be used to make horizontal incisions up to 5 cm wide and some 20 cm long, the length never exceeding half the circumference of the tree. These cuts are about 40 cm apart and on opposite sides of the tree. A herringbone system has also been applied, in which a central vertical channel transports the latex from grooves made at an angle of 45° with the vertical to a container driven into the bark of the tree. Inside the inclined grooves the fibres are punctured or cut at intervals of 2–3 cm, to tap the laticifers closest to the cambium. This, however, also punctures or cuts the cambium layer. An advantage of the herringbone system is that the latex is collected as a fluid and is of better quality than the 'scrap' collected from the horizontal incisions or from underneath the tree. The latex drips from the horizontal incisions for about 2–3 minutes and is collected on a mat or on leaves placed underneath the tree. The coagulated latex is collected 2–3 days later; when stripped off the incision a milky residue oozes from the wound, but this liquid contains no rubber. A well-developed planted tree can be tapped after 6–7 years, but with increasing age (and circumference of the tree) when the first tapping is done, both yield as well as rubber content of the latex increase.

There has been much debate and experimenting on the frequency of tapping. In this respect it is important that the latex extracted is not replaced and that there is no anastomosis between the laticifers, so only the latex from the immediate vicinity of the tapping wound exudes. This is why consecutive tappings, whether every day or once a year for three years, have shown a marked decrease in yield. Yields in g/tree from a tapping trial with 55 trees in Bogor for four harvests at intervals of 2, 3, and 4 years were 238 g, 67 g, 70 g and 320 g. This suggests that it takes four years before the laticifers are reconstituted. Provided the tree will survive, it is therefore more rational to extract the maximum amount of latex at once, rather than tapping trees several times over a period of few years.

Yield The yield of individual trees in plantations of *F. elastica* can vary very widely, the highest attains 30 times more than the lowest. The yield of the first harvest is directly influenced by the circumference of the tree and the horizontal length of the incision. A tree of 1.8 m in diameter yielded 15 kg rubber; the average yields in three consecutive years of 50 wild trees measuring 34 m tall and 5.7 m in diameter (aerial roots included) were 4, 1.9 and 0.4 kg/tree respectively. The average annual yield of 55 trees in Bogor Botanical Gardens tapped four times at the age of 8 to 17 years is only 41 g/tree. It has been reported that the first yield of a tapped aerial root with a diameter of 15 cm yielded 9.3 kg of rubber, but this exceptionally high yield was never confirmed by other measurements.

In Indonesia the latex product is known as 'getah munding', in Malaysia as 'getah rambong', 'getah karet' or 'getah achin'.

Handling after harvest The 'scrap' from *F. elastica* is sorted by hand and cleaned. The latex is difficult to coagulate: neither heating nor adding organic or mineral acids, even concentrated sulphuric acid, or alkali, will cause it to coagulate. Instead, it must be beaten and kneaded, and alcohol must be added. This yields a superior product which does not become sticky with time. Ammonia and tannin have been used as coagulants in Peninsular Malaysia. The 'scrap' and the coagulated latex are pressed into blocks, cakes or sheets before being traded.

Genetic resources No germplasm collections of *F. elastica* as an exudate are known to exist.

Breeding Superior mother trees of *F. elastica* with high latex yields have been selected to provide cuttings and air layers, but no breeding programmes as such have been developed. Several cultivars have been developed for the production of foliage pot plants.

Prospects *F. elastica* is an important ornamental tree in South-East Asia. Its use for producing India rubber is now negligible, because of the higher yield and better quality of para rubber. However, India rubber is hypoallergenic to individuals allergic to some proteins contained in *Hevea brasiliensis* rubber and may become important because of this special property.

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Cheksum Tawan

Hevea brasiliensis (Willd. ex Juss.) Müll.Arg.

Linnaea 34: 204 (1865).
EUPHORBIACEAE
$2n = 36$

Vernacular names Natural rubber, para rubber (En). Caoutchouc (Fr). Indonesia: karet. Malaysia: getah asli. Cambodia: kausuu. Laos: jaang. Thailand: yang phara. Vietnam: cao su.

Origin and geographic distribution The centre of origin of natural rubber covers part of the Amazon Basin, parts of Matto Grosso (Upper Orinoco) and the Guianas. Geographically, wild and semi-wild *Hevea* is found in the northern part of South America, from Brazil to Venezuela and Colombia to Peru and Bolivia.

Natural rubber was first introduced into South-East Asia from the Neotropics in 1876. Early attempts to encourage its planting were not well received. However, with the arrival and expansion of the motor car industry and the increased demand for natural rubber, it soon grew into an important plantation crop in a number of tropical and subtropical countries. Today, rubber is grown in Malaysia, Indonesia, Thailand, Vietnam, Sri Lanka, China, India and Papua New Guinea in Asia, as well as in Ivory Coast, Nigeria, Cameroon, Liberia and Gabon in Africa.

In South America, particularly in Brazil, despite massive opening of new land for rubber cultivation, production continues to be hampered by a major rubber leaf disease caused by *Microcyclus ulei*, known as South American Leaf Blight.

Uses When tapped, the rubber tree produces a milky liquid (latex). This can be processed into latex concentrate, sheet rubber or block rubber; it is marketed as natural raw rubber. The main users of natural raw rubber are the tyre manufacturers who consume 50–60% of the total world natural rubber produced. The balance is divided among manufacturers of rubber car components (producing e.g. engine mountings, bushes, weather strips, V-belts, hoses, joint rings), manufacturers of engineering components (e.g. building mounts, anti-vibration mounts, dock fenders, flooring, high quality sheeting), and manufacturers of consumer products (e.g. footwear, sport goods, toys, gloves, latex threads, catheters, swimming caps, condoms). Moreover, when felled for replanting, the rubber tree is also sawn to give rubberwood (i.e. timber). With proper treatment, this can be used for high value added products like furniture, chipboard, medium density fibre board, parquet and many other wood products. Furthermore, rubber wood can be converted into charcoal. Seeds contain a semi-drying oil that can be used in making paints and soap.

Production and international trade Of the total world consumption of about 16.4 million t of rubber in 1998, 6.6 million t or 40% was natural rubber, 9.8 million t or 60% was synthetic rubber. Almost all (95%) of the world natural rubber supply comes from Asia, with Malaysia, Indonesia, Thailand and Vietnam as major producers, together accounting for about 80%. The total area under natural rubber plantations is estimated to be around 7 million ha.

The most important group of rubber producers are smallholders who cultivate more than three quarters of the world acreage. In Thailand more than 95% of all rubber is grown on smallholdings. In Indonesia and Malaysia these proportions are about 80% and 85% respectively. The estates are now planting oil palm, since this is more profitable.

Most natural rubber is exported to industrialized countries. This explains why the commodity is actively traded on the international markets in Singapore, Tokyo and Kobe, where quotations of spot and future prices are readily available on every trading day.

Prices of natural rubber move in tandem with the level of industrial activities and in response to short-term imbalances of supply and demand in industrialized countries. Historically, price movement follows the rubber trade cycle averaging 48 months. Currently, natural rubber of all types and grades is very depressed, with the average price of US$ 0.89 per kg (1998), the lowest for 21 years.

The United States is still the world's largest consumer of natural rubber. In 1998, it consumed 1.16 million t or 17.5% of the world's total production; then China (839 000 t or 12.7%), Japan (707 300 t or 10.7%), Malaysia (334 100 t or 5.1%), India (254 330 t or 3.8%). Germany, France, Italy, the United Kingdom and Spain accounted for 916 400 t or 13.9%. All other countries accounted for 2.4 million t or 36.3%.

Properties Latex consists of a colloidal suspension of rubber particles in an aqueous serum. The rubber content of latex may vary from 25–40% but is usually between 30–35%. Properties of rubber depend on the processing of the raw product after collection in the field.

The natural rubber molecule is made up of many isoprene units forming a polymer with a high molecular weight, chemically known as cis-1,4-polyisoprene $(C_5H_8)_n$. Rubber generally has a high viscosity which, for freshly prepared natural rubber, ranges from 55–90 centipoise. In storage and during transit, the viscosity of natural rubber increases to 70–100 centipoise depending on the duration.

Owing to its high structural regularity, natural rubber tends to crystallize when stored at low temperature or when stretched. The strain-induced crystallization behaviour gives natural rubber its unique high tensile strength in pure gum or in non-reinforcing filler vulcanisates.

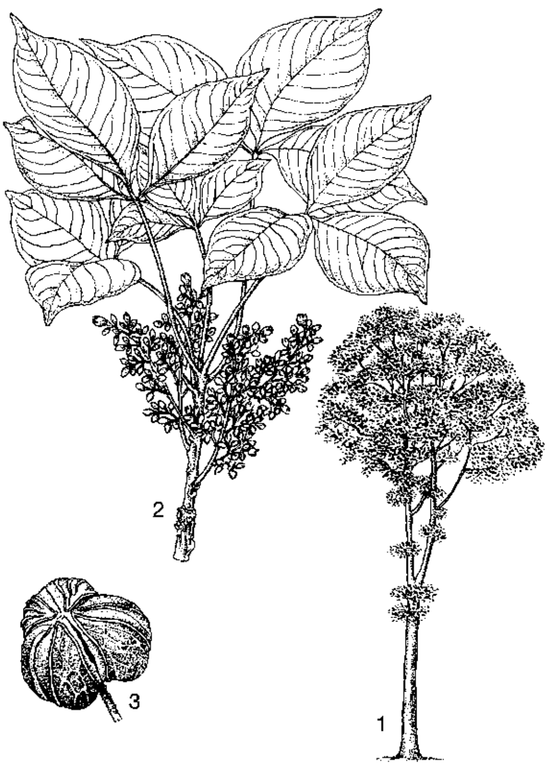
Natural rubber has an intrinsic density of about 0.92 g/cm^3 and a bulk density of 0.85 g/cm^3. It has a tendency to cold-flow unless restricted by physical constraints.

Properties of latex concentrate are specifically defined by the dry rubber content (d.r.c.), the volatile fatty acid number (V.F.A.), mechanical stability time (M.S.T.), the KOH number, alkalinity and colour. The properties for latex concentrate specify that the dry rubber content (%) should have a minimum of 60, the difference between d.r.c. and t.s.c. (total solid content) should not exceed 2%; the volatile fatty acid number should not exceed 0.20 but a typical latex concentrate can be kept at a low level of V.F.A. (e.g. <0.05) with good preservatives; the minimum requirement of mechanical stability time is 650 seconds; the KOH number (g), which determines the ionic content in latex, should not exceed 1.0, although immediately after production it is usually 0.4–0.5; the alkalinity of the latex with low ammonia type is 0.2% and with high ammonia type 0.6%; the coagulum content (%) should not be equal to or greater than 0.05; the dried latex film should be pale in colour.

The properties of raw rubber are subject to the Standard Malaysian Rubber (S.M.R.) grades. Currently, there are 9 S.M.R. grades (see reference 7 for their properties).

The heartwood of rubberwood is pale cream-coloured, often with a pink tinge, weathering to pale straw-coloured or pale brown, not distinctly demarcated from the sapwood. The density is 560–640 kg/m^3 at 15% moisture content. The grain is straight to shallowly interlocked, texture moderately coarse and even.

Description A deciduous, monoecious tree, 30–40 m tall, about 15(–25) m in cultivation; root system with a well-developed taproot of 1–2 m long, laterals spreading to about 10 m; bole usually straight but tapered, up to at least 50 cm in diameter, without buttresses; bark surface smooth to slightly corky, hoop marked, pale to dark brown, inner bark pale brown, with abundant



Hevea brasiliensis (Willd. ex Juss.) Müll.Arg. – 1, tree habit; 2, flowering twig; 3, fruit.

white latex; crown conical, branching pattern highly variable, stem leader dominant or soon divided into several heavy branches. Leaves arranged spirally, trifoliolate; petiole long with apical glands; stipules deciduous; leaflets entire, elliptical to obovate, 4–50 cm × 1.5–15 cm, acuminate, pinnately veined. Inflorescence a many-flowered, axillary, short-pubescent panicle on the basal part of a new flush; male and female flowers in the same panicle, small, without petals, female flowers less numerous and distributed at the apex of main and lateral branches; male flowers with a bell-shaped, 5-lobed perianth, yellow; stamens united into a column with 10 sessile anthers in 2 rows; female flowers with a green disk at base, ovary superior, 3-celled, with 3 sessile white stigmas. Fruit an exploding, 3-lobed capsule, 3–5 cm in diameter, pale brown when mature, with a thin rind and bony inner wall breaking into 6 pieces, each lobe with 1 seed. Seeds ovoid, about 2–3.5 cm long, testa waxy, with very numerous small dark brown spots and a variable number of irregularly shaped patches; endosperm abundant, almost completely enveloping the straight embryo. Seedling with hypogeal germination; hypocotyl elongating; cotyledons thin, leaf-like, green with pink or purple tinge.

Growth and development Rubber seeds usually germinate 7–10 days after sowing. Seedlings and buddings exhibit growth periodicity. Terminal buds of main stems produce long internodes with leaves clustered towards the end of them. The shoot pushes out vertically, slowly for 2–3 days, then rapidly before tailing off for 1–2 days. The energy for growth is then diverted into leaf development. Leaf petioles and leaf blades show the same kind of growth as the shoot, but the blades go on growing for 3–4 days longer than the petioles. When their growth ceases, the blades change colour from dark reddish to light green, and continue to droop. During the next stage the leaves rise to the horizontal position after which they become dark green. A complete cycle takes about 36 days, 18 for extension growth and 18 for leaf development. Subsequent growth proceeds in similar cycles and, as the plant grows, the leaves appear in whorls. After a period of about 2 months during which the plant becomes established, the growth rate is about 30 cm per month during the first year. A healthy seedling can reach a diameter of 2.5 cm in one year.

Branching is from the axils of leaves with average-sized petioles and begins after about 9 flushes; the branches are distinctly tiered. After the first year of growth, the plants then go through a phase of rapid vegetative growth for the next 4 years before they start flowering and fruiting. However, trees have been reported to flower when only 20 months old and to fruit in just over 3 years. Inflorescences appear in the axil of scale leaves towards the base of flushes on high-level branches of older trees. The development of flowers does not affect the growth of the shoot. The tree consequently has Rauh's architectural growth model, determined by a monopodial trunk which grows rhythmically, thus developing tiers of branches. 'Lampbrush' is a modification without ramification and with continuous growth according to Corner's architectural model. It can be induced by eliminating about one-third of each maturing leaf.

After branching, diameter increment starts and growth periodicity is less pronounced. Diameter increment decreases when trees are tapped. The trees attain a height of about 18 m in 8 years. To prevent wind damage, a rather short tree with a symmetrical crown starting about 3 m above ground level is preferred. When trees reach a certain age they shed all or some of their leaves, usually once a year. Before they fall, old leaves turn vivid orange or red, sometimes bright yellow. In Peninsular Malaysia, trees are briefly deciduous at the beginning of the year, and there is often a second complete or partial leaf-change in August–September. The intensity of leaf shedding, usually called wintering, depends on climatic conditions and varies with clone. A dry period of one month or longer causes partial or complete leaf fall. This causes a drop in latex production, especially during refoliation. Flowers are produced along with the new leaves. Both self- and cross-pollination is carried out by small insects. Self-incompatibility occurs in some clones. Natural pollination is poor and leads to only 1–4% of the female flowers setting fruit. Even with hand pollination no more than 5% of the pollinated female flowers develop into mature fruit. Fruits ripen in about 5 months. Seeds are actively dispersed for 10 m or more by the exploding capsules. Seeds are viable only for a few days, but storage in sealed containers with damp sawdust can extend the viability period to one month.

Other botanical information Of the 10 presently recognized *Hevea* species only *H. brasiliensis*, *H. guianensis* Aubl. and *H. benthamiana* Müll.Arg. yield usable rubber; the latex of other species is undesirable because of its high resin and low rubber contents. There are numerous cultivars (often clones) of *H. brasiliensis*.

From the periphery towards the centre the bark consists of cork layers, hard bark, and soft bark. Soft bark mainly consists of vertical rows of sieve tubes and latex vessels. Latex vessels are modified sieve tubes. They are formed from the cambium in concentric rings as cells which fuse longitudinally by gradual disintegration of the cross-walls. Within each ring, vessels are laterally interconnected but the connections are disrupted as the trunk expands. Latex vessels of stem, branches and leaves are interconnected. The latex-vessel cylinders generally run clockwise at an angle of about 3.5° to the vertical, which is why tapping cuts are made from upper-left to lower-right. The diameter of the latex vessels, the number of vessels per ring and the number of rings in the virgin bark are important characteristics, because they largely determine the content of the latex vessel system of a tree.

Ecology Rubber is a crop of the per-humid lowland tropics between 6°N and 6°S. Attempts to cultivate rubber as far south as the Sao Paolo Region in Brazil and as far north as Mexico and the Guangdong Province in China have met with some success. The optimum day temperature is 26–28°C. Rubber should preferably not be planted at altitudes above 400–500 m because the low ambient temperature retards diameter increment, delays tapping, and reduces latex production.

The annual rainfall requirement ranges from 2000–3000 mm with 170–200 rainy days. A well distributed annual rainfall of 1500 mm is considered the lower limit for commercial production. In Indonesia the best rubber areas have annual rainfall totals between 2500–4000 mm. In high rainfall areas soils should have good drainage. A large number of rainy days, especially with rain in the morning, is undesirable, because it disrupts the tapping schedule. In some areas rubber can also tolerate a 2–3 month drought. Wind is an important factor because it may snap trunks and branches.

Owing to its extensive root system rubber needs a well drained, root-penetrable soil, at least 1 m deep with an adequate moisture storage capacity. Temporary waterlogging with flowing water causes little damage. It can be grown in soils ranging from sandy to red lateritic and yellow podzols, young volcanic soils, alluvial clays and peat soil. Rubber is less demanding in terms of soil fertility and topography than other tree crops such as oil palm and cocoa and is often planted on land which is not suitable for these crops. In West Malaysia, rubber-producing areas have been classified into zones on the basis of factors limiting growth and production such as strong winds, disease incidence, soil type and topography.

Propagation and planting Rubber can be established by planting seed at stake or by raising plants in nurseries and later transplanting them to the field. Seedling trees are used, but improved vegetatively propagated planting material is often preferred. This can easily be obtained by bud grafting rootstock by a technique developed in 1916 in Indonesia.

Seed from vigorous high-yielding parents is used to produce rootstock. As seeds are viable for only a short time, they must be sown soon after harvesting. They are first germinated on shaded beds and transferred to the nursery soon after germination, where they are either planted in the ground or in perforated polythene bags.

Budwood is grown in special nurseries in which trees budded with the desired clone are closely spaced. Green budstick is obtained by cutting back the buddings, which then start producing numerous shoots. About 4 crops of budsticks can be obtained per year. About 1 crop of brown budwood can be harvested a year.

Bud grafting is carried out by making an inverted U-shaped incision on the rootstock 4–5 cm above soil level and inserting the bud patch without a petiole under the bark of the bud panel. It is essential that the rootstock and scion are at an active stage of growth and that their cambial tissue should be closely appressed and tied in place. About 3 weeks after budding the strips are opened and the successful stock stems cut back above the bud patch to allow the new bud to sprout.

'Brown budding' is the traditional bud grafting method in which 12–18 month old rootstock is budded with budwood of about the same age. This method was later superseded by the 'green budding' technique. This refers to budding 4–6-month-old, still green stock with buds from green budsticks. The advantage of this method is the short nursery period and the economic production of budwood. Green budding, however, requires greater skill than budding older stocks. Further improvement has been achieved by budding of 7–8(–10) week old rootstock. This is an early form of green budding called 'young budding' and it is used in raising advanced planting material. 'Crown budding' is a method of producing a 3-component tree which, for example, combines a disease-resistant crown with a high-yielding production trunk budded on a seedling rootstock. This technique is used in South America where *Microcyclus ulei* is a serious problem, and sometimes in Malaysia to overcome leaf disease.

After bud grafting the planting material can be nursed as bare-root stumps (e.g. budded stumps, stumped buddings and mini-stumps) or as polybag-raised buddings (2-whorl polybag-raised buddings, large polybag-raised buddings and soil-core whorled buddings). Raising bare-root planting material requires a suitable and well-prepared soil, whereas for polybag plants, only the potting medium and a good water supply matter. Lifting and root pruning of bare-root plants is time-consuming and laborious, but once this is done the material is easy to handle and to transport. Polybag plants need constant attention. They are ready for transplanting immediately but great care must be taken during their transport, to prevent root damage. Large polybag plants are cumbersome. Polybag plants, however, develop more quickly after planting. Soil-core buddings have much the same advantages and disadvantages as polybag plants, but as they are raised in the ground they are less susceptible to drought in the nursery.

'Clonal' seed obtained from monoclonal or polyclonal plantings which are known to produce high-yielding families is used for the production of seedling trees. These 'clonal' seedlings are cheaper to produce and they may have greater wind resistance and may reach maturity earlier than brown-budded rubber, but they are more variable and seedling plantings usually give lower yields. Germination and nursery procedures are essentially the same as for raising stock.

All planting material, buddings and seedlings are pruned to restrict development to one single stem free from any branches up to 3 m, to ensure enough tappable bark for high panel tapping.

In smallholdings temporary intercropping of young rubber with food crops is a common practice to provide cash income when the trees are still immature. On flat or undulating land intercropping can be carried out during the first 1–3 years after planting without adversely affecting rubber plants.

Budded stumps with bare roots are planted in holes of 45 cm × 45 cm × 45 cm. These are normally dug in advance, refilled and allowed to settle naturally with time and rain. Rock phosphate is added at a rate of about 100 g per hole during refilling. A similar procedure is used for planting advanced planting material (maxi-stumps) with bare roots, except that larger planting holes are used. Because of their susceptibility to drought, cylinders of polythene sheeting (sarongs) are temporarily placed in the planting hole around the upper half of the taproot. It is filled with a mixture of good soil and rock phosphate, watered and then mulched with grass. When the first leaves are properly hardened the sarongs are removed. For polybag plants, planting holes are made at the time of planting.

The preference for planting patterns has varied over the years between square spacings of about 5 m to avenue plantings with 8–10 m between the rows and 2–3 m in the row. The former has the advantage of optimal use of soil and space, early closure of the canopy and less wind damage, the latter of cheaper maintenance, lower tapping costs and space for temporary intercropping. The current recommendations of the Rubber Research Institute of Malaysia for smallholders practising intercropping is to plant rubber in east-west rows at distances of 9 m × 2.7–3 m.

High planting densities give the highest yields/ha but trees take a longer time to reach a tappable size and give lower yields per tree and per tapper. This is why smallholders, who are usually interested in maximization of yield/ha, plant at higher

densities (500–600 trees/ha) than estates (400–450 trees/ha) which are interested in maximization of net revenue.
Cover crop establishment is a standard practice in both new planting and when replanting on estates and is done just before planting the rubber. Drainage is required in areas which are waterlogged. The most common leguminous species used are *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth. Though legume cover crops compete rather strongly with the rubber in the first year of establishment, their overall effect on the rubber trees is beneficial and may extend over a 20-year period.

Husbandry The economic life cycle of rubber in plantation is 30–35 years. After each cycle, replanting is necessary to realize optimum use of the land. Land preparation for replanting is done mechanically, which involves cutting old stands, stacking and burning. This is followed by ploughing, rotavating, preparation of planting holes and planting. This last operation must coincide with the rainy season. If rubber is to be planted on land under forest, trees of economic importance are extracted first and then all other trees are felled and stumps are removed along the lines of the future planting. Burning follows, and then the non-burnt vegetation is wind-rowed. Recent public awareness of the importance of a clean environment and reduced air pollution has led to a zero-burning technique used in Malaysia. The wood of the stem is used as timber and remnant wood debris is stacked in alternate planting rows prior to lining and holing for planting.
Maintenance of young plants during immaturity includes weeding, manuring and sometimes mulching. Weeding is the most important and is also costly. Frequent weeding is required. Initially, only the tree circles to a radius of about 1 m are weeded, but later on this is done for the whole tree row or rubber strip. At the same time noxious weeds should be controlled or removed in the inter-row legume cover. Once the rubber trees reach maturity, the number of weeding rounds can be reduced due to shading by the tree canopy. It is then sufficient to weed the rubber strip and to slash the inter-row vegetation once or twice a year. On estates chemical weed control has replaced manual weeding except during the first year after planting when green scions and leaves are still found below a height of 1 m.
During the immature phase, branch pruning or controlled branch pruning is routinely carried out.
The amount of fertilizer applied to the trees is determined after assessing the nutrient status of both plant and soil. The method of fertilizer application varies with terrain. For flat to undulating terrain, a general broadcast of fertilizer is advocated, on hilly terrain the fertilizer should be applied along the planting rows after strip spraying. For immature rubber, the fertilizer should be evenly applied in a ring or broadcast along the planting strips.
In the nursery and during the first few years after field planting, fertilizers are frequently applied in small quantities. Subsequently, applications are made twice a year and, when trees have reached maturity, usually only once a year when the new leaves have emerged after wintering. The amount of nutrients removed in the latex is low, but may increase considerably when yield stimulants are used. To compensate for these losses and for the immobilization of nutrients in trunks and branches, annual fertilizer rates per ha used are in the order of 50 kg N, 20 kg P, 60 kg K and 20 kg Mg. Fertilizer recommendations for young trees are based on soil type, and for mature trees, on soil and leaf analysis, stimulation and on the specific requirements of clones. In Malaysia, young rubber receives mainly N and P, and fertilizer recommendations only differentiate between sandy and clayey soils. Mature trees receive N and K, but P and Mg are only given when leaf analysis indicates a need for them. Both organic and inorganic fertilizers are used; the former is preferred on sandy and lateritic soils.

Diseases and pests There are several important diseases and pests which attack rubber both in the nursery and in the field.
The 3 most important fungi in South-East Asia which cause root disease are, in order of significance, *Rigidoporus lignosus*, *Ganoderma pseudoferreum* and *Phellinus noxius*, giving rise to white, red and brown root disease respectively. They cause much destruction and total tree losses in new plantings and replanted areas of rubber. Hence proper control of these diseases during pre- and post-planting is essential. Pre-planting control is accomplished by removing all infected inoculum sources and post-planting control is achieved by regular inspection and by treating the affected plants with calixin. Early establishment of cover crops is also effective in controlling root diseases.
Important fungal leaf diseases are *Colletotrichum* and *Oidium*, causing secondary leaf fall, *Corynespora* (leaf spot) and *Phytophthora* (leaf fall). *Oidi-*

um attack can be controlled by protective sulphur dusting. In large areas of disease it can effectively be avoided by aerial spraying with defoliants a few weeks before wintering. Refoliation then takes place in a relatively dry period. Bird's eye spot disease caused by *Helminthosporium heveae* is also common, but is confined to the nursery. The most damaging and most feared leaf disease is South American Leaf Blight (SALB) caused by *Microcyclus ulei*. So far the disease has been confined to South and Central America. Infected trees lose their leaves after every new flush resulting in dieback and ultimately the death of the trees. At present the best solution to the SALB problem is an integrated approach combining the use of tolerant clones, judicious application of fungicides (e.g. carbamates), correct manuring and maintenance, and planting in somewhat drier areas.

Pink disease, caused by *Corticium salmonicolor*, is also of economic importance as it attacks the trunk and branches and causes branch snap. However, it is easily controlled by calixin or bordeaux mixture.

Underground pests are important and require attention at all stages of rubber growth. They include termites (*Coptotermes curvignathus*) and grubs of certain *Melolonthis* beetles. Among the aboveground pests, yellow tea mite (*Hemitarsonemus latus*) and thrips (*Scirtothrips dorsalis*) are commonly present in nurseries, where they cause defoliation of tender leaflets. Other common sap-sucking insects, such as scale insects and mealy bugs, may occasionally cause sufficient damage to warrant treatment in nurseries and of young plantings. Other pests that may require occasional attention in young rubber are slugs and snails, and a variety of mammals ranging from rats to elephants. Giant snails (*Achatina fulica*) cause damage in parts of Indonesia.

The first symptom of 'brown bast' or dryness is increased yield of watery latex, followed by a drying up of part or whole of the tapping cut. The cause is not known, but is generally considered to be a physiological condition due to overtapping.

Harvesting Tapping of rubber starts 5–6 years after planting. Trees are opened for tapping when 50–70% of the trees in a given area, measured at 150 cm height from the base, have attained girth size of at least 45 cm (15 cm diameter). Tapping involves cutting the bark from top left (at 150 cm height) to bottom right. The slope of the tapping cut is at an angle of about 30° to the horizontal. The amount of bark consumed is determined by the frequency of tapping. Cutting is carried out using a knife with a V-shaped cutting edge leaving a grooved channel along which the latex can flow (excision method).

The tapping system is characterized by a combination of the number of cuts per tree, the length of the cut and the frequency of tapping. According to an international notation the length of the cut is given as a fraction of the circumference: S/1 or S is a full spiral, S/2 a half spiral, S/4 a quarter spiral, S/R a reduced spiral. The frequency of tapping is expressed as d/1 for daily tapping, d/2 for alternate day tapping. The system S/2 d/2 is considered as standard. With the current labour shortage experienced by many countries and depressed rubber price, however, less intensive short cut tapping e.g. S/4 d/4 and S/4 d/6 is preferred. An alternative to low frequency tapping is periodic tapping, a system with nine months tapping and three months tapping rest e.g. S/2 d/3 (9/12 m). With appropriate stimulation these systems give yields comparable to those obtained with conventional methods.

At each tapping a thin slice of bark is removed. The latex runs along the cut and then down a vertical grove to a metal spout driven into the tree, which channels the latex into a cup. The conventional tapping method is one in which subsequent cuts move downwards until about 5 cm above the join in buddings. The bark above the cut is renewed from the cambium. To ensure good bark renewal tapping cuts should stop about 1.5 mm away from the cambium. Normal bark consumption for a half spiral cut tapped on alternate days is 2–2.5 cm a month. When there are no periodic resting periods it takes 5–6 years to tap the bark of a 150 cm high panel. After completing the first panel, the second one is opened at the same height on the opposite side of the trunk. When this panel has been used, tapping continues on the renewed bark of the first panel. Later, the renewed bark of the second panel is retapped. In this system about 10 years is allowed for bark renewal before tapping can resume. When this cycle is complete the trees are about 30 years old and are considered ready for replacement. However, they are intensively tapped (several panels per tree and high stimulant concentrations) for 3 years before being cut out.

In smallholdings where the trees are often tapped daily, bark consumption is much greater. After the first and second panels have been tapped twice the bark higher up the tree is exploited. A high panel, as it is called, is also used on estates, where it is often exploited in combination with a low, regenerated bark panel, either on the same or on the opposite side of the tree. In these double cut systems, periods in which only the upper or only the lower panel is tapped alternate. Upward tapping of high panels gives higher yields than downward tapping, but it requires greater skill to control the tapping knife. On older trees, control upward tapping (CUT) on the high panel is now an accepted practice.

Yield can be stimulated by applying ethylene-releasing chemicals (e.g. ethephon) on the tapping cut of young trees and on the bark of older trees either directly below (downward tapping) or above (upward tapping) the tapping cut. In young trees stimulation is usually not recommended, although in Ivory Coast and Malaysia, where labour is scarce, stimulation starts with the first panel. Non-intensive methods of stimulation involving low ethephon concentrations, low frequency of application plus periodic stimulation rest, may be used at an earlier stage. Stimulation should, in fact, always be combined with a lower tapping intensity than was used before the stimulation started. However, stimulation of trees requires increased fertilizer use. In practice, stimulation is considered as a means of maintaining or obtaining reasonably high yields at low tapping frequency, thus as a method of saving labour and costs.

As it is now common practice to use stimulants at a later stage of exploitation (probably after about 10 years of tapping) it is advisable from the outset to use systems that can be converted to lower intensity systems when stimulation is introduced. In view of this, S/2 d/2 is recommended for clones not susceptible to dryness ('brown bast') and S/2 d/3 for clones more prone to dryness. To avoid exhaustion of trees, special S/4 systems are recommended for smallholders tapping daily and using stimulants.

The advent of stimulants has enabled the development of unconventional methods using a needle instead of a tapping knife and requiring fewer and less skilled labourers. The most promising, called micro tapping techniques, are puncture tapping and micro-X tapping. In the first method 4–6 punctures are made per tap on a vertical strip of bark, 60–100 cm long and 1–2 cm wide, previously scraped and treated with ethephon. The second method combines puncture tapping and the conventional excision tapping methods. Here, 3 punctures are made on the existing half spiral 9 times on d/2 followed by 3 successive conventional tappings at the same frequency. In Malaysia a new puncture tapping method has been developed, in which ethylene gas is directly applied to a lightly scraped bark area on the panel and latex is extracted from the tree in a closed system into sealed receptacles containing a powerful anti-coagulant. This so-called RRIMFLOW system has several advantages compared to conventional tapping: trees can be exploited by unskilled labour, no yield is lost from rain interference, trees can be tapped overnight, thus maximizing productivity, and the entire yield can be harvested as latex, provided collection is completed within 72 hours after puncture tapping. This system, which is primarily intended for trees entering the last phase of their economic life, is still awaiting commercial application.

The number of trees a tapper is assigned to tap in a day is called a tapping task. It depends on the number of cuts per tree, their length, and on the age and condition of the trees and the topography of the land. A skilled tapper can tap (with half spiral downward) 400–500 trees in 3–4 hours. If a tapper begins at 6 a.m. he can start collecting the latex about 5 hours later when the latex flow from the cut has stopped. No tapping can be done during rain or when the panel is wet. If there is frequent morning rain then recovery tapping is carried out in the afternoon. An alternative solution to cope with rain interference is to use rainguards. These are used, for instance, in dense stands of young rubber, where tapping panels remain wet even after rain has long since stopped.

The latex is collected in buckets and brought to a central point for bulking and transport to the factory. On some estates the latex runs from the spouts into polythene bags which are collected at regular intervals by ordinary labourers. The bags contain coagulated latex from several tappings, which requires special processing. Because of the shortage of tappers, management research and development is currently paying special attention to the division of tapping and collecting labour and to optimizing tapping tasks.

Yield Yield of rubber is largely dependent on the cultivar planted and the agro-management inputs given to the trees during the periods of immaturity and production. Because of the superior management and better inputs, yields are normally higher on estates than on smallholdings.

In general, latex yield is expressed in kg/ha per year. In South-East Asia, average estate yield is about 1500 kg/ha per year, ranging from 1200–2000 kg/ha per year. The average yield from a smallholding is about 800 kg/ha per year and ranges from 400–1500 kg/ha per year. In Malaysia, the average national yield is about 1150 kg/ha per year.

Handling after harvest When rubber latex arrives at the factory, it is filtered and bulked before coagulation. After coagulation, it is processed into either sheet rubber, crepe rubber or block rubber. Generally, formic acid is used to coagulate the latex. Under normal factory conditions and depending upon the concentration of the latex and the acid used, this process takes a few hours.

If the production line is set up for sheet rubber, the coagulated rubber is milled through 3–4 different pairs of rollers. The first few rollers are usually smooth and the last is ribbed. The milled sheets are then dried in a smoke house for 4 days to produce ribbed smoked sheets (R.S.S.).

If crêpe rubber or air-dried sheet is required, the coagulated rubber is milled using a battery of power-driven crêpers to produce a well-knitted thin crêpe. After milling, the crêpe can then be dried in suitably constructed hot air rooms or chambers.

To produce SMR (Standard Malaysian Rubber) block rubber, the coagulum is generally crêped and hammer-milled to produce crumb rubber. The crumbs are dried in hot air at 110°C in deep-bed driers. The dried crumbs are then baled into 33⅓ kg bales, wrapped in polythene sheets and packed into 1 t wooden crates.

For latex concentrate production, the filtered latex is subjected to one of the following methods of processing: centrifugation, evaporation, or creaming. In South-East Asia, centrifugation is the most widely used. During centrifugation, the lighter rubber particles are separated from the heavier serum to produce a concentrated fraction of about 60% dry rubber content. These are then stored and tested before export. For export, the latex is either shipped in bulk in the ship's deep tank, or in containers, or in flexible bags, usually of 1 t capacity.

Genetic resources The surviving *Hevea* seedlings from Wickham's introduction in 1876 into South-East Asia provide only a narrow genetic base. Subsequent introductions into Indonesia made by the Dutch (1896, 1898 and 1913–1916) and by the British into Peninsular Malaysia (1951–1954) were added as genetic resources but did not have much impact on breeding progress. Another small introduction of various *Hevea* species was made into Malaysia in 1966. Further augmentation of genetic resources in the South-East Asian region was implemented through the introduction of large numbers of wild *Hevea* germplasm from Brazil in 1981 and 1992. Germplasm collections are maintained in Malaysia and Ivory Coast.

Breeding Selection and breeding of new rubber clones or cultivars are still the most efficient means of reducing the cost of production. However, it has now been realized that further spectacular yield increases as occurred during the early years of controlled breeding are most unlikely to occur again. Over the last 60 years, 6-fold yield increases, i.e. from 500 to 3000 kg/ha per year, have been achieved. Modern clones like RRIM (Rubber Research Institute of Malaysia) 600, 712, 901 and 2001, PR (Proefstation voor Rubber, Indonesia) 255 and 261, PB (Prang Besar, Peninsular Malaysia) 217, 235, 255, 260 and 350, and GT (Gondang Tapen, Indonesia) 1 are products of this achievement, with yield averaging about 2 t/ha per year after the first 5 years of tapping. However, present-day breeders recognize that emphasis should not be placed on yield alone but on other desirable characteristics as well, such as vigour, quality of virgin and renewed bark, colour and stability of latex, resistance to leaf and bark diseases and to wind damage and timber volume produced. Response to stimulation and to low intensity tapping has become an additional criterion in selection. The use of other *Hevea* species to incorporate resistance to leaf diseases (in particular South American Leaf Disease) has also been pursued in breeding.

Another *Hevea* species, *H. spruceana* Müll.Arg., was introduced into Indonesia in 1913 for breeding purposes, without any positive results. It easily hybridizes with *H. brasiliensis* and therefore seeds collected from areas containing *H. spruceana* progeny might constitute a danger to the established *H. brasiliensis* plantations, as both *H. spruceana* and its hybrid with *H. brasiliensis* yield only small amounts of rubber of poor quality. *H. spruceana* differs from *H. brasiliensis* e.g. in the veins on the lower leaf surface being hairy, the flowering shoots being situated at the end of strong twigs, the larger flowers which are tinged with red or mauve, and the fruit being pear-shaped.

Prospects The prospects for natural rubber are very good. Demand is expected to increase in view of the demands of the automobile industry and the possible diversification of rubber in manufacturing. This would help to stabilize prices at a favourable level on the world market and persuade planters to continue planting rubber. Rubberwood has important uses in the manufacture of medium density fibreboard, furniture and parquet which strengthen the economic viability of rubber growing.

In most rubber-producing countries, rubber will continue to be cultivated, although the scale and emphasis will vary from country to country. This is because in most countries rubber is still an important cash crop for planters. Various governments have increased the budgets for research and development and given new emphasis to the transfer of technology to smallholders. Incorporating new germplasm into *Hevea* breeding programmes has improved the prospects for further yield improvement.

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Hymenaea courbaril L.

Sp. pl.: 1192 (1753).
LEGUMINOSAE
$2n = 24$

Synonyms *Hymenaea candolleana* Kunth (1823), *Hymenaea retusa* Willd. ex Hayne (1830), *Inga megacarpa* M.E.Jones (1929).

Vernacular names West Indian locust, jatoba, courbaril (En). Indonesia: kobari, locus (general). Philippines: jatoba.

Origin and geographic distribution *H. courbaril* is native to the American tropics and is distributed in the West Indies, and in Central and South America from southern Mexico to Brazil. It is cultivated in the tropics, was introduced into Singapore in 1875 and is now found in Malesia, particularly in Peninsular Malaysia, Sabah and Java.

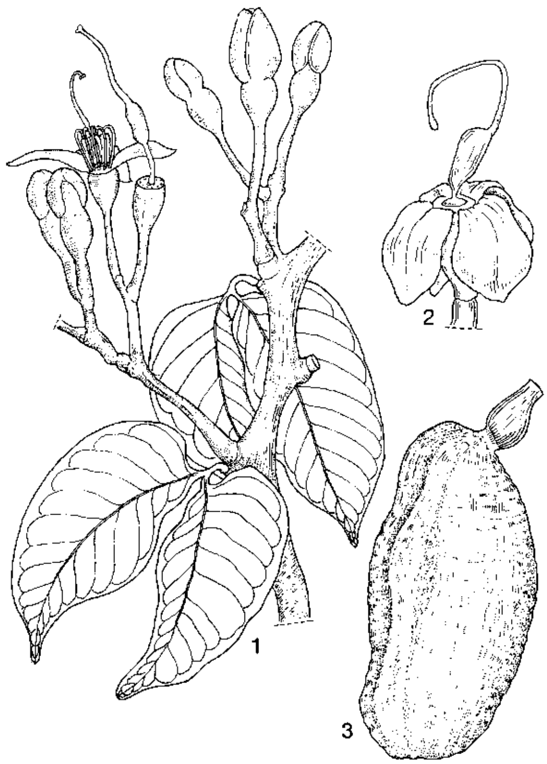
Uses All parts of *H. courbaril* contain a resin, but it is generally only tapped from the bark. The resin is used in special grades of varnishes, lacquers, paints, inks, plastics, sizing, adhesives, fireworks, and crockery cements. It is used to a lesser extent as incense and for medicinal purposes and for patent leather. Commercially the resin is known as 'South American copal'. In Brazil, it is the main source of the resin known as 'jatoba', 'jutaicica', 'jutai' or 'jutai-acu'.

The wood of *H. courbaril* is valuable and resembles mahogany (*Swietenia* Jacq.). It is hard and strong and used for construction, door and window frames, ship building, furniture, panelling and parquet flooring. The mealy pulp around the seeds is sometimes eaten by children, but it has an unpleasant smell. In Brazil, the fruit pulp is also used as a carbohydrate source in making alcoholic beverages for domestic consumption. The bark is a source of tannin and is so thick that it has been used by Indians to make canoes. In agroforestry it is employed as a nitrogen-fixing tree to rehabilitate degraded and marginal soils. It has also been planted as an ornamental tree, but its hard, heavy and malodorous fruits make it less suitable for this purpose. The flowers are attractive to bees and are used for honey production.

Production and international trade Brazil is the main source of the resin but international trade is believed to be very small or negligible. From 1976 to 1986 production in Brazil declined from 38 t to 23 t and the unit price also declined. No production data are available from South-East Asia. 'Recent copal', obtained by tapping, is sent to India and China, where it is manufactured into a coarse varnish.

Properties South American copal varies in colour from an almost colourless transparent mass to bright yellow-brown. It usually has a dull, rough outer surface where it has suffered oxidation. The resin contains a relatively large amount of tannin. It also contains about 13% copalic acid, a cyclic diterpene. The quality and hardness of the resin are likely to increase with age. It is probably inferior to 'East African copal' (*Hymenaea verrucosa* Gaertn., *Copaifera* spp.) and 'East Indian copal' (*Agathis borneensis* Warb.).
The heavy heartwood is red-brown, streaked, with a density of 730 kg/m³ at 15% moisture content for an Indonesian sample, and 880–1000 kg/m³ for South-American samples. The wood hardly shrinks or warps. It is very hard, very strong and very tough. It is difficult to work, but planes, turns and polishes well.

Description An evergreen, medium-sized tree up to 25(–40) m tall, bole 1 m or more in diameter, often much smaller in cultivation; bark smooth, becoming 2.5 cm or more thick, grey to pinkish-brown. Leaves alternate, bifoliolate, glossy green above, gland-dotted; petiole 1–2 cm long, petiolules twisted, 2–4 mm long; leaflet blade falcate, rarely oblong or obovate, 4–10 cm × 2–5 cm, coriaceous, base asymmetrical and rounded, margin entire, apex short to long acuminate. Inflorescence terminal, densely corymbose-paniculate, 8–15 cm long and wide; pedicel 6 mm long. Flowers large, buds up to 3.5 cm long, open flower 3 cm in diameter, all parts glandular punctate; calyx campanulate, 4-merous, grey-green, tube (hypanthium) 6 mm long, lobes ovate to elliptical, 15–18 mm × 8 mm, imbricate, coriaceous, pubescent outside, sericeous inside; petals 5, subequal, oblong, ovate or obovate, equalling the calyx lobes or slightly longer, not clawed, yellow, streaked with red; stamens 10, 3.5 cm long, free, filaments white, folded in bud, anthers red, dorsifixed; pistil with stipitate ovary, stipe 4–8 mm long, ovary with about 15 ovules, style slender, curved about 2.5 cm long. Fruit a compressed cylindrical pod, 8–20 cm × 4–8 cm, smooth or rough but not rugose, dark brown, indehiscent and often remaining for a long time on the tree, usually with 6–12 seeds embedded in pale yellow, unpleasant smelling fruit flesh. Seed flattened ellipsoidal, 2–3 cm long, dark red. Seedling with epigeal germination.



Hymenaea courbaril L. – 1, flowering branch; 2, flower (stamens removed); 3, fruit.

Growth and development *H. courbaril* develops according to the architectural model of Troll which is characterized by all axes being plagiotropic and is built by continuous superposition of branches thus forming a sympodial stem. Planted seedlings lack a leading shoot; they branch heavily, but will eventually form a clear bole. Young trees have a taproot, but later the root system spreads shallowly. In the Philippines, large nodules with a rough surface have been observed on the roots. In plantation trials in Peninsular Malaysia, trees attained 14 m height and 19 cm diameter in 8 years in the open. In trials in Java on fertile soil, *H. courbaril* had attained an average height of 20 m and an average diameter of 19–22 cm 10 years after planting. On moderately fertile soils trees also grow well. Fruiting is almost annual. In Singapore flowering starts in June and fruits need 10–11 months to ripen. In East Java *H. courbaril* flowers in November–April and ripe fruits are found in July–September. There are 280–300 dry seeds/kg as determined from trees grown in Indonesia; in India 800–900 dry seeds/kg have been counted. Dispersal of the seeds in Costa Rica is by agoutis (*Dasyprocta punctata*), a kind of rodent.

Other botanical information Within *H. courbaril* 6 varieties have been distinguished, of which 5 occur only in Brazil. Var. *courbaril* (described here) has a wide distribution in the American tropics and is also cultivated in the tropics of Africa and Asia, including South-East Asia.

H. verrucosa Gaertn. (synonym: *Trachylobium verrucosum* (Gaertn.) Oliv.) is a resin-producing species from tropical Africa which is also cultivated pantropically. Major differences with *H. courbaril* are: inflorescence up to 35 cm long, flowers small, buds less than 15 mm long, petals distinctly clawed, pod surface verrucose-rugose. See also the chapter on minor species.

Ecology *H. courbaril* is a light-demanding species and in South America it is found in secondary forest on sandy, well-drained soils. It mainly occurs in dry forests at low altitudes, although it can grow well at higher elevations.

Propagation and planting Seed of *H. courbaril* can be stored for a long time without losing viability but should be scarified before sowing either by filing the seed coat, or by treatment with hot water or with concentrated sulphuric acid. In an experiment in India 70–80% germination was obtained after treatment with hot water or with concentrated sulphuric acid for 5–25 minutes whereas untreated seed did not germinate. In Costa Rica, seeds germinate well under natural conditions at temperatures above 23°C and in humid soil. Stripped seedlings or stumps can be used as planting stock giving a satisfactory survival, whereas direct seeding has also been used.

Planting trials on degraded land in West Java (Indonesia) were not very successful, with only 9% survival after 2 years in one site and 68% survival after 8 months in another. On fertile soil, trials were more successful. A spacing of 3 m × 2 m was applied, but because of the heavy branching 3 m × 1 m has been recommended.

Management *H. courbaril* has never been planted for its resin. For timber production the young trees need strong lateral competition because of the weak apical dominance. Even large branches are readily shed.

Diseases and pests No particular diseases or pests have been observed in *H. courbaril* in South-East Asia. In South America several pathogens have been identified, but their importance is probably minor.

Harvesting In South America trees of *H. courbaril* used to be tapped. The fresh resin obtained by tapping the trees ('recent copal') is much softer than that dug up from the ground ('fossil copal'). It has the nature of a balsam or soft elemi and is also used medicinally. The pale yellow or reddish resin exudes from the bark and trickles to the ground where it hardens into lumps and eventually become covered with soil. In the course of time considerable quantities of resin collect in this way.

Yield Native collectors in South America can obtain a barrel full of resin of *H. courbaril* by digging around the roots of a tree, and several barrels from the former site of a large tree that has long since decayed. In a 60-year-old trial plantation in Peninsular Malaysia a mean annual volume increment of 3.7 m^3/ha was obtained and 3 m^3/ha was produced in East Java by an 11-year-old trial plantation.

Handling after harvest The resin of *H. courbaril* is not processed further and is used directly for the manufacture of varnishes and lacquers.

Genetic resources and breeding There are no known germplasm collections or breeding programmes for *H. courbaril*. It is not threatened by extinction.

Prospects *H. courbaril* is more important for timber production than for its resin; its fairly fast growth and good wood quality may hold promise for the future. The prospects for the resin market, however, are not promising.

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N.O. Aguilar

Madhuca Buch.-Ham. ex J.F.Gmel.

Syst. nat. 2: 773, 799 (1791).
SAPOTACEAE
x = unknown

Major species and synonyms
- *Madhuca curtisii* (King & Gamble) Ridl., Fl. Mal. Pen. 5 (Suppl.): 319 (1925), synonyms: *Ganua curtisii* (King & Gamble) H.J.Lam (1925), *Madhuca chrysocarpa* (Pierre ex Dubard) Ridl. (1925), *M. perakensis* (King & Gamble) Ridl. (1925).
- *Madhuca motleyana* (de Vriese) J.F.Macbr., Contr. Gray Herb. Harvard Univ., New Ser. 53: 18 (1918), synonyms: *Ganua motleyana* (de Vriese) Pierre ex Dubard (1908), *G. scortechinii* (King & Gamble) H.J.Lam (1925).

Vernacular names General: nyatoh (En).
- *M. curtisii*: Malaysia: mentua taban (Peninsular).
- *M. motleyana*: Indonesia: ketiau, bengku (Sumatra), nyatu bekas (Kalimantan). Malaysia: nyatoh ketiau (Peninsular), ketiau (Sarawak, Sabah). Thailand: sateeyo (peninsular).

Origin and geographic distribution *Madhuca* (including *Ganua* Pierre ex Dubard), comprising about 100 species, has a western Malesian centre of diversity. It is distributed from India, Sri Lanka and south-eastern China to New Guinea. *M. curtisii* occurs in Peninsular Malaysia and Borneo and *M. motleyana* is found in Peninsular Thailand, Peninsular Malaysia, Sumatra, the Riau Archipelago, Belitung and Borneo.

Uses The latex of *Madhuca* is used as gutta-percha, but of inferior quality. Gutta-percha is derived from the latex of *Sapotaceae*, primarily *Palaquium* spp. It has been used in the manufacture of chewing gum.
The timber of *Madhuca* is commercially important and is sold as 'nyatoh', the lightweight to medium-weight trade group of many genera of the *Sapotaceae*. Oil from the seeds of *M. motleyana* (known as 'ketia oil') is used as food ingredient and the manufacture of soap and candles. Its fruits are eaten locally.

Production and international trade Mean annual Indonesian exports of 'getah ketiau' from *M. motleyana* over the years 1928–1938 were 1070 t (495–2137 t), with 95% originating from south-eastern Kalimantan. The 'getah ketiau' was exported to Singapore and the United States. Exports from Sarawak of 'getah jangkar', which is the gutta-percha from *M. motleyana*, *Payena leerii* (Teijsm. & Binnend.) Kurz and *Pouteria malaccensis* (C.B.Clarke) Baehni, for the period 1949–1953 were 26–75 t annually. More recent statistics are not available.

Properties The latex of *M. motleyana* contains 80% resin, a relatively high amount by comparison with the resin content of the latex of *Palaquium* and *Payena* spp. Its gutta-percha, therefore, is of lower quality. The physical properties of the getah ketiau are intermediate to those of the elastic rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.) that consists mainly of cis-polyisoprene and the non-elastic, thermoplastic gutta-percha (*Palaquium* spp., *Payena* spp.) that are mainly trans-polyisoprene. When traded in the 1920s getah ketiau was much more valuable than 'jelutong' (*Dyera* spp.).
Kernels of *M. motleyana* yield about 50% oil which is edible and contains 0.02–0.14% HCN. Hence, the press cake is bitter and poisonous. The oil contains about 50% oleic acid, 28% palmitic acid, 15% stearic acid and 8% linoleic acid.

Description Small to large trees, with latex, sometimes up to 50 m tall, usually with columnar bole up to 100 cm in diameter, with or without buttresses, often branchless for a considerable length; outer bark smooth, cracked or fissured, usually brownish, inner bark soft and fibrous,

Madhuca curtisii (King & Gamble) Ridl. – 1, branch with leaves and fruiting calyces; 2, branch with fruits.

pinkish to reddish-brown, sometimes yellowish; twigs usually slender, hairy (sometimes woolly), scurfy or glabrous at tips. Leaves generally arranged spirally, usually closely to loosely clustered at ends of twigs, sometimes scattered; stipules usually small and caducous, more rarely large and fairly persistent; petiole generally of even thickness throughout its length; blade simple and entire, usually obovate or elliptical, often glabrous when mature but sometimes velvety or woolly beneath; secondary veins usually fairly numerous, straight or curved, usually diminishing until inconspicuous at the leaf margin, sometimes joined near the margin by an intramarginal vein, tertiary veins usually reticulate, sometimes parallel or transverse. Inflorescence an axillary fascicle, 2–many-flowered. Flowers bisexual; sepals 4, in 2 whorls of 2, glabrous or tufted with some hairs at apex; corolla (6–)8–12(–17)-lobed, tube often about as long as the lobes, usually woolly between the stamens at throat of the tube, whitish, pale yellow or pale green; stamens (12–)14–36(–43), in 1–3 whorls inserted at the corolla throat, often with short filaments, anthers mostly mucronate at apex; pistil 1, with (5–)8–9(–15)-celled ovary and long style. Fruit a berry with thin to thick pericarp, 1(–4)-seeded. Seed with thin, hard, shiny testa, contrasting with a narrow (rarely broad), linear, pale dull scar usually with membranous albumen and thick cotyledons. Seedling with epigeal germination and a strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves arranged spirally and soon similar to leaves of adult trees.

- *M. curtisii*. A medium-sized tree up to 30 m tall with columnar bole up to 60 cm in diameter, buttresses absent or small, latex bluish, at first very sticky; leaves evenly distributed to loosely clustered; stipules up to 5 mm long; petiole longer than 1.5 cm, blade narrowly obovate to obovate or elliptical, 7.5–15.5 cm × 3.5–7 cm, primary vein flat to rounded above, secondary veins 11–18, joined near margin, glabrous; flowers greenish or white, sepals tufted with some hairs at apex, corolla 8–10-lobed, glabrous except for apex of lobes, stamens 16–22, ovary hairy; fruit ovoid to ellipsoidal, about 2 cm × 1.3 cm, reddish-brown hairy, 1–2-seeded; seed without or with very thin endosperm, cotyledons thick.
- *M. motleyana*. A medium-sized to large tree up to 40 m tall with columnar bole up to 100 cm in diameter, buttresses absent or small and sometimes developing pneumatophores; outer bark often pinkish, latex white; crown extraordinarily dense; leaves evenly distributed or loosely clustered at tips of twigs, stipules very small, petiole up to 4 cm long, blade ovate, obovate or elliptical, 5–20 cm × 2.5–8.5 cm, primary vein keeled above, secondary veins 13–23, joined in arches near margin, glabrous; flowers yellow to green, with sepals pubescent outside and tufted with some dark hairs at apex, corolla 8–10-lobed, glabrous except for throat, stamens 16–22, ovary glabrous or hairy; fruit ellipsoidal, 1.5–3 cm × 1–2 cm, glabrous, green, yellowish to reddish, 1–2-seeded; seed without or with thin endosperm, cotyledons thick.

Growth and development In Kalimantan, *M. motleyana* flowers annually and ripe fruits are observed in December–March. Its fruits are relished by wild pigs, deer, bears and birds which disperse the seeds. It has been estimated that a tree with a diameter of 60 cm is about 30 years old, which implies a mean annual diameter increment of 2 cm.

Other botanical information Both *Madhuca* species have often been considered to belong to the genus *Ganua* Pierre ex Dubard, which was thought to differ in having characteristic tufts of hairs at the apex of the sepals, and in a thinner pericarp. These distinguishing characters are, however, not reliable and it seems better to merge *Ganua* and *Madhuca*. Usually *Madhuca* can be distinguished from other *Sapotaceae* genera by the flowers having 4 sepals and a corolla with 8 or more lobes, and by the seed having a thin endosperm and thick cotyledons.

Ecology *M. curtisii* is found in primary forest on low hills up to 700 m altitude and is locally common in Peninsular Malaysia in Penang and Perak. *M. motleyana* occurs in lowland areas up to 600 m altitude, growing in periodically inundated forest, freshwater and peat swamps, sometimes on upland locations.

Propagation and planting *Madhuca* species are normally propagated by seed. Regeneration of *M. motleyana* is very profuse in peat swamps.

Management Planting of *Madhuca* is not practised and the latex is collected from natural forest.

Harvesting Latex is collected from *Madhuca* throughout the year, usually by felling the tree. Immediately after felling, the tree is ringed just below the crown to prevent the latex from going to the leaves. Then, rings are made at 60–70 cm intervals and the thick exuding latex is collected in small containers. After about one hour the containers are collected and taken to where the latex is to be coagulated. One tapper can collect latex from 5–8 trees in one day.

Yield Three *M. motleyana* trees of 50–60 cm in diameter yielded 8.9 kg latex from which 6.3 kg coagulated product was prepared. Usually, however, trees cut have only a diameter of 20–25 cm.

Handling after harvest The collected latex of *Madhuca* is taken to a temporary shelter in the forest or to the village. The latex is put in a wooden barrel of whose interior has been coated with yellow clay to prevent the latex from sticking to it. An equal amount of boiling water is added to the latex and the mixture is stirred continuously. Coagulation starts after 10 minutes and is complete after half an hour. After cooling the coagulated mass is taken from the barrels and kneaded with the feet on wooden boards. Water is added to wash away the clay particles and the product is formed into blocks and stored under water. If it is not stored under water the coagulated latex disintegrates and crumbles in one year. Adulteration with the less valuable 'jelutong' (*Dyera* spp.) or with coagulated latex from *Moraceae* or other *Sapotaceae* has been reported.

Genetic resources and breeding At present both *Madhuca* species are only harvested for timber, but it is uncertain to what extent current harvesting is accelerating genetic erosion. There are no known germplasm collections or breeding programmes.

Prospects At present, the latex of *Madhuca* is no longer traded and it is very unlikely that it will be in the near future as better synthetic substitutes are available.

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Isa Ipor

Palaquium Blanco

Fl. Filip.: 403 (1837).
SAPOTACEAE
x = unknown

Major species and synonyms

- *Palaquium calophyllum* (Teijsm. & Binnend.) Pierre, Ann. Jard. bot. Buitenz. 5: 28 (1886), synonym: *Isonandra calophylla* Teijsm. & Binnend. (1864).
- *Palaquium gutta* (Hook.f.) Baill. – see separate article.
- *Palaquium leiocarpum* Boerl., Bull. Inst. bot. Buitenzorg 5: 24 (1900), synonyms: *Palaquium molle* Pierre (1902), *Croixia leiocarpa* (Boerl.) Baehni (1965).
- *Palaquium luzoniense* (Fern.-Vill.) S.Vidal, Revis. pl. vasc. Filip.: 176 (1886), synonyms: *Palaquium ahernianum* Merr. (1903), *Croixia luzoniensis* (Fern.-Vill.) Baehni (1965).
- *Palaquium obovatum* (Griff.) Engl., Bot. Jahrb. Syst. 12: 511 (1890), synonyms: *Isonandra obovata* Griff. (1854), *Palaquium theoideum* Elmer (1910; '*theoidea*').

Vernacular names General: gutta-percha (also used for other *Sapotaceae* species whose latex is used), nyatoh, bitis.

- *P. calophyllum*: Indonesia: nyatoh jankar merah, nyatoh tunjung, karikip (Kalimantan). Malaysia: getah tunjung, hangkang karikit, getah tewe (Sarawak). Philippines: natong-ganda.
- *P. leiocarpum*: Indonesia: jongkang, hangkang (Kalimantan). Malaysia: nyatoh jangkar, jangkai (Sarawak).
- *P. luzoniense*: Philippines: kalipaya, nato (general), dolitan (Tagalog).
- *P. obovatum*: Indonesia: mayang katapong, balam terupuh (Sumatra), siki putih (Ambon). Malaysia: nyatoh puteh (Peninsular). Philippines: lahas (Subanon). Burma (Myanmar): pinle-byin. Cambodia: sang das, chor ny, chlôr. Thailand: khanun-nok, saang (south-eastern), yue-raa-toh (peninsular). Vietnam: ch[aa]y.

Origin and geographic distribution *Palaquium* consists of about 110 species distributed from western India and Sri Lanka to southern China and east to Polynesia (Samoa). The centre of diversity is western Malesia and most species are found in the Philippines (about 30) and Borneo (about 35), many of them endemic. Peninsular Malaysia and Sumatra have comparatively fewer species (about 20). New Guinea is considered an important secondary centre of diversity, with about 13 species. *P. calophyllum* occurs in Borneo and in the Philippines (Mindoro). Its occurrence in Sulawesi and New Guinea is doubtful. *P. leiocarpum* is found in Borneo and Sulawesi, possibly also in Peninsular Malaysia. *P. luzoniense* has its natural distribution throughout the Philippines, but probably not in Palawan. *P. obovatum* is widespread and found in India, Burma (Myanmar), Indo-China, Thailand, Peninsular Malaysia, Sumatra, Lingga, the Riau Archipelago, Bangka, Borneo (Sarawak), Sulawesi, Flores, the Moluccas and the Philippines (Luzon, Mindoro, Sibuyan, Samar).

Uses Gutta-percha, the coagulated latex from the bark or leaves of several *Sapotaceae* species including *Palaquium*, has been used extensively for submarine and underground cables due to its non-conductivity for electricity and heat, and imperviousness to water. Golf balls used to be manufactured with an outer cover of gutta-percha. This was the only significant end-use in the 1960s and 1970s. It has also been used for medical and chemical instruments, in dentistry, transmission belts, acid-resistant receptacles, as adhesives, waterproofing agents and as an ingredient of chewing gum. The advent of synthetic resins and other petroleum-based polymeric materials led to the rapid decline in the use of the natural material. At present its main application is for protecting wounds and in dental clinics, where it is proving to be useful for people allergic to synthetic fillers. Locally the gutta-percha is used for fixing tool handles.
The timber of *Palaquium* is of major importance. Species are traded as 'nyatoh' containing the lightweight to medium-weight *Sapotaceae* species (e.g. *P. leiocarpum*, *P. luzoniense*, *P. obovatum*) or as 'bitis' comprising the heavy hardwoods.

Production and international trade Indonesia is probably the largest producer and exporter of gutta-percha. Annual exports during the period 1988–1993 varied considerably from 3–366 t, but these figures may not be reliable. In 1963–1972 the average annual import in the United States from Indonesia was 1140 t. The products of *Palaquium gutta* and *Payena leerii* (Teijsm. & Binnend.) Kurz are included in these figures. Early in the 20th Century the average annual world consumption of gutta-percha was 850 t, but an average annual export of 14 000 t over the period 1900–1920 from Singapore has also been reported. Exports of 'getah hangkang', the gutta-percha of *P. leiocarpum* from Indonesia in the period 1928–1938 were 670–1260 t/year. International trade in gutta-percha, in particular to Europe, started in the second half of the 19th Century, with Singa-

pore as the centre. After the trees around Singapore had been felled the search for gutta-percha quickly extended northward into Peninsular Malaysia, and south and east into Indonesia, through the Riau Archipelago to Kalimantan, to Sarawak and Sabah and eventually to the Philippines.
The *Palaquium* species yielding gutta-percha only account for a minor part of the amount of nyatoh timber traded.

Properties Gutta-percha is non-elastic, but becomes plastic when heated and retains any form given while cooling. It is generally a white substance, which turns pink to dark red upon exposure due to oxidation and formation of resins. Moreover, it acquires a pungent odour when oxidation sets in. It resists concentrated alkalies and dilute acids (even hydrofluoric acid). It consists mainly of trans-polyisoprene, very little rubber (cis-polyisoprene) and a varying amount of resins but never less than 10%. The higher the resin content the lower the quality of the gutta-percha, as at lower temperatures it becomes more brittle and becomes plastic. Getah hangkang consists of about 75% resin. Refining raw gutta-percha lowers the resin content. The resins found in the latex are albane and fluavile.
The more important *Palaquium* species yielding gutta-percha are lightweight to medium-weight hardwoods with a density of 440–790 kg/m^3 at 15% moisture content.

Description Small to very large trees, with latex in all tissues, sometimes up to 60 m tall, usually with columnar buttressed bole up to 130 (–250) cm in diameter, often branchless for a considerable length; outer bark smooth, cracked or fissured, usually brown to reddish-brown, inner bark soft and fibrous, pinkish-yellow, pink, red or reddish-brown; twigs usually slender, often hairy or scurfy at least at tips, often with distinctly developed terminal cone-like buds. Leaves arranged spirally, usually densely to loosely clustered at ends of twigs; stipules small to large, usually early caducous, rarely absent; petiole usually of even thickness throughout its length; blade simple and entire, usually obovate, generally glabrous above and more or less hairy beneath when mature; secondary veins straight, curving towards apex and often joined near leaf margin, tertiary veins transverse or parallel to secondary ones or reticulate. Inflorescence an axillary or rarely terminal fascicle, 1–many-flowered; flowers bisexual or rarely unisexual; sepals (4–)6(–7), generally in two whorls of 3, ovate or triangular; corolla (5–)6-lobed, with usually short tube and imbricate, often contort lobes, white to yellowish or greenish; stamens (10–)12–18(–36), inserted at the throat of the corolla tube, with acute anthers; pistil 1, with (5–)6(–10)-celled ovary and usually long style. Fruit a berry with fleshy pericarp, 1–3-seeded. Seed with a crustaceous to coriaceous testa and a large hilum often covering up to two-thirds of the surface of the seed; endosperm usually absent and cotyledons thick and fleshy. Seedling usually with epigeal germination and strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves arranged spirally and soon similar to leaves of adult trees.

Palaquium calophyllum (Teijsm. & Binnend.) Pierre – 1, branchlet with leaves and immature fruits; 2, tertiairy venation of leaf; 3, flower, with only part of the stamens drawn; 4, seed.

– *P. calophyllum*: a small tree up to 15 m tall; leaves evenly distributed, obovate, rarely elliptical, 3.5–9 cm × 7–19 cm, tomentose or velvety beneath, tertiary veins transverse to secondary ones; flowers in 2–11-flowered clusters; pedicel 10–25 mm long (in fruit up to 30 mm), rust- or golden-coloured tomentose; fruit depressed globose, 2 cm × 2.5 cm, densely red-brown tomentose.

- *P. leiocarpum*: a small to fairly large tree up to 35 m tall; leaves evenly distributed or loosely clustered at tip of twigs, ovate, obovate or elliptical, 5–27 cm × 4–10 cm, with few transverse tertiary veins almost parallel to secondary veins and with a reticulate venation in between, velvety beneath; flowers whitish in 3–6-flowered clusters; pedicel 8–15 mm long (in fruit up to 30 mm); fruit globose to ellipsoidal, 15–25 mm long, glabrous.
- *P. luzoniense*: a small to medium-sized tree up to 25 m tall, with bole up to 50 cm in diameter, but sometimes attaining 120 cm, lacking buttresses; leaves clustered at tip of twigs, obovate, oblong or elliptical, 11–20 cm × 2–10 cm, with transverse to reticulate tertiary venation, minutely hairy beneath; flowers yellowish-green or whitish, in 1–4-flowered clusters; pedicel slender, 20–65 mm long; fruit ellipsoidal, 3.5–4 cm long, initially minutely hairy but glabrescent, dull green.
- *P. obovatum*: a medium-sized to large tree up to 45 m tall, with columnar bole up to 80(–110) cm in diameter; leaves usually densely clustered at tip of branches, obovate to oblong, 6–45 cm × 3–17 cm, with distinct, transverse tertiary venation, puberulous or glabrous and glaucous beneath; flowers greenish-yellow or greenish-white, in 4–12-flowered clusters; pedicel up to 2 cm long; fruit globose, ellipsoidal to obpyriform, 2–3 cm long, glabrous; germination hypogeal.

Growth and development In many cases *Palaquium* flowers do not reach maturity because of attack by insects and/or unfavourable weather conditions. Flowers may remain closed for a long time (up to 18 months), probably waiting for favourable weather conditions for opening. A regular periodicity of flowering and fruiting seasons does not exist but in certain years there is a general and heavy seed crop. Ripe fruits are eaten by animals who thus disperse the seeds. The average annual increment of *P. obovatum* trees as observed in transformed natural forest in Peninsular Malaysia was 1.3 cm.

Other botanical information Other *Palaquium* species whose latex has been collected are: *P. hexandrum* (Griff.) Baill., *P. hispidum* H.J. Lam, *P. maingayi* (C.B.Clarke) King & Gamble, *P. mindanaense* Merr., *P. oxleyanum* Pierre, *P. philippense* (Perr.) C.B.Rob. and *P. quercifolium* (de Vriese) Burck. Their gutta-percha was usually mixed with gutta-percha of higher quality.

In *P. obovatum* two varieties have been distinguished: var. *obovatum* found from India to Sumatra and Borneo, and var. *orientale* H.J.Lam found in the Philippines, Sulawesi and the Moluccas. The latter variety differs particularly in having more oblong leaves with more acuminate apex, and shorter pedicels.

Ecology Most *Palaquium* species grow in lowland forest, where trees usually occur scattered. Many species are common in freshwater swamp forest, some grow commonly in peat swamp. *P. calophyllum* is common along rivers, up to 200 m altitude. In Borneo, *P. leiocarpum* is found in primary forest at low altitudes, but sometimes up to 1000 m. *P. luzoniense* and *P. obovatum* are fairly common in lowland forest, but the latter may ascend up to 1300 m altitude.

Propagation and planting No *Palaquium* species apart from *P. gutta* are known to be planted for the production of gutta-percha.

Management In Peninsular Malaysia early in the 20th Century 3000 ha of natural forest were transformed to almost pure gutta-percha forest (containing *P. gutta* and *P. obovatum*). This type of forest management was abandoned in the 1960s.

Diseases and pests Tapping wounds often start rotting or are attacked by termites.

Harvesting Traditionally the latex is harvested by felling the tree, lopping off the branches and by cutting a number of rings in the bark at a spacing of 30–60(–100) cm. The exuding latex is collected in containers placed under the tree. This destructive method had already been abandoned in the first half of the 20th Century in several countries because resources had depleted rapidly. Various methods have been developed for tapping the living trees. Usually a series of V-shaped cuts 20–30 cm apart at an angle of 45° to the vertical are made and these cuts are joined by a vertical cut. The cuts are made on two sides of the tree, leaving a strip of untapped bark 10 cm wide. Most of the latex coagulates in the cuts and exuding latex is collected in a small cup attached to the bark. The coagulated latex is scraped off and formed into a ball, which is then pressed into the cuts and rolled along them. Each time the ball is rolled along a cut, the removal of the coagulated latex re-opens the cut ends of the latex cavities and the flow recommences. A rest period of at least 2 years was reported to be necessary before trees could be tapped again, to maintain the economic productivity. *Palaquium* trees contain irregular latex cavities in the bark which are not connected, so they cannot be tapped continuously like para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.).

Cloudy, moist conditions allow the latex to flow more easily than during hot, sunny periods, when there is some loss of water by evaporation.

Yield Yields of gutta-percha per tree are very variable, 0.45–3.6 kg has been reported for destructively harvested trees leaving an estimated 6–40 times of the latex unharvested. The latex yield obtained by tapping is much lower. Higher yields are obtained when tapping the upper portion of the trunk and branches than when tapping the lower part. In *P. obovatum* the latex flows more easily than in other species and latex yield is higher.

Handling after harvest The latex of *P. leiocarpum*, which does not coagulate on the tree, is heated over a fire while stirred continuously until coagulation is completed and water has evaporated. Primary processing of other partially coagulated latex is done in a similar manner. The coagulum is then pressed into blocks after first softening it in hot water and removing larger pieces of foreign matter. The blocks are then transported to the factory for further processing. The blocks can best be stored under water, to avoid spoilage by aerial oxidation. In former days gutta-percha was deliberately adulterated with chopped bark, wood and even stones to increase its weight. Purified gutta-percha can be prepared by dissolving the resinous fraction in cold petroleum spirit, and then dissolving the remaining, separated gutta fraction in hot petroleum spirit. The hot extract is drained from any insoluble foreign matter and then allowed to cool, whereupon the purified gutta-percha separates out. After separation and distillation of residual solvent the hot, plasticized gutta is rolled into sheets and stored, either in the dark in well-sealed tins, or in water. This chemical method yields the 'white gutta-percha', which has a resin content of 1% and hardly any foreign matter. The problem is that the natural anti-oxidants in the gutta-percha are also extracted, hence, the gutta-percha becomes susceptible to deterioration through oxidation. However, chemical anti-oxidants may be added. The mechanical method involves processing the raw gutta-percha by treatment with hot water to remove impurities, and collecting and pressing it into blocks. This yields 'yellow gutta-percha' with about 9% resin and 3% impurities.

Genetic resources As *Palaquium* trees are harvested for timber and hardly for gutta-percha, timber exploitation is the main determinant of the risk of genetic erosion. Germplasm collections do not exist.

Prospects It is unlikely that the present use of gutta-percha from wild *Palaquium* trees will increase, as many synthetic products are available. Its special and local applications will remain of limited economic importance.

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S. Aggarwal

Palaquium gutta (Hook.f.) Baill.

Traité bot. méd. phan., Add.: 1500 (1884).
SAPOTACEAE
$n = 24$

Synonyms *Palaquium acuminatum* Burck (1886), *P. oblongifolium* (Burck) Burck (1886), *P. optimum* Becc. (1902).

Vernacular names Gutta-percha tree (En). Indonesia: balam merah (Sumatra), getah merah, getah sambun (Kalimantan). Malaysia: taban merah, nyatoh taban merah (Peninsular), (nyatoh) rian (Sarawak). Thailand: chik-nom, saeo (peninsular).

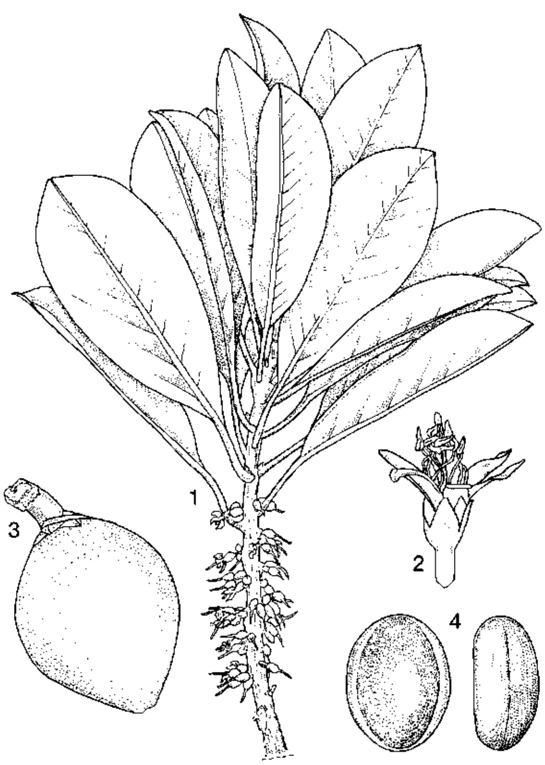
Origin and geographic distribution *P. gutta* occurs naturally in Peninsular Malaysia, Singapore, Sumatra and Borneo; it is cultivated elsewhere, e.g. in Java.

Uses From the latex of the leaves of *P. gutta* the best grade of gutta-percha is produced. Gutta-percha is the coagulum of the latex; it is scarcely elastic but on exposure it sets to a substance possessing the property of softening with heat and hardening again when allowed to cool. Gutta-percha has been used extensively for submarine and underground cables due to its non-conductivity for electricity and heat, and imperviousness to water. Golf balls used to be manufactured with an outer cover of gutta-percha. By the 1960s and 1970s, golf ball manufacture was the only significant end use for gutta-percha. It has also been used for medical and chemical instruments, in dentistry, for transmission belts and acid-resistant receptacles, as an adhesive, as a water-proofing agent and as an ingredient of chewing gum. The advent of synthetic resins and other petroleum-based polymeric materials led to the rapid decline in use of the natural material. At present its main application is for protecting wounds and in dental clinics (as 'dental points'), where it is proving to be useful for people allergic to synthetic fillers. Locally, gutta-percha is used for fixing tools in their handles.
The timber is used as 'nyatoh', for planks (not exposed to the weather or ground), panelling, and for the manufacture of fine furniture, decorative doors and veneers. The seeds contain a fat used for the manufacture of soap and candles, and sometimes for cooking.

Production and international trade Indonesia is probably the largest producer and exporter of gutta-percha. Annual exports were (3–)195(–366) t in 1988–1993, but these figures may not be reliable. In 1963–1972 average annual imports in the United States from Indonesia were 1140 t. Average annual gutta-percha exports from Singapore in 1961–1980 were 225 t. These figures include gutta-percha from other *Palaquium* species and *Payena leerii* (Teijsm. & Binnend.) Kurz. Early in the 20th Century the average annual world consumption of gutta-percha was 850 t, but average annual exports over the period 1900–1920 from Singapore of 14 000 t have also been reported. Exports of 'getah merah' (only gutta-percha from *P. gutta*) from Kalimantan and Sumatra were 4–51 t/year in the period 1928–1938. Exports of gutta-percha from plantations in Java were 35–230 t/year in 1927–1940.

Properties Gutta-percha is the coagulum of the latex of several species of *Sapotaceae*. It is non-elastic, but becomes plastic when heated at temperatures over 50°C and retains any form given while cooling. It is generally a white substance, which turns pink to dark red upon exposure due to oxidation and the formation of resins. Moreover, it acquires a pungent odour when oxidation sets in. It resists concentrated alkalies, dilute acids and even hydrofluoric acid. It consists mainly of trans-polyisoprene with a molecular weight of about 30 000, very little rubber (cis-polyisoprene) and a varying amount of resins, ranging from 20–30%. The higher the resin content the lower the quality of the gutta-percha, as it becomes more brittle and plastic at a lower temperature. Refining raw gutta-percha lowers the resin content, and the final product of *P. gutta* contains 87–99% gutta, 1–9% resin and 0.2–3.3% foreign matter. The resins found in the latex are albane and fluavile. The gutta-percha content of leaves increases with age, from about 3% in young leaves and 8% in medium-aged leaves to 10% in old leaves. The reaction with sulphur is utilized to vulcanize gutta-percha, rendering it non-plastic and insoluble.
The seeds contain 58–63% fat.

Description A medium-sized to large tree up to 45 m tall, but generally much shorter (about 25 m) with columnar bole, up to 60 cm in diameter and with usually small buttresses; twigs usually slender, often hairy or scurfy at least at tips, with 1 cm long terminal cone-like buds. Leaves alternate, clustered at tip of twigs or evenly distributed; stipules up to 3 mm long, falling off early; petiole 1–6 cm long; blade obovate, ovate, elliptical or narrowly elliptical, (8–)12–17(–50) cm × 2–6(–12) cm, with transverse or reticulate tertiary veins (sometimes parallel to secondary veins), distinct or inconspicuous, golden-brownish velvety beneath. Inflorescence an axillary fascicle with 2–7(–10) flow-



Palaquium gutta (Hook.f.) Baill. – 1, flowering twig; 2, flower; 3, fruit; 4, seed (front and side view).

ers; flowers bisexual; pedicel 2–9(–12) mm long; sepals (4–)6(–7), generally in two whorls of 3, ovate or triangular, about 4 mm long; corolla tubular, up to 9 mm long, (5–)6-lobed, with usually short tube and imbricate, often contort lobes, white to yellowish or greenish; stamens (10–)12–18(–36), inserted at the throat of the corolla tube, with acute anthers; pistil 1, with (5–)6(–10)-celled ovary and usually long style. Fruit globose, ellipsoidal or ovoid, 2–3.5 cm long, finely hairy and green. Seedling with semi-hypogeal germination, cotyledons emergent, with strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves arranged spirally and soon similar to leaves of adult trees.

Growth and development In northern Peninsular Malaysia (Penang) trees of *P. gutta* flower from January–April and in the central part of Peninsular Malaysia from July–September. In Java flowering occurs in the months of June–August and fruits reach maturity in January–March. In many cases flowers do not reach maturity because of attack by insects or unfavourable weather conditions. There are, however, certain years when there is a generally heavy seed crop. The ripe fruit, but not the seeds, is eaten by fruit bats. There are often numerous ripe seeds on the ground underneath bat roosts. Fallen fruits are quickly consumed by squirrels, birds, insects and other animals, so only a small proportion of the seeds survives. In Peninsular Malaysia, *P. gutta* has a mean annual diameter increment of 1.2 cm and attains about 8 m tall in 7 years, 17 m in 23 years and a diameter of about 50 cm in 50 years.

Other botanical information Although *P. gutta* is a rather variable species, the many existing subclassifications in the literature are not justified because they are often based on small differences, e.g. on the shape and size of the leaf, the apex of the leaf, the number and shape of secondary and tertiary veins, the lengths of the petiole and of the pedicel, all of which fall within the normal variability of a species.

Palaquium acuminatum Burck, *P. selendit* Burck and *P. treubii* Burck used to be considered as separate species because they produced an inferior quality gutta-percha. At present, however, they are considered as synonyms because morphologically they fall within the normal variability of *P. gutta*.

Ecology *P. gutta* occurs scattered in lowland forest, but sometimes occurs up to 1600 m altitude (Sabah). Plantations thrive in areas with precipitation over 2500 mm annually and without pronounced dry season. *P. gutta* requires a loose and well aerated soil rich in organic matter.

Propagation and planting Trial plantings of *P. gutta* were made in Singapore as early as 1845. In 1885 important plantations for gutta-percha production by tapping were established in Cipetir (West Java) at 550 m altitude and with 3000 mm annual rainfall. Seed production of *P. gutta* is unreliable and depends on the weather during flowering. Seed loses its viability in 2(–8) weeks, but fresh seed has a germination rate of 75–85%. Seed should be sown in deep nursery beds, as the seedlings develop a taproot. A minimum spacing of 15 cm is required. Young plants need shade and plenty of water, and when sown in February (West Java) they measure about 25 cm at the beginning of the rainy season in December when they are ready for planting out. Seedlings can be planted either as bare-rooted stock or as containerized planting stock, but mortality after planting is usually high: up to 35%. Older seedlings may be planted as stumps. In Cipetir seedlings used to be planted at 1.2 m × 1.2 m, whereas in Peninsular Malaysia the spacing applied was 1.5 m × 1.8 m.

Husbandry Young plantations of *P. gutta* require shade. This has been successfully supplied by *Paraserianthes falcataria* (L.) Nielsen, *Derris microphylla* (Miq.) B.D.Jacks. and *Adenanthera microsperma* Teijsm. & Binnend. Competition from grasses should be eliminated and green manure species should be planted to ameliorate the soil. In Cipetir, *Sesbania sesban* (L.) Merr. has proved to be very successful both for shade and in improving the soil. When it became possible to extract latex from leaves, planted trees needed to be managed as shrubs, for easy harvesting of leaves, instead of allowed to develop tappable stems. To achieve this, selective thinning is done to eliminate individuals with too few branches, stems are cut when they reach 60–75 cm tall, and branches are cut back to encourage leafing. Pruning should not be done before a dry period or on poor growing sites. Normally, pruning is done every 2.5–3.5 years. In Peninsular Malaysia, a 1000 ha plantation was established in 1905 with seed from Cipetir. In 1900–1910 many small plantations were established in Java and eastern Sumatra, but these were all abandoned when para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.) became profitable. In Peninsular Malaysia, 6000 ha of natural forest were transformed early in the 20th Century to almost pure gutta-percha forest (containing *P. gutta* and *P. obovatum* (Griff.) Engl.). Commercial plantations in Peninsular Malaysia ceased exploitation in 1967. In Cipetir, one commercial gutta-percha plantation of about 4000 ha was still active at the time of writing. In Singapore, a small plantation can be found in the foothills of Bukit Timah Nature Reserve.

Diseases and pests A severe attack of *P. gutta* by a leaf roller, *Rhodoneura myrthea*, has been observed in Java. This leaf roller spins younger leaves together, often causing the growing apex to rot. In severe cases loss in leaf production has been estimated to be about 20%.

Harvesting Traditionally the latex of *P. gutta* is harvested by felling the tree, lopping off the branches and cutting a number of rings in the bark at 30–60(–100) cm intervals. The exuding latex is collected in containers placed under the tree. This destructive method was prohibited in the first half of the 20th Century in several countries, as resources were dwindling rapidly. Various methods have been developed for tapping the living trees. A rest period of at least 2 years was thought to be necessary between successive tappings to keep the tree economically productive. *Palaquium* trees contain irregular latex cavities in the bark which are not connected, and tapping cannot be done repeatedly as in the case of para rubber. Cloudy, moist conditions allow the latex to flow more easily than hot, sunny periods, when there is some loss of water by evaporation.

In plantations, extraction of gutta-percha from the leaves of the trees is more productive than collection of latex by tapping. This type of exploitation started early in the 1900s when a process was developed to extract gutta-percha from the leaves. Harvesting is done partly by plucking twigs with 4–6 leaves (about every 40 days) and partly by collecting prunings which comprise leaves, twigs and small branches. Old leaves or even fallen leaves are harvested preferentially, as their gutta content is higher.

Yield Higher latex yields are obtained by tapping the upper portion of the trunk and branches of *P. gutta* than by tapping the lower part. Yields of gutta-percha per tree are also very variable. About 1.5 kg was reported to be a good average yield for destructive harvesting. The latex yield obtained by tapping living trees is much lower. The average annual yield of leaves is 3000–4000 kg/ha when leaves have a moisture content of 30%. Wide variations occur, however. The approximate gutta-percha yield per ha was 450 kg (2.3% from treated leaves) in 1920; a recent estimate from the company exploiting the Cipetir plantation was only 20 kg/ha annually, probably because of the extensive way of exploitation nowadays.

Handling after harvest A factory for gutta-percha extraction was established in Cipetir in 1930 and is still functional. The present method of processing involves digesting of pulverized leaf material in hot water having a temperature of 70°C, and then rinsing with cold water. The coagulated latex then separates from the leaf pulp residue, which sinks in water. Purified gutta-percha can be prepared by dissolving the resinous fraction from the coagulated latex in cold petroleum spirit, and then dissolving the remaining, separated gutta fraction in hot petroleum spirit. Bleaching earth is added to the hot mixture to remove unwanted leaf pigments. The hot extract is separated from any insoluble foreign matter and then allowed to cool, whereupon the purified gutta-percha separates out. After separation and distillation of residual solvent the hot, plasticized gutta is pressed into round blocks of about 1.5 kg. These blocks are packed in round well-sealed containers for shipping. This chemical method yields

the 'white gutta-percha', which has a resin content of 1% and almost no foreign matter. The problem is that the natural anti-oxidants in the gutta-percha are also extracted and that makes gutta-percha susceptible to deterioration through oxidation. However, chemical anti-oxidants may be added by the manufacturer of end-products, and the choice of anti-oxidants differs with the type of end-product.
Leaves have also been processed mechanically. This involves collecting the coagulated latex after the hot water treatment of the pulverized leaves, and pressing it into blocks. This method yields about 3% gutta. The leaves contain about 3.5% gutta.
Latex obtained by tapping the trees used to be processed by pressing the partially formed coagulum into blocks after first softening it in hot water and removing larger pieces of foreign matter. The blocks were then transported to the factory for further processing. These blocks were stored under water to avoid spoilage by aerial oxidation. The gutta-percha blocks were deliberately adulterated with chopped bark, wood and even stones to increase weight. The crude gutta-percha was processed in the factory either mechanically or chemically. The mechanical method consisted of processing the raw gutta-percha by treatment with hot water to remove impurities, and collecting and pressing it into blocks. This yielded the 'yellow gutta-percha' with about 9% resin and 3% impurities. Chemical treatment by solvent extraction of the chopped crude gutta-percha followed the same principles as those mentioned earlier for processing gutta-percha obtained from leaves.

Genetic resources Although several *Palaquium* species have been planted in Cipetir, the quality of the gutta-percha from *P. gutta* proved to be superior to that of other species, so the existing plantation is currently a monoculture of *P. gutta*. There are no known germplasm collections.

Breeding At the end of the 19th Century, best-yielding trees were selected in their natural habitat for the establishment of the plantation of *P. gutta* in Cipetir. No later selection and breeding programmes are known of.

Prospects Although the market is currently very small with only one enterprise producing gutta-percha from *P. gutta*, it is expected that gutta-percha as a product of natural origin will maintain its market share.

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N.O. Aguilar

Payena leerii (Teijsm. & Binnend.) Kurz

Journ. As. Soc. Beng. 40: 69 (1871).
SAPOTACEAE
x = unknown

Synonyms *Payena croixiana* Pierre (1885), *Madhuca leerii* (Teijsm. & Binnend.) Merr. (1923).

Vernacular names Indonesia: balam beringin, balam suntei (Sumatra), kolan (Kalimantan). Malaysia: getah sundek, balam sundek (Peninsular). Philippines: edkoyan (Tagbanua).

Origin and geographic distribution *P. leerii* is found in Peninsular Malaysia, Sumatra, the Riau Archipelago, Bangka, Borneo and the southern Philippines (Palawan, Mindanao, Sulu Archipelago); it is cultivated in Java, and rarely also in tropical Africa and South America.

Uses The gutta-percha from *P. leerii* is of good quality and is used similarly to that of *Palaquium gutta* (Hook.f.) Baill. It has been used extensively for submarine and underground cables due to its non-conductivity for electricity and heat, and its imperviousness to water. Golf balls used to be manufactured with an outer cover of gutta-percha. It has also been used for medical and chemical instruments, in dental clinics, transmission belts, acid-resistant receptacles, as adhesives, waterproofing agent and an ingredient of chewing gum. The advent of synthetic resins and other petroleum-based polymeric materials led to the rapid decline in use of the natural material. At present its main application is for protecting wounds and in dental clinics, where it is proving to be useful for people allergic to synthetic fillers. Locally the gutta-percha is used for fixing tools in their handles. In South Sumatra the gutta-percha from *P. leerii* is known as 'getah sontik', in South Kalimantan as 'getah beringing', and in Sarawak as 'getah jangkar'.

The timber is used as 'bitis', occasionally as 'nyatoh'. Bitis is a durable timber used for heavy constructional work, agricultural implements and for heavy-duty flooring, posts, and door and window frames. Nyatoh is a less durable timber when in contact with the ground; it is important for the manufacture of fine furniture, decorative doors and veneers and panelling. The fruits are edible and taste like sapodilla (*Manilkara zapota* (L.) P.Royen), but have little pulp.

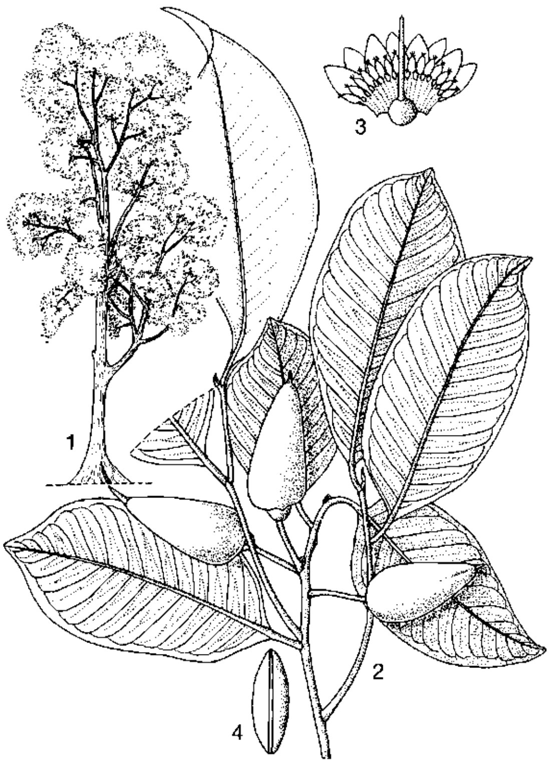
Production and international trade Indonesia is probably the largest producer and exporter of gutta-percha. The annual exports were 3–366 t in 1988–1993, but these figures may not be reliable. In 1963–1972 the average annual import in the United States from Indonesia was 1140 t. The gutta-percha of *Palaquium gutta* and other *Palaquium* spp. is included in these figures, *P. leerii* probably only yields a small part of the gutta-percha traded. Early in the 20th Century the average annual world consumption of gutta-percha was 850 t, but an average annual export of 14 000 t from Singapore over the period 1900–1920 has also been reported. Export from Sarawak of 'getah jangkar', the gutta-percha from *P. leerii, Madhuca motleyana* (de Vriese) J.F.Macbr. and *Pouteria malaccensis* (C.B.Clarke) Baehni, was 26–75 t annually in the period 1949–1953.

'Bitis' timber is usually converted to scantling sizes, and sold unclassified. Although *Madhuca utilis* (Ridl.) H.J.Lam ex K.Heyne, *Palaquium ridleyi* King & Gamble and *Palaquium stellatum* King & Gamble are the main bitis-producing species, *Payena leerii* may also supply this type of timber.

Properties As the latex of *P. leerii* is collected and not the coagulated product (as in the case of *Palaquium* spp.), the product contains less debris and is whiter than the 'getah merah' from *Palaquium gutta*. However, the gutta-percha from *P. leerii* becomes yellow when exposed. Raw gutta-percha from *Payena* spp., probably mainly *P. leerii*, contains 14–26% water, 40–46% gutta, 30–32% resin and 3–8% foreign material; when purified it contains 54% gutta and 46% resin. The gutta-percha has a comparatively high plasticity and, unlike the large amount of resin it contains, is of good quality. The gutta-percha is not sticky, but rapidly changes with time, it then becomes brittle on the surface and sticky when heated. Some trees seem to yield a sticky gutta-percha and others yield a non-sticky gutta-percha.

The timber is heavy with a density of 760–1060 kg/m^3 at 15% moisture content. The heartwood is deep pink, red, red-brown or purple-brown, sometimes with dark streaks, distinctly to indistinctly demarcated from the pale red sapwood. The grain is shallowly to moderately interlocked, sometimes wavy and the texture moderately fine to slightly coarse. The seed contains 3.5–4.5% oil.

Description A medium-sized to fairly large tree up to 40 m tall, with columnar bole up to 80 cm in diameter, buttressed, containing white latex which turns yellow upon exposure; twigs slender and terete, usually hairy or scurfy. Leaves alternate or arranged spirally, simple, entire; stipules 3–4 mm long, falling off early; petiole 0.5–1.5 cm long; blade broadly ovate to oblong-lanceolate, 5–16 cm × 1.5–8 cm, base cuneate to rounded, apex acuminate, glabrous on both sides; midrib sunken above and prominent below, secondary veins 11–18, straight, curving towards apex and joined near leaf margin, tertiary veins mostly descending from marginal conjunctions of secondary veins and ramifying into 2–3 branches which run parallel towards the midrib, tertiary vein just visible on lower leaf surface. Inflorescence a small, axillary (sometimes pseudo-terminal) fascicle, 1–8-flowered, often in defoliate leaf-axils; pedicel 1–1.5 cm long; flowers bisexual, very small, up to 0.5 cm long, white to yellow-white; sepals 4, 2–4 mm long, 2 outer ones thick and fleshy, 2 inner ones thinner; corolla 8-lobed, 2 mm long, with short tube, glabrous, white or yellowish-white; stamens 16, inserted at the throat of the corolla tube, with short, pubescent filaments, acute anthers and long-ciliated connective; pistil 1, with long conoidal 8-celled ovary and persistent style, 6–8 mm long. Fruit a berry, cone-shaped or narrowly so,



Payena leerii (Teijsm. & Binnend.) Kurz – 1, tree habit; 2, fruiting twig; 3, opened flower; 4, seed.

with a flat broad base, 2.5–5 cm × 1–2.5 cm, glabrous or subglabrous, abruptly passing into the style at apex, usually 1-seeded, green. Seedling with epigeal germination, hypocotyl elongated; cotyledons emergent; leaves alternate-spiral from the start.

Growth and development In a plantation in West Java trees of *P. leerii* flower and fruit already at an age of about 7 years. Although the tree can be found flowering and fruiting year-round, major flowering time is April–August in Malesia.

Other botanical information *P. leerii* is closely related to *P. obscura* Burck from which it can be distinguished by its conical fruit with an abrupt slender style and a rather flat broad base. Gutta-percha of *P. dantung* H.J.Lam has also been used; the product is more like rubber than like gutta-percha but, like gutta-percha, it becomes plastic when heated.

Ecology *P. leerii* is most commonly found in primary forest, up to 1000 m altitude.

Propagation and planting *P. leerii* can be propagated by seed; propagation by cuttings is possible but difficult. Seed loses its viability in 2(–8) weeks and should be sown in deep nursery beds, as the seedlings form a well-developed taproot. Young plants need shade and plenty of water. Planting should be done with great care, so as not to injure the taproot and to ensure that the taproot is straight when planted. Early in the 20th Century *P. leerii* was planted experimentally in Java, e.g. in the gutta-percha plantations in Cipetir, West Java; growth was very good, but tapping these trees gave only very low yields. The spacing applied was 2 m × 2 m. Planting has been tried in Singapore and Peninsular Malaysia but these trials were abandoned when wild supplies, which had escaped notice, were discovered.

Management In young plantations of *P. leerii*, *Paraserianthes falcataria* (L.) Nielsen is often used to provide shade. In the first 7–8 years after planting, weeding is necessary about 4 times per year, later only once a year. The canopy closes 10–12 years after planting when weeds are shaded out completely. The trees then reach 6–13 m in height.

Harvesting In the bark of felled trees of *P. leerii* 1–1.5 cm wide rings are cut from which the latex exudes and is collected in containers placed underneath. The latex is more fluid than that of other *Sapotaceae* species which yield gutta-percha and does not (partially) coagulate during collection. The destructive method of collection had already been forbidden in several countries in the first half of the 20th Century, as resources were being rapidly depleted. Various methods for tapping the living trees have been developed, but yields are so low that *P. leerii* has never been tapped on an economic scale. *Payena* trees contain irregular latex cavities in the bark which are not connected, and tapping cannot be done repeatedly as in the case of para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.).

Yield The yield of gutta-percha of *P. leerii* is generally low: only 60–270 g of gutta-percha could be obtained from felled trees of 17–26 cm in diameter. Tapping trials gave only 3–22 g of gutta-percha per tree.

Handling after harvest The latex of *P. leerii* is heated over a fire and stirred continuously until coagulation is complete. The coagulum is then pressed into blocks after first softening it in hot water and removing larger pieces of foreign matter. The blocks are then transported to the factory for further processing. The blocks can best be stored underwater to avoid spoilage by oxidation on exposure to air. Purified gutta-percha can be prepared by a chemical method which entails dissolving the resinous fraction in cold petroleum spirit, and then dissolving the remaining, separated gutta fraction in hot petroleum spirit. The hot extract is drained from any insoluble foreign matter and then allowed to cool, whereupon the purified gutta-percha separates out. After separation and distillation of residual solvent the hot, plasticized gutta is rolled into sheets and stored, either in the dark in well sealed tins, or in water. The problem is that the natural anti-oxidants in the gutta-percha are also extracted, increasing susceptibility to deterioration through oxidation; however, chemical anti-oxidants may be added. The mechanical method involves processing the raw gutta-percha by treating it with hot water to remove impurities, and collecting and pressing it into blocks. The gutta-percha used to be adulterated with inferior gutta-percha, such as that from *Palaquium leiocarpum* Boerl. and low-quality gutta-percha from *Palaquium gutta* and with jelutong (*Dyera* spp).

Genetic resources and breeding Resources of *P. leerii* were already dwindling early in the 20th Century when destructive collection of latex was forbidden. As trees occur scattered in the natural forest, they are liable to genetic erosion due to logging. There are no known germplasm collections or breeding programmes for *P. leerii*.

Prospects Gutta-percha from *P. leerii* is not an important commodity. *P. leerii* is much more important as a timber-yielding tree.

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E. Boer

Pinus L.

Sp. pl. 2: 1000 (1753).

PINACEAE

$x = 12$; $2n = 24$ (for most species)

Major species and synonyms

- *Pinus kesiya* Royle ex Gordon, Loudon, Gard. Mag. 16: 8 (1840), synonyms: *P. insularis* Endl. (1847), *P. khasya* Royle ex Hook.f. (1888).
- *Pinus merkusii* Jungh. & de Vriese, Pl. Nov. Ind. Bat. Or.: 5, t. 2 (1845), synonyms: *P. sumatrana* Jungh. (1846), *P. merkusiana* Cooling & Gaussen (1970).

Vernacular names

- *P. kesiya*: Benguet pine, Khasya pine (En). Pin à trois feuilles (Fr). Philippines: saleng (general), tapulao (Zambales), bariat (Bontoc). Burma (Myanmar): tinyu. Laos: khoua, mai hing. Thailand: son-sambai (central), chuang, kai-plueak-daeng (northern). Vietnam: th[oo]ng ba l[as], x[af] nu.
- *P. merkusii*: merkus pine, Mindoro pine, Sumatran pine (En). Indonesia: tusam (general), damar batu, damar bunga (Aceh, Sumatra). Philippines: tapulau (Sambali, Tagalog). Thailand: son-songbai, son-haang-maa (central), kai-plueak-dam (northern). Vietnam: th[oo]ng nh[uwj]a, th[oo]ng hai l[as].

Origin and geographic distribution *Pinus* comprises slightly more than 100 species. Its evolutionary origin has been located in the early Jurassic or late Triassic period. The earliest fossil records are all from eastern Siberia. The present-day centres of diversity are located in Mexico, the eastern United States, and the mainland of eastern Asia. Only 2 species occur naturally in the Malesian region: *P. kesiya* (eastern India, Burma (Myanmar), Indo-China, southern China, northern Thailand and the Philippines (northern Luzon)); and *P. merkusii* (eastern Burma (Myanmar), Indo-China, southern China, northern Thailand, the Philippines (Mindoro, western Luzon), Sumatra (Aceh, Tapanuli region, Kerinci mountain)). Thus *P. merkusii* is the only *Pinus* occurring south of the Equator. *P. kesiya* is planted throughout the tropics, in South-East Asia in Thailand, the Philippines, Malaysia and Papua New Guinea whereas *P. merkusii* is mainly planted in South-East Asia.

Uses Pines are tapped worldwide for the resin the sapwood exudes when only the cambium or both cambium and sapwood are injured. 'Gum rosin' and 'gum turpentine' are produced from this so-called 'crude resin' by steam distillation. Rosin and turpentine can also be obtained as a by-product of the sulphate or Kraft process in pulping pine wood ('tall oil rosin' and 'sulphate turpentine') and by extracting from the stumps of pines long after they have been felled, which yields 'wood rosin' and 'wood turpentine'. Rosin, a brittle, transparent, glossy, faintly aromatic solid, has a wide range of applications, such as in the manufacture of adhesives, paper-sizing agents, printing inks, solders and fluxes, various surface coatings, insulating materials for the electronic industry, synthetic rubber, chewing gums, soaps and detergents. Whereas the use of rosin for paper size is decreasing, it is increasing for the manufacture of printing inks. Turpentine, a clear liquid with a pungent odour and bitter taste, is used either as a solvent for paints and varnishes, or as a raw material for fractionation and value-added derivative manufacture of fragrances, flavours, vitamins, polyterpene resins and adhesives. Its use as a solvent has now largely been replaced by 'white spirit' derived from petroleum. The biggest single turpentine derivative, synthetic 'pine oil', is used in disinfectants, cleaning agents and other products with a 'pine' odour. Other derivatives including isobornyl acetate, camphor, linalool, citral, citronellol, citronellal, and menthol are used either on their own or in the elaboration of other fragrance and flavour compounds. The resin of *P. merkusii*, known as 'gondorukem' is one of the ingredients in the wax used for the manufacture of batik fabric.

Pine is a good general-purpose timber, although in woodworking and finishing aspects its resinous nature requires special attention. It is an excellent construction material. In the mining area of *P. kesiya* in northern Luzon, the Philippines, it is used as mine props. It is also used as piles, posts, Christmas trees, and as raw material for pulp and paper. Pine trees also make good fuel, both for cooking and heating. The wood of *Pinus* grown in Malesia is moderately hard to hard, but the heartwood is not very durable.

P. kesiya is also planted as a soil stabilizer to prevent erosion.

Production and international trade 'Naval stores' is the commercial name for a number of pine-derived products including gum rosin, wood rosin, tall oil, turpentine, tar, pitch, pine oil and terpene isolates. The name dates back several centuries, to when tar and pitch were used for caulking and weatherproofing the timbers and rigging of wooden ships. The 1994 world production of rosin was 1.2 million t annually of which 60% was gum rosin (valued at US$ 420 million), 35% tall oil rosin and 5% wood rosin. The annual world production of turpentine is 330 000 t of which an estimated 30% is gum turpentine (valued at US$ 50 million) and the remainder mainly sulphate turpentine. Early in the 1990s the annual turpentine production of China was 50 000 t (of which 5 500 t was exported), that of Indonesia 12 000 t (of which 7 500 t was exported). Indonesia produces about 10% of the total crude resin worldwide and in 1993, it produced 69 000 t of rosin of which 46 000 t was exported. In Vietnam the annual production of crude resin was 2500 t over 1986–1990. Crude resin is obtained by tapping, which is labour-intensive and has therefore declined in recent decades, especially in the United States, Portugal, Spain, France and Brazil, due to high labour costs. In 1995 the price of gum rosin from Indonesia was US$ 650–670/t. The average price of gum turpentine early in the 1990s was US$ 1–1.5/kg, that of sulphate turpentine US$ 0.15–0.30/kg. The use of turpentine for aroma chemicals is currently growing by 3–5% per year and for resins and adhesives by 2–3%. Its use for pine oil manufacture and as solvent has halved since 1970, but still accounts for half of the total annual consumption. Of the total annual turpentine consumption 35% is absorbed by the flavour and fragrance industry, which in 1998 commanded prices over US$ 6/kg, and some 15% is used in the manufacture of resins and adhesives, where it costs US$ 2/kg (1998).

The Gayu region (central Aceh, Indonesia) has been an important area of production from natural forest; since 1925 the area under exploitation (and hence production) has risen sharply. In 1941 production in this region reached 12 000 t. In Java, production from plantations only started in 1947.

Nowadays turpentine and rosin are facing intense competition from synthetic, petroleum-based resins and derivatives.

Properties Crude resin obtained by tapping living pine trees is a thick, sticky, but usually still fluid material. It is opaque (due to the presence of occluded moisture) and milk-grey. Typically, crude resin comprises 70–75% rosin, 15–20% turpentine and 10% foreign matter (pine needles, insects, etc.) and rainwater. Rosin is the brittle solid remaining as the involatile residue after crude resin has been steam distilled to obtain turpentine. It is insoluble in water but soluble in many organic solvents and consists primarily of a mixture of acids of abietic and pimaric type, with smaller amounts of neutral compounds. Since rosin is an acidic material and the manufacturer of downstream derivatives depends on its acid functionality, a high acid number (and saponification number) is also an indication of good quality. The better quality rosins usually have an acid number in the range 160–170. Rosin derived from *P. merkusii* has a higher acid number (190 or more) due to the presence of merkusic acid, a rather rare resin acid with two carboxylic acid groups. Rosin from *P. merkusii* in Indonesia is pale brown, has a softening point of 75–78°C, an acid number of 160–200 and a saponification number of 170–210. Anything above about 10% unsaponifiable matter would be considered a poorer quality rosin. The resin acid composition of rosin from *P. merkusii* is as follows: 10% sandaracopimaric acid, 15% isopimaric acid, 38% palustric acid, 16% abietic acid, 3% neoabietic acid, 8% dehydroabietic acid and 10% merkusic acid. Rosin from *P. kesiya* is dark red-brown; its acid number is 166–168.

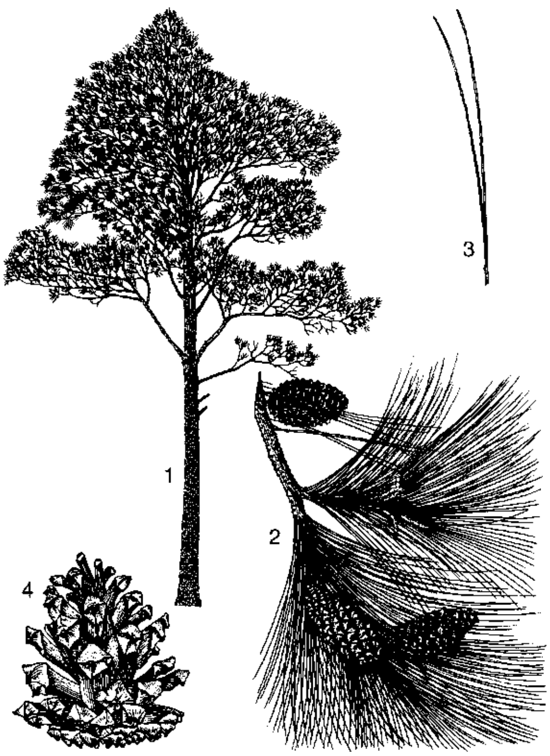
Turpentine is a clear, flammable liquid, with a pungent odour and bitter taste. It is immiscible with water and has a boiling point over 150°C and consists of a mixture of organic compounds, mainly terpenes, and its composition can vary considerably (more so than rosin), depending on the species of pine it came from.

The α-pinene and β-pinene constituents of turpentine, in particular, are the starting material for synthesis of a wide range of fragrances, flavours, vitamins and polyterpene resin; β-pinene is favoured over α-pinene. Δ 3-carene is a constituent of turpentine which is not preferred as it is difficult to manipulate. Turpentine from *P. merkusii* provenances from Tapanuli (North Sumatra) consists of almost pure α-pinene, various Aceh provenances contain more Δ 3-carene, whereas samples from some provenances from Indo-China have a more complex composition with large amounts of α-pinene and Δ 3-carene and significant amounts of limonene, β-pinene, myrcene and longifolene. Turpentine obtained from *P. kesiya* from Aceh (Sumatra) contains 90% α-pinene. The average α-pinene content, Δ 3-carene content and the turpentine yield for 11 Thai provenances of *P. merkusii* were found to be 43–90%, 1–36% and 28–37% respectively. For 5 Philippine provenances the α-pinene and Δ 3-carene content were 95–96% and 0–1.3% respectively. Provenances from Assam (India) of *P. kesiya* have a high β-pinene content (26–43% of the turpentine) whereas other provenances usually only contain 1–2% β-pinene and more. In Orissa, the composition of turpentine from *P. kesiya* is 44% α-pinene and 45% β-pinene.

'Sulphate naval stores' are the by-products recovered during the conversion of pine wood chips to pulp by the sulphate (kraft) pulping process. 'Sulphate turpentine' is retrieved by condensation of the alkaline liquors. 'Crude tall oil' is fractionated into various products including 'tall oil rosin' and 'tall oil fatty acids'.

'Wood naval stores' are obtained from resin-saturated pine stumps long after the tree has been felled. When the sapwood has decayed, the stumps are uprooted, chipped and extracted with solvent to give 'wood turpentine', 'wood rosin', dipentene and 'natural pine oil'. Crude tall oil contains 30–50% resin acids and 25–40% fatty acids.

Description Usually medium-sized, monoecious evergreen trees of 15–45(–70) m tall, usually with a straight bole and a diameter of up to 100(–140) cm; bole without buttresses but distinctly broadened at base in solitary trees; bark usually thick; branches in regular whorls, branchlets glabrous, with a leafless base. Leaves in mature trees of two kinds: scale leaves which are triangular-lanceolate, early deciduous, bearing the short shoots in their axils, and needle-like leaves, in clusters of 2–4(–5), the latter persistent for two or more years, either semicircular or triangular in cross-section and the margin often minutely toothed. Male strobili cylindrical, produced in clusters around the base of the young shoot, yellow or reddish, consisting of numerous scales, arranged spirally, each with 2 inverted pollen sacs. Female cones usually terminal or subterminal, very variable in outline, consisting of scales arranged spirally which are thickened at the apex (called the apophysis), and bearing a stout prickle, mucro or hook (the umbo); each scale bearing 2 ovules. Seed often egg-shaped with a coat of varying hardness, usually having a large papery wing. Seedling with hypogeal germination; cotyledons plumose; the primary leaves (scale leaves) appearing within a few weeks and secondary leaves (needle-like leaves) usually appearing during the second year; root system consisting of a taproot with



Pinus merkusii Jungh. & de Vriese – 1, tree habit; 2, twig with young female cones; 3, pair of needles; 4, mature female cone.

fine roots near the soil surface and near the root tip.

- *P. kesiya*: A large tree up to 45 m tall and up to 100 cm in diameter, bark thick, reticulately and deeply fissured, branchlets often pruinose with a waxy bloom; needles in bundles of (2–)3(–4), very slender and flexible, (10–)12–21(–25) cm long, bright grass green; mature cones up to 3 together, pendulous, ovoid to ovoid-conical, (4–)5–8 (–10) cm long, subsessile or on a short stalk up to 10 mm long; apophysis beaked or flattened with a short, blunt, deciduous umbo; seed small with a short wing 1.5–2.5 cm long.
- *P. merkusii*: A large tree up to 50(–70) m tall and up to 55(–140) cm in diameter, bark thick forming plates and grey-brown underneath, but scaly and more reddish tinged upwards, branches heavy, horizontal or ascending; needles in pairs, slender but rigid, 16–25 cm long, with persistent basal sheaths; cones solitary or in pairs, almost sessile, cylindrical, 5–11 cm long, after opening twice as thick and ovoid, generally falling off soon; apophysis broadly tetragonal with a smooth, almost depressed umbo; seed small with a deciduous wing of about 2.5 cm long.

Growth and development Young trees of mainland provenances of *P. merkusii* take 3–5 years to pass through a so-called 'grass stage' which is characterized by densely clustered and slightly longer needles and short shoots and minimal height growth. Their cones are less cylindrical, and the seeds nearly twice as heavy. However, Sumatran provenances of the same species have no 'grass stage' and they develop rapidly in height. This improves their chances in the competition with weeds which grow vigorously in the moist climate. Mycorrhiza are required for successful growth and allow seedlings to survive in more adverse sites. Generally, pines grow according to Rauh's architectural model. The trunk is monopodial and grows rhythmically, and develops tiers of branches; the formation of cones does not affect shoot formation. *P. merkusii* sometimes develops 'foxtails', plants without branches and without growth rings in the wood. In early stages of growth, trees of *P. kesiya* are prone to fire damage. The annual increment of *P. kesiya* in the Philippines is 1–2 cm in diameter and 0.5–1.4 m in height.

In plantations, trees of *P. merkusii* reach sexual maturity when about 20 years old. They bear cones every year, although seed production varies. Pollination and seed dispersal is by wind. Sometimes birds, rodents and people who gather the seeds for food, also disperse them.

Other botanical information On a world scale, 10 pine species are tapped commercially. *P. massoniana* Lamb. is the most important one yielding the majority of crude resin produced in China. The union of *P. khasya* and *P. insularis* into *P. kesiya* has been argued, because of their different field characteristics and products, and some authors contend that *P. kesiya* has not been properly described. In Sumatra three different strains of *P. merkusii* have been recognized (the Aceh, Tapanuli and Kerinci strains) which differ markedly in e.g. stem form, branching, bark, resin content and susceptibility to attack by the caterpillars of the moth *Milionia basalis*.

Ecology The naturally occurring pines of South-East Asia (*P. kesiya* and *P. merkusii*) inhabit a wide range of forest and savanna habitats. They are pioneers and their natural range is extended by colonization following disturbances such as fire. They grow, for instance, scattered in fire-prone grassland and woodland. The trees increase in number in recently disturbed areas.

They are strongly light-demanding and habitually grow in pure stands. Pines grow naturally in South-East Asia only in strongly seasonal environments.
P. kesiya grows in areas with a mean annual rainfall of 700–1800 mm and a pronounced dry season. Mean annual temperature in the area of distribution is 17–22°C, mean maximum temperature of the hottest month 26–30°C, mean minimum temperature of the coldest month 10–18°C. It generally grows naturally above 1000 m altitude. It is locally common in northern Luzon, often occurring in open pure stands on steep slopes at elevations of 300–2700 m. The best stands are found in moist well-drained localities at high altitudes where the soil is rich enough for hardwoods but because of the elevation the commercial hardwood species cannot thrive.
P. merkusii occurs in areas with a mean annual rainfall of 1000–2800(–3500) mm, mean annual temperature 21–28°C, mean maximum temperature of the hottest month of 24–32°C, and mean minimum temperature of the coldest month 18–24°C. It mostly occurs below 1000 m altitude, in Mindoro it grows naturally as low as 60 m above sea-level. It is locally common in northern Sumatra up to 2000 m altitude.

Propagation and planting Successful natural regeneration of pines is only possible where a relatively large amount of sunlight reaches the ground. In Sumatra ripe seeds are produced most abundantly between July and November, but viable seeds are produced throughout the year. Only cones that have just changed their colour from green to brown should be collected and air dried; in the Philippines *P. kesiya* cones can be harvested in November–January. The viability of seeds harvested from *P. kesiya* trees is not affected by tapping. Therefore seeds can be collected from superior seed trees, provided such trees are not tapped on more than 2 faces and not longer than 3 years. Per kg there are 55 000–62 500 dry seeds of *P. kesiya* and 58 000 seeds of *P. merkusii* from Sumatran provenances and 42 000–55 000 seeds from continental provenances. *P. merkusii* seeds can be stored after sun-drying for 5 days when the moisture content has decreased to 5–8%. They can be stored in polythene bags for 2 years in a refrigerator (4–6°C) or for 6 months in an airconditioned room (16–17°C) without appreciable loss of viability. Seeds germinate in 8–12(–21) days, and need no pretreatment. However, they are often soaked in cold water overnight before sowing. For *P. merkusii* seeds, a germination rate of 40–60% may be expected. When seedlings are 5–10 cm tall they are transplanted from the nursery bed to polythene bags.
Vegetative propagation of pines has had only minimal success. Marcotting of *P. kesiya* has been found possible with *Sphagnum* moss, pine sawdust and pine topsoil as marcotting medium. Marcotting should be done in May–June when pine trees are in a dormant growth stage. Branches in the middle of the crown with a diameter of 2–3 cm are best for marcotting. During dry periods the marcots should be watered.
Seedlings need ectomycorrhiza for optimal growth. Natural infection may occur locally, but a reliable method of inducing seedlings to form mycorrhizal associations is to expose them to saplings of 30–80 cm tall which are already infected. The 'mother trees' are planted in the nursery beds a year before sowing, at a spacing of 1 m × 1 m. Another method of obtaining mycorrhiza is to mix ordinary topsoil from pine forests with potting medium (in a ratio of 1 : 4–10), or to inoculate with vegetative mycelia, spores, mycorrhizal capsules or tablets. The latter methods will probably gain importance in the near future. The fungi used for inoculation of pines in South-East Asia include *Pisolithus tinctorius*, *Scleroderma* sp., *Thelephora terrestris*, *Cenococcocum graniforme* and *Rhizopogon* sp. Root pruning is done when the seedling height is 10–15 cm to reduce shoot growth and to boost root development. After about 8 months the seedlings of *P. merkusii* in nursery beds are 20–25 cm tall and ready for planting out in the field. Seedlings of *P. kesiya* may already be suitable for transplanting after 4–6 months. Planting out in the field is carried out at the onset of the rainy season at spacings of 4 m × 4 m (for resin production) or 3 m × 1–2 m (for timber production).
Virtually all crude resin production in Indonesia is based on extensive areas of *P. merkusii* plantations in Java. In 1991 the production came from about 100 000 ha, but the total area planted to this species in Java is about 400 000 ha and pine plantations are increasing on Sumatra, Kalimantan and Sulawesi. In the Philippines, *P. kesiya* is planted at 3 m × 3 m as a shade tree for coffee plantations.

Management Plantation establishment is generally easy, as pines are pioneer species and can be planted in the open. Weeding is done 2–4 times during the first year after planting, the frequency decreasing with increasing size of the trees.
For plantations in Aceh a tapping and thinning schedule has been worked out in which the trees

to be thinned are heavily tapped 2–4 years prior to being felled. Between 7 and 19 years 4 thinnings take place, in which 75 trees for the first 2 thinnings and 50 trees per ha in the second 2 thinnings are tapped and removed.

Diseases and pests Generally, damping-off in pines caused by different fungi in the nursery can be controlled by proper nursery techniques, especially by avoiding over-watering. Stain disease, possibly caused by *Trichoderma koningii*, has been observed in 80% of the 21–38-year-old trees in a *P. kesiya* plantation in Bukidnon (the Philippines). In the Philippines, bark beetles (*Ips calligraphus*), pine shoot moths (*Dioryctria rubella*) and pine tip moths (*Petrova cristata*) cause problems in plantations of *P. kesiya* and *P. merkusii*. Pine shoot moths have infested almost all young pine plantations. Their larvae tunnel and feed inside the shoots, thus reducing the quality of the timber. Moreover, they also attack the young cones of *P. kesiya*, thus reducing seed production. Pine shoot moths can be effectively controlled by using the insecticides fenitrothion (0.1%) and fenvalerate (0.2%), or by *Bacillus thuringiensis* when applied before the larvae bore into the shoots, although their effectiveness to control is also reported to be not significant. The main pests in northern Sumatra are members of the Psychid and Geometrid families (e.g. *Milionia basalis*), shoot- and stem-boring Pyralids, and local squirrels.

Harvesting Pine trees in plantations can be tapped 10–15 years after planting when they have attained a diameter of at least 17 cm. In the Philippines, it is recommended to tap only *P. kesiya* trees with a crown length of at least 35% of the total height, as tapping other trees would not be economical. In Thailand, *P. merkusii* is tapped, but *P. kesiya* is not, as its resin yield is too small to be economically viable. Some countries have regulations which limit tapping to those trees with a diameter greater than about 20–25 cm. Different methods of harvesting have been experimented with, such as a reversed U-shape or V-shape (herringbone) in the bark or by drilling holes into the wood. However, the best and easiest method to apply is the 'koakan' or 'quare' method in which a rectangular tapping panel of 10 cm high, 9–12 cm wide and 1–2 cm deep is made, removing only bark and no or very little sapwood. A container is fixed to the tree to collect the viscous exudate. The panel is enlarged every 3 days by removing a strip of 0.5 cm of bark on the upper side of the panel. Resin flow stops after 3 days, hence every 3 days 'streaking' or 'rechipping' is done. The term 'streaking', however, is occasionally also used to indicate the application of stimulant on freshly made cuts. It has been suggested to make streaks at an angle, to encourage the resin to flow faster into the cup, thus reducing contamination, but it is doubtful whether this is being applied on a larger scale. A stimulant is usually applied only where the bark and the sapwood meet, i.e. the cambium layer. Stimulant should never be applied to the sapwood, as this causes the sapwood tissue to die. In Indonesia, a stimulant composed of sulphuric acid and nitric acid at a concentration of 7.5% or 15% proved to be effective. Stimulant is not applied every 3 days when the trees are streaked, but every 8–10 days, when resin is collected. 'Ethrel' added to the stimulant has been found to enhance resin yield. Tapping without the application of stimulants is more labour-intensive, as it requires more frequent visits. Scrape, the solidified resin on the wood surface of the panel, should only be removed towards the end of the tapping season, as it protects the bole from decay. Its quality is lower than that of resin collected in the containers and is processed separately.

It is fairly common practice to tap trees 3–5 years before being felled, including those to be felled in thinning operations. Tapping of these trees is more intense, with more and wider panels, than tapping trees destined to produce for a prolonged time. Tapping may continue for 20 years. Although even when little sapwood is removed, tapping does not impede the vigour of the tree; when acids are used as stimulants it does retard growth. High temperatures are conducive to good resin flow, while prolonged periods of high rainfall are not, and the extent of seasonal changes in climate will largely determine the period during the year for profitable tapping. In the tropics and subtropics tapping may be done all year round, although seasonal heavy rains may interrupt it.

Yield The most important and obvious factor affecting resin yield of pines is the diameter of the trees tapped. There is a linear relationship between tree basal area and resin yield. Moreover, the bigger the proportion of the live crown, the greater the resin yield. The average annual yield of *P. merkusii* is 1.4–2.7 kg/tree, for plantations in Java it is 3 kg/tree for *P. merkusii* and 1.5 kg/tree for *P. kesiya*. The annual yield of *P. kesiya* trees with an average diameter of 50 cm in the Philippines is 1.6 kg without the application of a stimulant, and up to 4.1 kg when 60% sulphuric acid is used as a stimulant. The annual resin yield of young *P. merkusii* plantations (7–19 years) in

Aceh by tapping the trees to be thinned is 340–520 kg per ha, the increase corresponding with the age of the trees. The production of 520 kg of resin is obtained from 50 trees. The minimum acceptable yield is around 2 kg/tree, as lower yields make the operation economically unviable.
Per t wood processed by sulphate pulping 15–20 kg of crude tall oil, i.e. 5–10 kg of tall rosin and 3–5 l sulphate turpentine are obtained.

Handling after harvest Rosin is graded and sold on the basis of colour, the palest shades of yellow-brown being better quality and commanding higher prices. Commercial grades most often traded are WW ('water-white') and WG ('window-glass'), X is a superior grade sometimes traded, whereas darker grades are N, M, K, I, H and lower. Most rosin is used in a chemically modified form rather than in the raw state. Like rosin, turpentine is also a very versatile material chemically, and nowadays it is used mostly after further processing. It usually undergoes distillation to isolate the desirable chemicals (mainly α-pinene and β-pinene) which are then transformed into value-added derivatives.

Genetic resources The standard seed source areas for *P. merkusii* are Sumatra and Thailand. Seedlings raised from Sumatran seeds often miss the 'grass stage' and are thus better suited for plantations. The sources of genetically superior *P. merkusii* seed in Sumatra should be protected. Natural stands of *P. kesiya* in the Philippines should be earmarked for seed collection and gene conservation. The natural areas of distribution of both pines in Malesia are comparatively small, and therefore their protection should be guaranteed.
The genetic variation has been studied in natural populations of *P. kesiya* and *P. merkusii* in Thailand and Vietnam. In *P. kesiya* considerable variability was found between individuals within a population, but only weak variability between populations. Remarkably, the opposite was true for *P. merkusii*, with very low variability between individuals of a population but high variability between populations.
International provenance trials of *P. kesiya* and *P. merkusii* have been established throughout South-East Asia and also in northern Australia; they are coordinated by the Oxford Forestry Institute (Oxford, United Kingdom). *P. merkusii* seed orchards have been established in Indonesia.
In the Philippines, *P. merkusii* logging and tapping heve been banned since the early 1970s.

Breeding In Thailand, trials on provenance hybrids of *P. merkusii* showed that hybrids of Thailand and Papua New Guinea provenances had better survival and height-growth than local provenances. There are no known breeding programmes for pines aimed at higher resin production.

Prospects While Chinese production of gum naval stores is unlikely to increase further, Indonesia has an ample (and growing) number of pine trees available for tapping and the potential to increase production significantly in the years to come.

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E.P. Militante

Shorea javanica Koord. & Valeton

Bull. Inst. Bot. Buitenzorg 2: 3 (1899).
DIPTEROCARPACEAE
x = unknown

Synonyms *Shorea vandekoppelii* Parijs (1933).

Vernacular names Indonesia: damar mata kucing (southern Sumatra), damar sibolga (northern Sumatra), damar kaca or 'glass damar' (general).

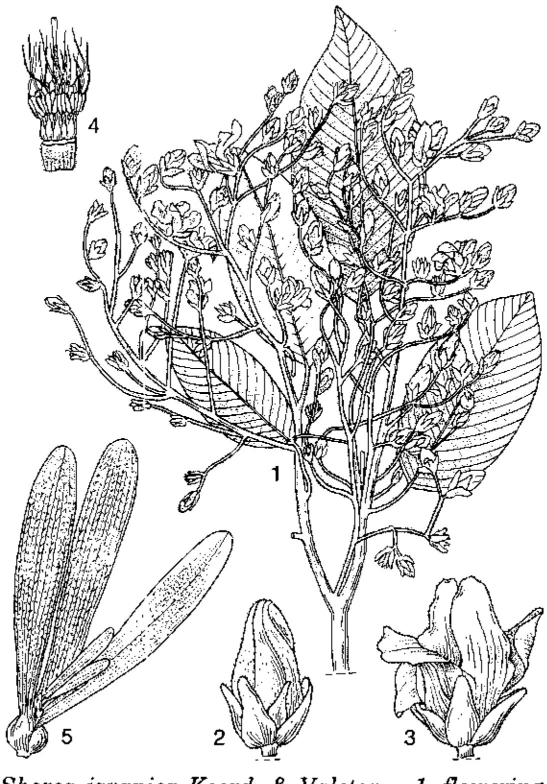
Origin and geographic distribution *S. javanica* is indigenous to Indonesia (widespread and common in Sumatra, rare in Central Java).

Uses The resin from the wood of *S. javanica*, 'damar mata kucing' or 'cat's eye damar', is used in paints and varnishes, in the linoleum industry, in pharmaceuticals, cosmetic products and as a food additive. Traditionally, the resin has been used for torches, caulking boats and baskets and colouring batik.
Its timber is traded as a 'white meranti' and is important in the manufacture of plywood and veneer; it is also used for light construction. The importance of *S. javanica* in the white meranti trade group is difficult to assess.

Production and international trade Between 1975–1995 the price of 'damar mata kucing' was stable. Currently, this type of damar (resin from *Dipterocarpaceae*) is the most important in the Indonesian domestic market and the international market. The estimated total production from the Krui area in Lampung Province was 8000 t in 1984 and 10 000 t in 1994. Total damar exports ('damar', 'mata kucing' and 'batu') from Indonesia were 14 750 t and 9900 t in 1994 and 1995; mata kucing exports were 3400 t and 2900 t. In 1995 there were about 50 000 ha of damar gardens over 15 years old in this area. In the period 1928–1938 the annual export of damar mata kucing from Indonesia was 4300–7400 t.

Properties Damar mata kucing is a transparent, colourless to slightly yellow solid in the form of balls, with a specific gravity of 1.05, 1.4% moisture content, a softening point of 75–85°C and an acid number of 19–31. It is soluble in aromatic hydrocarbon solvents (benzol, toluol) or in a mixture of these with alcohol but is only slightly soluble in turpentine or mineral aromatic hydrocarbons. Damar mata kucing is produced by several *Shorea* and *Hopea* species. The quality of the damar mata kucing from *S. javanica* is one of the best as it contains relatively little β-resene. This is a wax-like compound that causes varnishes made from damar mata kucing to become dull. It needs to be removed if nitrocellulose lacquers are to be manufactured. When treated with alkaline solutions, damar mata kucing yields about 40% resin acids of high quality for varnish manufacture, 45% α-resene and 15% β-resene.
The resin is found in resin canals in tangential rows and elongated groups embedded in wood parenchyma. The density of the wood is 450–840 kg/m^3 at 15% moisture content.

Description A large tree up to 40–50 m tall, bole with a diameter of up to 150 cm, buttresses prominent, up to 1.5 m high; bark surface with irregular fissures, outer bark usually thick, chocolate brown, inner bark laminated with bands of orange-yellow and whitish tissue, exuding a clear, whitish to yellowish resin; mature crown hemispherical or dome-shaped, sympodial; twigs, leaf buds, stipule outside, panicles, calyx, parts of petals exposed in bud, ovary and nut persistently evenly tawny brown pubescent; twigs terete, 2–3 mm in diameter apically. Leaves alternate, simple; petiole 16–22 mm long; blade elliptical-oblong to ovate, (6.5–)10–15 cm × (3.5–)4–8 cm, base ob-



Shorea javanica Koord. & Valeton – 1, flowering branch; 2, flower bud; 3, mature flower; 4, flower with sepals and petals removed; 5, fruit.

tuse to shallowly caudate, margin entire, top with acumen, up to 7 mm long, thinly leathery, with 19–25 pairs of parallel secondary veins, lower surface evenly tomentose on the veins. Inflorescence terminal or axillary, paniculate, up to 14 cm long, branchlets to 4 cm long, bearing up to 3 flowers facing the same direction; flowers bisexual, 5-merous, about 1 cm long in bud, actinomorphic, scented; calyx lobes free, narrowly ovoid, acuminate, somewhat unequal, much enlarged and persistent in fruit; petals white, broadly elliptical or ovate-lanceolate, loosely connate at base; stamens 15, the anthers with 4 pollen sacs, narrowly oblong to linear, with prominent scabrous or glabrous appendages; ovary superior or semi-inferior, (2–)3-locular, stylopodium narrow. Fruit samara-like, consisting of an ovoid, apiculate nut, 14 mm × 10 mm, surrounded by the enlarged calyx with lobes like wings, base obtuse; the 3 outer calyx lobes much longer than the 2 inner ones, thinly spatulate, up to 18 cm × 1.5 cm.

Growth and development Seedlings need shade until they reach a height of about 1.5 m, after which more sunlight can be provided. Mycorrhizal infection promotes growth considerably, and for *S. javanica* 5 common ectomycorrhizal fungi are *Amanita hemibapha, Cantharellus cibarius, Lactarius* sp., *Russula* sp. and *Scleroderma* sp. *S. javanica* flowers and fruits only every 3–5 years. In Lampung Province (Sumatra) it flowers in January. In 50 years a height of 40–50 m can be reached.

Other botanical information Over the years many other *Dipterocarpaceae* have been exploited for their resin ('damar'). Only *Hopea dryobalanoides* Miq. has ever been planted, but generally the resin has been harvested from natural forest. Other species yielding damar mata kucing are: *Shorea lamellata* Foxw., *S. retinodes* Slooten, *Hopea dryobalanoides*, and *H. celebica* Burck.

Ecology *S. javanica* occurs in primary and secondary forest in dry or periodically inundated locations on flat land or on slopes up to 300(–500) m altitude. Plantations have been established in southern Sumatra where it grows best on deep loamy soils and where the mean annual rainfall is 3300 mm with no dry season. Saplings of 1 m tall can survive and grow in open cropped land and when they reach 3–4 m they behave like true pioneers and need full sunlight. Seedlings at planting time need some shade (usually provided by coffee trees and *Erythrina* in new plantations), but heavy shade adversely affects growth and survival. The mortality of 50 cm tall seedlings 6 years after planting in a mature agroforest under a closed canopy was 45% compared to 8% mortality when planted under a more open canopy. Growth under more open conditions was much faster, with a mean annual height increment of 0.7 m compared to 0.3 m for the seedlings planted in the mature agroforest.

Propagation and planting When people started planting *S. javanica* in southern Sumatra in the middle to the end of the 19th Century, they obtained planting stock either from wild and cultivated seedlings or from young forest trees by successive air layering. In the latter case, the bark of these 'damar trees' with a diameter of 10–20 cm was notched all around the stem and packed with soil and leaves. When the first roots appeared, the tree was cut down 1 m above and 25 cm below the notch. The rooted stem segment was planted in the field or in the village and the coppice sprouts from these segments were air layered again when about 30 cm long. These rooted layers were used for planting. The next step in cultivation was the use of the seeds from the planted trees. *S. javanica*, however, flowers and bears fruit only once every 3–5 years, so seed is available very irregularly. Moreover, seeds are recalcitrant and cannot be stored under dry conditions or at low temperatures. When available, the fruits are even sold in local markets. Instead of storing seeds farmers in southern Sumatra store seedlings. Fruits are collected in old damar plantations, the wings are cut off and the fruit is soaked in water for 2–3 days. The germination percentage is close to 100%. Germinated seeds are put in small bamboo pots or planted very densely in the soil of prepared nursery beds. All small-scale private nurseries, either close to the house or, more usually, in old damar plantations, are shaded. Seedlings grow to 20–30 cm and then growth seems to stop. Seedlings can survive for 3–4 years, and there seems to be only a low rate of mortality. A good nursery must supply seedlings from one fruiting season to the next. The stock is renewed at each fruiting season. Seedlings are planted out in the damar gardens with earth from the nursery, in spots where light intensity is intermediate, so neither under closed canopy nor in large, open areas. Mortality is low. When establishing new damar gardens, seedlings are planted after coffee, that was planted in the second upland rice crop after land clearing. The seedlings benefit from the shade provided by the rice or the coffee. This coffee stage is itself a mixture of various species: *Erythrina* is almost always planted as a shade tree, but also as living poles for pepper which is very often associated with coffee. Fruit trees (e.g. durian, duku, jackfruit, mangosteen, rambutan and mango) are also planted along with the damar trees, so that the latter never develop in an open environment. Damar tree density at planting is very variable, depending on the farmer's short and long term objectives. However, damar tree planting density for a damar agroforest objective is 100–150 trees/ha. The damar trees are 4–5 m tall when the coffee becomes unproductive about 10 years after planting. Initially, these gardens are even-aged, but they will gradually become more complex, involving more species and more differences in age. Direct seeding is not practised, as seed predation is severe.

Vegetative propagation on an experimental scale using cuttings of 2-month-old seedlings is successful, with rooting percentages of 85–95%.

Management In southern Sumatra, the exploitation of *S. javanica* for resin production has gradually shifted from exploitation of natural forest to a highly diversified agroforestry system where species composition and regeneration of the *S. javanica* trees are completely controlled by man. In the Krui region on the west coast of Lampung Province, damar gardens, also called damar agroforests, are dominated by *S. javanica* (about 65% of the trees) and some 20% of the trees are fruit trees such as 'durian' (*Durio zibethinus* Murray) and 'duku' (*Lansium domesticum* Correa). Naturally established trees left for the production of timber comprise another 10–15% of the trees. On average, 245 trees/ha of 39 different species were recorded in an inventory of trees with at least 20 cm diameter. There is a close structural similarity between a mature damar garden and natural forest. The silvicultural rotation of individual damar trees is about 50–70 years, which is when they are physiologically old because of reduced photosynthetic and metabolic capacity after 30–50 years of resin tapping. Old trees are not cut down, they fall spontaneously creating a gap in the canopy. In small gaps weeds are controlled to favour young damar trees. In larger gaps heliophilous plants like banana and *Sauropus androgynus* (L.) Merr. are planted to provide shade. Damar seedlings are planted near the fallen trunk for protection and nutrients. A fairly recent development, however, is the introduction of chainsaws, which has facilitated the felling of old and unproductive trees. This highly selective felling involves on average 1 tree/ha per year, corresponding to about 0.25% of the standing volume. The increased use of the timber from the damar gardens is the next step in the management intensification of the damar gardens.

Apart from the economic benefits of the damar gardens, they also provide environmental benefits by conserving an important part of natural forest biodiversity, protecting the soil and water resources of the area, whose steep slopes are prone to erosion and landslides.

Damar gardens are individually owned and individually managed. They are usually small (0.5–2 ha), but because they are contiguous, there are large damar agroforest areas (100–1000 ha) on the hills.

Diseases and pests *Bacterium tumefaciens* is a gall disease observed in West Java on planted *S. javanica* seedlings in the second year. Although the disease is not fatal, the affected seedlings continually form new shoots but do not grow any more in height. Damar farmers have reported two unidentified insects (*Homopterae*) as having a deleterious impact on damar production: 'tetuer', a leaf hopper (*Cicadellidae*) and 'tenangao', a brightly coloured red and green bug (*Heteropterae*). Both insects feed on the sap of the plant.

Harvesting In the Krui area, tapping of *S. javanica* starts when the trees are about 20 years old and have attained a diameter of 25–30 cm. Trees are prepared for tapping by cutting 3–4 rows of small holes, 3 cm in diameter and 2 cm deep. These holes are made with a hatchet fitted with a 2 cm × 4 cm steel blade. Monthly, any exuded resin, or newly formed periderm, is stripped away. Occasionally, the holes are covered by a piece of bark. Though in most cases the holes have filled with resin by the third month, the procedure continues. These small holes presumably render the tree susceptible to fungal attack, which induces resin flow as part of the defensive response. The first triangular holes are made at 1 m height. The triangle points upwards and can function as a foothold for tappers while climbing. These holes may become circular with age, but good tapping is achieved when holes stay triangular and, according to local people, are a sign of careful tapping. The holes are arranged in vertical rows along the stem and 40–50 cm apart. Later, more holes are made, all around and up the stem. The first triangular holes are several centimetres wide and are enlarged with every tapping. When old, these holes can measure 15–20 cm in width and depth, the holes becoming deeper and deeper due to diameter growth of the tree. With increasing age the number of rows increases to a maximum of 4–5 rows. Each row may comprise 9–11 holes for trees

30–35 m tall and 60–80 cm in diameter, the highest holes are 5(–8) m above the ground. Abandoned holes which have become too deep are filled with soil to promote wound healing, which usually occurs within 1–1.5 years. The use of fire to increase resin production has never been reported for southern Sumatra.

The resin is dry when harvested and in the form of solidified drops or strings of drops, or solidified resin stuck on the wood. The periodicity of tapping and harvesting is usually 1 month, but depends on the distance from the village and ranges from 1 week to 2 months. Tapping stimulates the tree to produce reaction wood, so that the trunk is thickened up to the level of the highest scars. Wood of the tapped portion of the stem is only used as firewood, that of the upper part is converted into timber.

Yield Data from the early 20th Century indicate a yield of 0.6 kg/tap with tapping every 2–3 months. This means that the annual yield is 2.4–3.6 kg/tree probably for fairly young trees of 25–30 years. In the Krui area, the average annual yield of mature trees over 60 years old is 15.6 kg/tree. Some big trees of 60–80 cm in diameter yield 4–5 kg monthly. The resin production of flowering and fruiting trees decreases by about 25% for 2 months, after which it gradually increases to the previous levels.

Handling after harvest Grading of damar mata kucing is based on colour, cleanness and the size of the damar particles. Grades A, B and C are the 'export quality' grades, with a good quality, i.e. transparent, whitish or yellowish where grade A comprises large lumps of up to 10–15 cm, grade B lumps of 1–2 cm and grade C lumps smaller than 1 cm. Grades D and E are of medium quality, opaque and dusty lumps, grade D are the particles over 1 cm in size and grade E the small particles of several mm. Grade 'tebu' corresponds to dust and grade 'beku garam' comprises dusty agglomerated lumps, often mixed with small pieces of wood or bark. Medium and low quality damar is used and processed in Indonesia: part of it goes to paint industries near Jakarta, another part to the batik industry in Central Java, and the rest is used as incense, quite often mixed with benzoin. No added-value processing of high grades occurs in Indonesia before exporting.

Genetic resources and breeding There is a locally well-known difference in yield between individual *S. javanica* trees. As the damar gardens are only regenerated by using planting stock obtained from seed, there is no risk of genetic erosion through selection and domestication. There are no known germplasm collections or breeding programmes.

Prospects The damar agroforests in southern Sumatra, mainly of *S. javanica*, have been maintained for well over a century now and will continue to be of prime economic importance to the local population as long as damar mata kucing remains an important export commodity. The high quality, the specific characteristics and the homogeneity of damar mata kucing resin are being increasingly recognized, and the traditional demand from the paint and varnish industry is not declining. Moreover, new applications have been developed in the last 10 years by the food industry, where it is increasingly used as food additive in soft drinks. Last but not least, damar mata kucing resin is produced from environmentally sustainable and socially equitable plantations. This production mode ensures a continuous and 'safe' source of supply for downstream industries, as well as the possibility of green labelling for industrial products. This greatly improves its prospects.

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H. de Foresta & E. Boer

Sindora Miq.

Fl. Ind. Bat., suppl. 1(2): 287 (1861).

LEGUMINOSAE

$x = 12$

Major species and synonyms

- *Sindora inermis* Merr., Philipp. Journ. Sc. 10: 314 (1915).
- *Sindora sumatrana* Miq., Fl. Ind. Bat., suppl. 1(2): 288 (1861).
- *Sindora supa* Merr., Philipp. Journ. Sc., Bot. 1, suppl. 3: 198 (1906).
- *Sindora velutina* J.G.Baker, Fl. Brit. India 2: 269 (1878), synonyms: *S. parvifolia* Backer ex K.Heyne (1927), *S. parvifoliola* Symington (1938).

Vernacular names General: sepetir.

- *S. inermis*: Philippines: kayu-galu (Magindanao), nito-nitong puti (Bikol), sinsud (Sulu).
- *S. sumatrana*: Indonesia: sindur, tampar hantu (Palembang, Sumatra).
- *S. supa*: Philippines: supa (Bikol, Tagalog), baloyong (Batangas), manapo (Tayabas).
- *S. velutina*: Indonesia: sindur, kaparantu (Sumatra), kayu bulan (East Kalimantan). Malaysia: sepetir beludu besar, sepetir beludu kechil (Peninsular), ensunut (Sarawak).

Origin and geographic distribution *Sindora* consists of about 20 species confined to Indo-China and western and central Malesia, except for one species which occurs in tropical Africa (Gabon). It is absent from the Lesser Sunda Islands and New Guinea. *S. inermis* is found in the Philippines (southern Luzon, Mindanao and the Sulu Archipelago), *S. sumatrana* in Sumatra and Bangka, *S. supa* in the Philippines (Luzon, Mindoro) and *S. velutina* in Peninsular Malaysia, Sumatra and Borneo.

Uses Many *Sindora* species yield a wood-oil used for making paints and varnishes, for illumination, for caulking boats and to adulterate other oils. The wood-oil of *S. inermis* has a pleasant persistent odour and is used in the perfume industry. It is sometimes used medicinally against skin diseases and rheumatism and has been applied in the manufacture of birdlime.

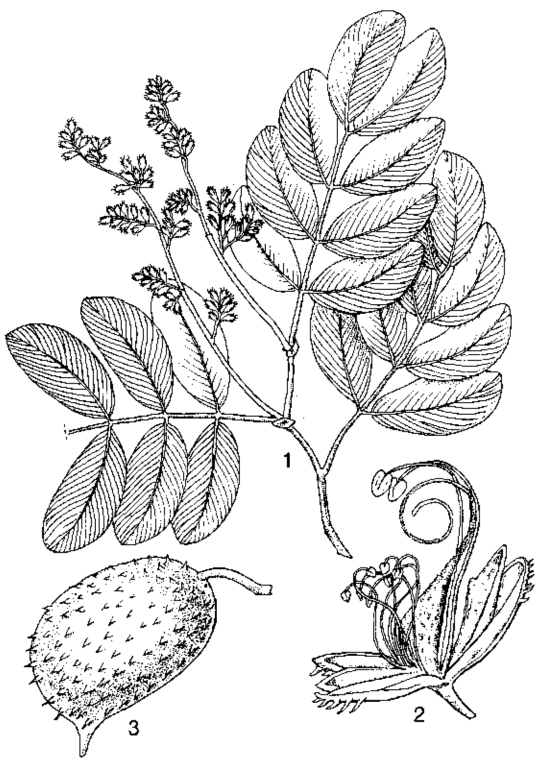
Sindora yields an important timber (sepetir) of which the sometimes attractively figured wood is highly appreciated. It is particularly used for bowling alleys. The aril of the seed of *S. siamensis* Teijsm. ex Miq. is sometimes used as a substitute for betel (*Areca catechu* L.). The fruits of *S. sumatrana* are widely used in local medicine against fever, serious bleeding in the uterus and scalp eczema. The pods of other species are used in compound traditional medicines, particularly in connection with childbirth.

Production and international trade Small quantities of wood-oil from *S. inermis* are exported from the Philippines to Singapore for the perfume industry. The medicinal fruits of *S. sumatrana* used to be exported from Indonesia.

The export of sepetir timber is more important.

Properties *Sindora* wood-oil from Malaysia has a clear light brown colour, a pleasant smell, and a gummy consistency. The specific gravity is 0.9657 and the optical rotation at 29°C is +27.8°. Distillation with steam gives 65% colourless essential oil with an optical rotation of −6.5°. Wood-oil from *S. supa* from the Philippines is a light yellow, non-drying, transparent oil and has a specific gravity of 0.9202 and optical rotation of −31.3°. It consists mainly of sesquiterpenes and is soluble in organic solvents except alcohol. *Sindora* wood-oil originating from Pontianak (West Kalimantan) is pale brown with a specific gravity of 0.9550, a refractive index of 1.5119, and an optical rotation of −25.0°. The wood-oil yields 53% essential oil after steam distillation with the following physical properties: specific gravity 0.9142, refractive index 1.4958, and optical rotation −10.4°. The wood-oil of *S. velutina* has been analysed. After distillation the oil had the following physical properties: specific gravity 0.946 and boiling range 250–280°C. This oil consists of sesquiterpenoid hydrocarbons with three major compounds, namely α-copaene (41.3%), β-cubebene (15.4%) and β-cadinene (7.2%). The fruits of *S. sumatrana* yield an essential oil which almost exclusively contains sesquiterpene oxides and sesquiterpene alcohols.

The density of the wood of the species yielding wood-oil is 530–830 kg/m³ at 15% moisture content.



Sindora supa Merr. – 1, flowering branch; 2, flower; 3, fruit.

Description Usually medium-sized but sometimes large, briefly deciduous trees, 20–35(–46) m tall with cylindrical bole having a diameter of up to 100(–180) cm, non-buttressed or flaring out at base or with steep thick buttresses; bark smooth, thin and brittle, rugulose with distant, prominent lenticels, dark purplish-grey and often flecked with green, brown or yellow. Leaves alternate, paripinnate, 2–10-jugate; leaflets opposite, shortly stalked, usually firmly leathery, often reticulately veined on both surfaces and slightly asymmetrical, the midrib on the lower surface often ending in a gland. Inflorescence made up of solitary or gregarious panicles, often velvety pubescent; flowers bisexual, zygomorphic, sessile or shortly pedicelled; calyx with a short tube, tawny velvety pubescent, and 4 lobes, usually unequal in size, with or sometimes without spinescent outgrowths; petal 1, fleshy in the lower half, with an indistinct, yellow or red claw; stamens (9–)10, 9 fused in hirsute sheath, the uppermost one free and reduced to a short staminode; usually 2 stamens are better developed than the others; ovary with a short, free stipe, with 2–5(–more)-ovules, flat, hirsute at least along the suture, style recurved, stigma small. Fruit a flat pod, circular to oblong, dehiscent with 2 valves, smooth but more often set with hollow spines. Seeds 1–2, flat, hard and stony, black on top of a red or yellow aril about as large as the seed. Seedling with epigeal germination; hypocotyl elongate; first two leaves alternate, leaflets larger and thinner than those of mature trees.

- *S. inermis*. Tree, up to 30 m tall, bole 75–95 cm in diameter. Leaves 2–4-jugate; petiole 2–4 cm long, rachis 8–15 cm long; leaflets elliptical to ovate or obovate, 6–13 cm × 4–7 cm. Inflorescence 10–15 cm long with brown, glabrous flowers. Fruit broadly ellipsoidal, up to 7 cm × 5 cm, unarmed, glabrous.
- *S. sumatrana*. Tree, medium-sized to large, Leaves often 3-jugate; petiole up to 3 cm long, rachis up to 9.5 cm long; leaflets elliptical to obovate-oblong, 6–12 cm × 2–6 cm, glabrous. Infructescence paniculate, up to 13 cm long; fruit flattened globose to broadly ellipsoidal, up to 4 cm long, with many short but stout spines with a swollen base and abundant resin. Seed subglobose, flattened, about 1 cm in diameter, black, aril irregular. No information is available on the flowers.
- *S. supa*. Tree, 15(–30) m tall and 30(–180) cm in diameter. Leaves 2–4-jugate; petiole 1–2.5 cm long, rachis 1–7 cm long; leaflets elliptical, 2–8 cm × 2–4 cm. Inflorescence paniculate, up to 20 cm long; calyx lobes 6–12 mm long; petal sublanceolate, 10–12 mm long; 2 perfect stamens with anthers 3.5 mm long, other anthers much smaller. Fruit broadly ellipsoidal, 4–5 cm × 3–3.5 cm, with straight sharp spines 5 mm long. Seeds 2–4, ovoid, 3 cm × 2 cm, black.
- *S. velutina*. Tree, 15–50 m tall, 20–95 cm in diameter, densely rusty pubescent on twigs and leaf undersides. Leaves 3–7-jugate; petiole 2–5 cm long, rachis 5–20 cm long; leaflets ovate to elliptical, 3–14 cm × 1.5–7 cm. Inflorescence paniculate, up to 20 cm long; calyx lobes 11-13 mm long; petal lanceolate, 10–12 mm long, woolly outside; 2 perfect stamens with 3–4 mm long anthers, other anthers much smaller. Fruit ovoid, 6–15 cm × 5–8 cm, with sharp spines 4 mm long. Seed irregular, flattened ovoid, 1.5–2 cm long and wide, purple-black.

Growth and development *Sindora* trees are deciduous and may remain leafless for several weeks, the young leaves being bronze or pale green. Flowers appear shortly after the new leaves. *S. velutina* flowers are pollinated by small social bees. Fruits take about 2 months to reach maturity. The waxy aril of the seeds is especially attractive to rodents, which disperse the seeds.

Other botanical information *Sindora* is a well-defined genus and rather easy to recognize by its pubescent flowers with a single fleshy petal, its peculiar pods and arillate seeds. It belongs to the subfamily *Caesalpinioideae* and the tribe *Detarieae*.

In addition to the species dealt with here in more detail, the following species have also been reported as producing wood-oil: *S. beccariana* Backer ex de Wit (tall tree from Borneo, pod with straight sharp spines); *S. coriacea* Maingay ex Prain (tree 20–30 m tall from Thailand, Peninsular Malaysia, Sumatra and Borneo, leaves glabrous, flowers yellow to red and pods unarmed); *S. javanica* (Koord. & Valeton) Backer ex K.Heyne (tree 20–30 m tall, in Java on poor soils, the pods have an excessive resin excretion, the flower has no free staminode); *S. leiocarpa* Backer ex K.Heyne (tree 25–45 m tall from Sumatra and Borneo, inflorescences abundant and fragrant, pods unarmed); *S. siamensis* Teijsm. ex Miq. (synonym: *S. cochinchinensis* Baill.) (small tree up to 15 m tall from Thailand, Indo-China and Peninsular Malaysia; fruits are armed (var. *siamensis*) or unarmed (var. *maritima* (Pierre) K. & S.S.Larsen) and are used as a substitute for areca nut in betel chewing); and *S. wallichii* Graham ex Benth. (tree 20–30 m tall from Peninsular Malaysia, Sumatra and Borneo, flowers bright red, pod dark purple with a velvety brown pubescence).

Several species are poorly known and certainly deserve more attention from field botanists.

Ecology *Sindora* trees occur usually scattered, sometimes gregarious, in lowland dipterocarp forest on flat land and hillsides, up to 800 m altitude. They generally favour well-drained soils, which are at least moderately fertile. Occasionally, they are found near the banks of brooks or small rivers. *S. inermis* may also occur along the seashore and near the mangrove zone, while *S. sumatrana* prefers periodically inundated sandy sites, *S. supa* is especially found on limestone ridges in regions with a distinct dry season and *S. velutina* prefers dryland forests.

Propagation and planting *Sindora* seeds survive for more than 3 years without any specific treatment. Germination is usually delayed. When the seed-coat is mechanically scarified on one or both sides of the seed, and the seeds are soaked in water at room temperature for 24 hours, the germination rate within one month is about 70%. An effective method of mechanical scarification is to scrape off the protrusion of the seed-coat located next to the hilum. Treatment with dilute sulphuric acid or hot water is much less successful. However, seeds treated with concentrated sulphuric acid for one hour may give 80% germination.

For seedlings of *S. supa* a 1:1 mixture of sand and humus appeared to be the most satisfactory potting medium. When potted in this mixture seedlings attain an average height of about 20 cm after 7 months. A mixture of ordinary garden soil and sand (2:1) gives slightly inferior results.

Management In logged-over forest the regeneration of *Sindora* is often abundant. Usually the number of seedlings is larger than in undisturbed forest. From Peninsular Malaysia an average of one large tree (over 60 cm in diameter) per 5 ha of undisturbed forest has been reported, although locally *Sindora* is more common: up to one large tree per 2 ha.

Diseases and pests During very rainy weather in the Philippines, *Sclerotium rolfsii* has been observed to attack very young *Sindora* seedlings under 20 cm tall causing 'damping-off'.

Harvesting Wood-oil of *Sindora* is obtained by cutting downward slanting cavities in the stem. They may cover up to half of the circumference of the tree and go as deep as the centre of the stem. In each cavity the wood-oil collects and the flow of oil is increased by a fire which is maintained for half a day. The wood-oil is subsequently removed from the cavities. This destructive method of harvesting wood-oil was practised in the Philippines, Indonesia and Malaysia. Occasionally, whole trees are cut and chopped to obtain the wood-oil.

Yield A freshly cut tree of *S. supa* in the Philippines may yield about 10 litres of wood-oil. A single *S. velutina* tree 40 m tall and 85 cm in diameter may yield 30 litres of oil.

Handling after harvest The wood-oil of *Sindora* can be used directly. Sometimes the essential oils are extracted by steam distillation.

Genetic resources Most *Sindora* species are uncommon and occur scattered. Large-scale exploitation of forest, as practised in many locations, puts these species at risk of extinction. Proper and sustainable management of the forest should guarantee survival of its component trees, including *Sindora*.

Prospects At present, the wood-oil of *Sindora* is not traded and there seems to be no future for its increased utilization. *Sindora* timber will remain of importance, provided the forests in which

Sindora occurs as scattered trees are wisely managed.

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H.C. Ong

Styrax L.

Sp. pl.: 444 (1753); Gen pl., ed. 5: 203 (1754).
STYRACACEAE
$x = 8$

Major species and synonyms
- *Styrax benzoin* Dryand., Philos. Trans. 77(2): 308, t. 12 (1787), synonyms: *Benzoin officinale* Hayne (1841), *Cyrta dealbata* Miers (1851), *Plagiospermum benzoin* Pierre (1892).
- *Styrax paralleloneurum* Perkins, Bot. Jahrb. 31: 484 (1902), synonym: *S. sumatranus* J.J.Sm. (1917).
- *Styrax tonkinensis* (Pierre) Craib ex Hartwich, Apoth. Zeit. 28: 698 (1913), synonyms: *Anthostyrax tonkinense* Pierre (1892), *Styrax macrothyrsus* Perkins (1902), *S. hypoglaucus* Perkins (1902).

Vernacular names General: benzoin tree (En). Indonesia: haminjon (Batak, Sumatra), kemenyan (Java). Laos: nha:n.
- *S. benzoin*: Sumatra benzoin tree, gum benjamin tree (En). Indonesia: kemenyan (general), haminjon durame, menyan (Java). Malaysia: kemenyan (Peninsular). Laos: kam nha:n (general). Thailand: kam yaan (peninsular). Vietnam: b[oof] [dd][eef] nh[uwj] (northern), an t[uws]c, k[ow] ngan (southern).
- *S. paralleloneurum*: Sumatra benzoin tree, gum benjamin tree (En). Indonesia: kemenyan (general), haminjon toba, kumayan putih (Batak, Sumatra).
- *S. tonkinensis*: Siam benzoin tree, Lao benzoin tree (En). Laos: nha:n kh'an th'ung, nha:n ngwà, (kôk) ph'ung. Vietnam: (c[aa]y) b[oo] [dd][ee], (c[aa]y) nh[af]n, mu kh[or]a [dd]eng.

Origin and geographic distribution *Styrax* comprises some 120 species in the tropics, subtropics and temperate zones of Asia, Europe and America. In Malesia 8 species occur.
S. benzoin occurs naturally in India, Burma (Myanmar), Thailand, Cambodia, Laos, Vietnam, Peninsular Malaysia, Borneo, Sumatra and is rare in West Java; it has been cultivated in Sumatra since early the 19th Century, and is also cultivated in Java and West Kalimantan. *S. paralleloneurum* occurs naturally in Thailand, Sumatra and Peninsular Malaysia and has also been planted in Java. *S. tonkinensis* occurs naturally in southern China (Guangdong, Guangxi) and in the northern parts of Laos and Vietnam. Vietnam is the only country where it has been planted on a large scale, although not for benzoin but for pulp production; it has been planted experimentally in Java.

Uses Benzoin is a balsam obtained by wounding the stem cambium of several *Styrax* species. It finds extensive use worldwide as incense and in the flavour, fragrance and pharmaceutical industries. In volume terms, Sumatra benzoin (the product of *S. benzoin* and *S. paralleloneurum*) is the most important type of benzoin and it is used for incense in e.g. the Middle East, North Africa, parts of Asia and the Indian sub-continent. Most commonly, small or crushed pieces of the raw benzoin in semi-processed block form are simply placed on an open fire, either in the house or in the place of worship. Sometimes it is mixed with other natural fragrance resins such as frankincense (*Boswellia* spp.), myrrh (*Copaifera* spp.) and storax (*Liquidambar orientalis* Mill.). Extracts of Sumatra benzoin are used to produce fragrances for joss sticks. In Java, benzoin is applied for ritual ceremonies related to death or spirits. Siam and Sumatra benzoin are both used for flavour and fragrance purposes but usually satisfy different parts of the markets. Siam benzoin has a rounder, more vanilla-like odour than Sumatra benzoin, which is harsher to the nose. The better grades of benzoin are extracted for the manufacture of fragrant products. These include personal health care products (e.g. toilet soaps, shampoos, body lotions, creams) and household and other products (e.g. liquid soaps, air fresheners, washing detergents). Although there is occasional overlap in end-use, the pleasant, rounder fragrance of the more expensive Siam benzoin is generally found in fine fragrances (perfumes and colognes) and the more expensive soaps. Although benzoin contributes its own fragrance to the final, formulated product, one of its important functions is to serve as a fixative for the other fragrance materials, increasing the tenacity and preventing loss of the middle and top notes of the more volatile components.

Benzoin's principal role in foods is as a flavouring agent. Sumatra benzoin is used particularly in the manufacture of chocolate flavours for chocolate bars, ice-cream, milk products, syrups and other products. Benzoin is popular in Scandinavia as a flavouring in baked goods containing vanilla or cassia, where it also serves to 'fix' the other flavours and increase their spiciness. In Japan benzoin is applied as a chewing gum base. In Central Java (Indonesia) an important outlet for Sumatra benzoin is in flavouring tobacco by mixing it with tobacco when making cigarettes. However, it finds wider application in the production of 'Manila' and other types of tobacco flavour. Benzoin is also employed by the tobacco industry in China.

Benzoin is well-known in both allopathic and traditional medicine. Several national pharmacopoeias specify either Siam or Sumatra types, while others include both. In the form of a tincture, benzoin is inhaled with steam for the relief of catarrh, laryngitis, bronchitis and upper respiratory tract disorders. It is also used for the prevention and treatment of cold sores, for the treatment of warts and to freshen and soothe dry skin and ameliorate skin allergies. Benzoin is employed similarly in the form of over-the-counter herbal medicines and in aromatherapy in western societies. Taken internally, benzoin acts as a carminative, expectorant and diuretic.

In Vietnam, *S. tonkinensis* is planted for pulp production. In the past, matches were made from the wood. In the highlands of Laos the wood is an appreciated source of building material because of its resistance to insects.

Production and international trade Sumatra benzoin is one of the oldest known export items from Indonesia and was traded as early as the 8th Century. Indonesia is the only producer of this type of benzoin, which dominates world trade. It is collected in the Tapanuli region of North Sumatra, mainly in the highlands to the west and south of Lake Toba. Some production is from wild trees but many families plant *Styrax* as a source of cash income. The large amounts of semi-processed block benzoin exported from Indonesia make it exceedingly difficult to quantify real production of benzoin, as it contains other resins as well. Production estimates vary from over 4000 t for each of the years 1990–1993 in northern Tapanuli, to about 470 t in 1986 of which 420 t was from Tapanuli. It seems probable that production is at least several thousand t per year.

In Palembang, South Sumatra, the benzoin plantations were replaced by para rubber (*Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.) in the 1920s. The Tapanuli area around lake Toba, North Sumatra, however, is too high for para rubber and continues to be important for benzoin cultivation and production.

In contrast, annual production of Siam benzoin, mostly in Laos, is around 50 t. Collection takes place in the mountainous northern provinces, where the trees are managed within the shifting cultivation cycle that is widely practised. Although production is relatively small, it provides a welcome source of cash income. Unlike Sumatra benzoin, for which there is a large domestic market (mainly Java), virtually all the benzoin produced in Laos is exported. Vietnam and China are the only other (minor) producers of Siam benzoin. Exports from Vietnam are small (probably around 12 t/year at most) and do not necessarily represent indigenous production – some benzoin enters Vietnam from Laos and is re-exported.

Exports of raw and processed benzoin from Indonesia averaged 1010 t annually in the period 1987–1995, valued at US$ 1–1.6 million. Most of this was shipped to Singapore, where much of the raw benzoin is processed into block form, and re-exported to the major markets in the Middle East, Africa, the Indian sub-continent and Asia. The main Asian market for benzoin is Malaysia. Most Siam benzoin is exported to Europe, principally France; recorded exports from Laos showed an upward trend from 27 t in 1990 to 51 t in 1995.

Recent prices in 1997 in Medan for best quality Sumatra benzoin 'almonds' per kg and free-on-board (FOB) have ranged from US$ 8 for large pieces (grade 1) to US$ 2 for dust/small particles (grade 4). The superior sensory properties of Siam benzoin are reflected in the higher prices fetched in 1997 in Marseille by comparable grades of benzoin from Laos per kg and cost and freight: US$ 16 for the top grade to US$ 8–9 for dust/small particles. Prices for semi-processed block Sumatra benzoin in 1997 in Singapore varied per kg and FOB in the range US$ 0.80–4.00.

Properties It is difficult to find reliable data on properties of benzoin. Samples may or may not be representative. For the two best balsam grades of *S. benzoin* ('red benzoin') and *S. paralleloneurum* ('white benzoin') the following data are an indication of their chemical content: insolubility in ethanol 1.2–2.8% and 1.3–3.7%, ash content 0.09–0.17% and 0.03–0.07%, cinnamic acid 0% and 24.5–30.6% and benzoic acid 26.2–27.2% and 11.5–12.9%. Sumatra benzoin is usually 75% soluble in ethanol, but when of very high quality it is 95% soluble. As Sumatra benzoin is sold in blocks its quality is variable, partly because it includes pieces and dust of 'damar', the exudate from *Dipterocarpaceae*. The aromatic compounds of the different benzoin species (balsamic acids (i.e. benzoic acids and cinnamic acids), vanillin, cinnamic-, p-coumaryl- and coniferylalcohol) are probably products of an injury-induced change to the lignin metabolism. It is unknown whether sumaresinol acid occurs in the bark or wood of non-injured trees. Unlike many other balsams, benzoin produces negligible amounts of essential oil on distillation.

Paleness and purity (without extraneous matter i.e. high alcohol solubility) are important indicators of quality. A tentative FAO/WHO specification exists for 'benzoin gum' as a food additive: for Sumatra benzoin and Siam benzoin the ethanol solubility should be respectively ≥ 75% and ≥ 90% and the acid-insoluble ash should be respectively ≤ 1% and ≤ 0.5%. Pharmaceutical uses of benzoin generally require compliance with national pharmacopoeia specifications and these vary according to the pharmacopoeia and the type of benzoin. Loss on drying should usually be ≤ 10% for both types of benzoin, but alcohol solubility is ≥ 70–80% for Sumatra benzoin and ≥ 90–98% for Siam benzoin. Balsamic acid content is important, and both types of benzoin are usually required to contain a minimum of 25% acids (calculated as cinnamic acid for Sumatra benzoin and benzoic acid for Siam benzoin). Total ash and acid-insoluble ash are also specified in some pharmacopoeias.

The wood is dull red to pale brown with irregular white flecks, grain very coarse, 470–710 kg/m^3 at 15% moisture content, rather soft, moderately strong and non-durable to slightly durable.

Description Evergreen shrubs or trees, bole usually with small buttresses, excreting a fragrant balsam on being bruised; bark surface smooth to vertically cracked or finely fissured, inner bark soft, brown to deep red, pink or purplish-red, sapwood white. Leaves simple, spirally arranged, without stipules; petiole grooved; blade ovate to oblong or lanceolate, margin entire or shallowly serrate-dentate, apex acuminate, secondary veins in 5–13 pairs, underside with white stellate hairs or scales. Inflorescence a terminal or axillary raceme or leafy panicle; flowers regular, bisexual, 4–7-merous; calyx campanulate or cup-shaped, free or the base connate to the ovary, truncate or rarely 4–5-dentate, persistent in fruit; corolla connate at the base (1–2 mm) with annular staminal tube, deeply 4–7-lobed, subfleshy; stamens twice the number of petals, in one whorl, basally fused to each other and to the corolla tube, staminal tube up to 4 mm long, anthers splitting lengthwise; ovary superior, imperfectly 3-locular with 1 to few ovules per cell, densely hairy, style filiform, 3-angular, stigma capitate or indistinctly 3-lobed. Fruit a globose or depressed globose drupe, dehiscent or indehiscent, pericarp 3–5 mm thick. Seeds 1(–2), attached basally; testa with 2 layers, the outer layer thick and stony and the inner one membranous. Seedling with epigeal germination; cotyledons subfleshy; hypocotyl with purple flecks; first pair of leaves opposite, subsequent ones alternate to spiral.

Styrax benzoin Dryand. – 1, flowering branch; 2, section through flower; 3, fruit.

- *S. benzoin*. Tree, 8–34 m tall, trunk 10–100 cm in diameter, young twigs grey. Leaf blade 8–13 cm × 2–5 cm, undersurface with white woolly indumentum of stellate hairs, veins in 7–13 pairs. Inflorescence a panicle up to 20 cm long, but usually smaller than the leaves, flowers fragrant, white; pedicel up to 4 mm long; corolla tube 1–2 mm long, lobes 9–12 mm × 2–3.5 mm. Fruit 2–3 cm × 2 cm, indehiscent. Seed subglobose, 1.5–2 cm in diameter, dull pale brown.
- *S. paralleloneurum*. Tree, 5–35 m tall, trunk 23–60 cm in diameter. Leaf blade 6–16 cm × 2–7 cm, underside with white stellate hairs and golden-brown stellate scales, veins in 6–8 pairs with distinct transverse veins. Inflorescence a panicle, up to 11 cm long, with drooping, violet-scented flowers; pedicel 4–6 mm long; corolla tube 4 mm long, lobes 12 mm × 3 mm. Fruit globose, 2–3 cm in diameter with large cupular calyx, indehiscent. Seed shiny dark brown.
- *S. tonkinensis*. Tree, up to 20 m tall, trunk up to 40 cm in diameter. Leaf blade 5–20 cm × 2–12 cm, underside with white stellate hairs, secondary veins in 7–9 pairs with distinct transverse tertiary cnes. Inflorescence a panicle, up to 18 cm long, with white flowers up to 1.5 cm long; pedicel 3–5 mm long; corolla tube 2.5–3 mm long, lobes 6–8.5 mm × 2–3 mm. Fruit ovoid, 1 cm × 0.7 cm, dehiscent with 3 valves. Seed orange.

Growth and development In Peninsular Malaysia *S. benzoin* flowers annually from November to May, in Sumatra throughout the year. In Indo-China it flowers from February to June and fruits from August to September. In western Malesia, *S. paralleloneurum* generally flowers from March to July and fruits from July to November. In Indo-China, flowering and fruiting of *S. tonkinensis* are from April to June and from July to October, respectively. Very peculiar bark galls are found in *Styrax*, caused by *Astegopteryx* (*Aphidae*). In *S. benzoin* the galls are comprised of tubes radiating from a central point. They are flat and only 4–5 cm long. In *S. paralleloneurum* the tubes, which also radiate from a central point are generally spirally contorted and 15–20 cm long. These tubes contain hundreds of lice in different developmental stages. *Styrax* fruits are only rarely dispersed by pigs and deer.

Other botanical information The two Malesian species *S benzoin* and *S. paralleloneurum* can be distinguished by their microscopic stellate hairs on the underside of leaves. In the arms of the stellate hairs of the former species the hairs radiate in many planes while in the latter stellate hairs are flattened into scales and the arms radiate in one plane.

The following *Styrax* species have also occasionally been reported to produce benzoin; at present they are usually more important as ornamentals: *S. benzoides* Craib – tree, 10–15 m tall, occurring in Thailand, Laos and Vietnam; especially formerly an important source of Siam benzoin; *S. crotonoides* Clarke – tree, up to 30 m tall, occurring in Peninsular Malaysia and Vietnam; *S. japonicum* Siebold & Zucc. – shrub, 2–3 m tall, occurring in Japan, northern China, Taiwan and (rarely) in the Philippines; *S. officinalis* L. – shrub or very small tree, occurring in the Mediterranean; *S. ridleyanum* Perkins – tree, 30 m tall, occurring in Burma (Myanmar), Peninsular Malaysia and Sumatra; *S. serrulatum* Roxb. – tree, 6–12 m tall, occurring from India throughout continental South-East Asia to Taiwan.

Ecology *Styrax* prefers mixed primary forest with rich clayey soils. It is less common in dense secondary forest. *S. benzoin* is found at altitudes of 100–700(–1600) m, outside Malesia it is restricted to 200–500 m. *S. paralleloneurum* occurs at (575–)800–1700 m altitude. In Laos, *S. tonkinensis* occurs predominantly at (600–)800–1600 m elevation, while in Vietnam it occurs mostly below 1000 m. *S. tonkinensis* is a light-demanding species and in open habitats it often occurs in the upper storey. Seedlings cannot survive shade in dense forest. Benzoin trees need well-drained soils, as excessive water leads to dying back. In *Styrax*'s area of natural distribution the mean annual rainfall is usually 1500–2200 mm, with no distinct dry season (or only a few drier months). However, under cultivation it will thrive in areas with mean annual rainfall of 1300 mm and 3–6 dry months. Mean annual temperature in its natural range is 15–26°C but it can tolerate extremes of −4°C and +45°C for a short period. The success of *S. tonkinensis* owes much to human activities and to its pioneer characteristics: fire accelerates seed germination and many stands occupy sites previously used in shifting cultivation. Bamboo is one of the most common associates of *S. tonkinensis* and in natural regeneration in shifting cultivation systems *Imperata cylindrica* (L.) Raeusch. and *Erianthus arundinaceus* (Retz.) Jeswiet are common undergrowth.

Propagation and planting In Sumatra plantations of benzoin trees are established and regenerated by planting wildlings collected from existing plantations, but direct sowing is also applied on a small scale. *S. benzoin* has 400–850 dry seeds/kg. The seed can be stored for up to 1 month without loss of viability; at storage from 2–8 months, germination percentage drops to 50–60%. Dry seeds of *S. paralleloneurum* (750–1150 per kg) can be stored up to 4 months and then have a germination rate of 35%. Vegetative propagation of *S. benzoin* using shoot cuttings treated with Rootone-F (20 g/l) proved successful in North Sumatra. Young seedlings need partial shade for satisfactory development. In North Sumatra planting or direct sowing is presently done at a spacing of 2 m × 3 m. A wider spacing is undesirable, as this allows too much light for weed development and individuals become too branchy.

In Vietnam over 50 000 ha of *S. tonkinensis* has been planted for pulp production. Collected seed must be stored properly to maintain viability. Premature germination can be prevented by storing at moisture levels ≤ 17%. Germination is promoted by soaking in water; alternatively, the seed can be stored in moist sand. Depending on circumstances, seed may be sown directly, or nursery-raised stock may be planted. In the nursery, seeds are sown in well-drained germination beds kept moist. Germinated seeds with fully expanded cotyledons are transplanted into tubes containing forest topsoil. They are protected from full sunlight until the first two leaves appear and are ready for planting after 2 months, when about 15 cm tall. Alternatively, seedlings can be raised in nursery beds for 10–12 months and 1–1.5 m tall. After lifting, the stem is cut off 3–5 cm above the root collar and some lateral roots are trimmed to prepare stumps. Three density regimes are currently used in Vietnam: 1600–2000 stems/ha, when soils are fertile, well drained and not erosion-prone; 2000–2500 stems/ha, when soils are relatively fertile and well drained but erosion-prone; and 2500–3300 stems/ha, when soil fertility is low, drainage is poor or erosion is anticipated.

Management The forest in Tapanuli region, North Sumatra, consisting mainly of Merkus pine (*Pinus merkusii* Jungh. & de Vriese), has gradually been modified into a forest with a high density of benzoin trees represented by a wide range of sizes. At an elevation of 1300 m *S. paralleloneurum* is dominant and, at lower altitudes *S. benzoin* is prominent. The estimated density of benzoin trees is about 1375/ha of all sizes. Benzoin plantations have also been established by sowing before upland rice is sown. In the early stages benzoin trees need shading. Recently, there have been experiments with planting coffee under large benzoin trees while also maintaining a few benzoin seedlings and saplings.

In Laos, *S. tonkinensis* is managed with agroforestry techniques within a shifting cultivation system. After clearing regrowth of *Styrax* forest, upland rice is sown and natural regeneration of the *Styrax* is allowed to proceed freely. Seed germination is promoted by burning the fields before sowing rice. The trees are distributed irregularly and may be kept at a density of 500–600/ha. After harvesting the rice, the fields are left fallow until the *Styrax* trees are large enough for tapping. During this period terminal shoots are often cut, to stimulate diameter increment and benzoin production. The fallow period varies considerably but has been reduced in recent years as the pressure on land for rice cultivation has increased. Many stands are now clear-felled after 5–7 years, in which case they are tapped for the last 1–2 years only. Young trees are browsed by cattle, buffaloes and goats.

In Vietnam, nitrogen is given in 3 applications of 20 g per plant within one month of planting *S. tonkinensis*. Plantations should be kept weed-free in the first two years by regularly removing of ground cover and cultivating the soil in a 50–60 cm radius around each plant. In plantations for pulp production with a rotation of 10 years, two thinnings (at 2 years and 3 years old) are required to achieve a final density of 600–800 stems/ha. Under favourable conditions a mean height of 18–25 m and diameter at breast height of 20–24 cm may be achieved after 10 years.

Diseases and pests In North Tapanuli fungal diseases have been recorded in benzoin trees but their importance is minor. An unidentified insect, locally known as 'tapponok' often attacks young *Styrax* shoots.

A defoliator (*Fentonia* sp., Lepidoptera: *Notodontidae*) causes damage to thousands of hectares of *S. tonkinensis* plantations in Vietnam every year. The larval stage has four instars, with the third and fourth instars being most damaging, each larva consuming 6–7 g of leaves per day. Control measures involving chemical sprays have been recommended but *Fentonia* also has several natural predators, including two ant species (*Oecophylla smaragdina* and *Cremastogaster* sp.) and two bees (*Anastatus* spp.) which need consideration. In Laos young trees are attacked by fungi and various insects (crickets, termites, stemborers), which still need to be identified.

Harvesting The balsam is only produced when the cambium is wounded, probably in newly formed cells at the end of rays in the xylem. Tapped trees generally exude throughout the year, except during periods of heavy rainfall. Tapping of Sumatra benzoin trees may start when 7 years old. After cleaning and smoothening the bark a piece of bark (2 cm wide and 2–4 cm long) is loosened from the wood with a tapping chisel and the bark is lightly beaten. The tapping wounds are made on two sides of the stem and from its base up to 3–5 m (reached by climbing the tree). Occasionally the balsam exudes so fast that it is necessary to use a container to collect the fluid. When harvesting *S. paralleloneurum*, the balsam under the loosened piece of bark is cut from the tree and graded into 'large almonds' ('mata kasar', 'mata besar') and 'small almonds' (or 'mata halus'). Then the wood of the tapping wounds is exposed, the bark of the borders of the wounds is cut and the balsam is scraped off after a few weeks ('jurus'). Three months later the rest of the balsam is collected ('tahir'). The second and third harvests yield a brownish sticky balsam, used to prepare the trade product. *S. paralleloneurum* in North Sumatra is tapped from June to September. Once or twice a year the trees are tapped again, making new wounds above the old ones where wood is exposed. Although callus formation is rare, the soft wood is rarely attacked by wood-rotting fungi or wood-boring insects. The balsam of *S. benzoin* does not harden but remains sticky. It oozes from the wound and forms long threads on the stem, resembling yellow rice straw (hence 'haminjan durame'). At the first harvest the bark and sticky balsam are removed ('parung') and generally the threads formed on the stem are added to this grade. The second quality is 'longkap' and the third one with many impurities is 'jarir'. Tapping of planted *S. benzoin* trees in Java has not been successful.

Traditionally, tapping of *S. tonkinensis* in Laos may start when trees are about 8 years old, allowing for 4 years or more of production until the fallow period of the shifting cultivation cycle ends and the trees are felled. Trees can be tapped for 6–7 years, then production declines and trees die when about 15 years, irrespective of whether they have been tapped or not. During the fallow period there are about 300 trees per ha, but only 50 are selected for tapping. Tapping entails making cuts into the stem wood and collecting the exuded balsam at a later date after it has dried. In Luang Prabang Province, tapping is carried out at the end of the rainy season, usually around September–October. The balsam remains on the tree during the dry season and is collected before the onset of the rains, usually about March. A series of staggered incisions is made into the stem, starting as near the base as is convenient and extending upwards over a height of 2 m or more. If the tree is tapped the following year, a further 2 m section is cut above the first, or tapping is continued to the first branches. The lower part of the cut bark is allowed to remain attached to the tree and this serves to trap the balsam when it flows from the wound. In this way the balsam is prevented from running down the face of the tree and accumulating dirt and other foreign matter. The hardened balsam forms flat pieces, characteristic of Siam benzoin ('almonds').

Yield The annual balsam yield of a *S. benzoin* tree is estimated at 0.5–1.3 kg. Even higher yields are reported from Indonesia. During a good year a large tree may yield 0.6–1.9 kg of balsam in 3 months. In one year a vigorous *S. paralleloneurum* tree can yield up to 0.5 kg of first quality 'kasar' benzoin and also 0.5 kg of second quality 'barbar' benzoin. The average annual production of 10-year-old *S. paralleloneurum* trees, 14–24 cm in diameter is 0.3 kg/tree when they are tapped once in three months with 8 tapping positions. Horizontal tapping of 15–20-year old *S. paralleloneurum* trees with a panel of 4 cm wide and 3 cm high yielded an average of 15.6 g per tap and per panel, which is more than for vertical panels (11.9 g) and triangular panels (8.9 g). Sumatra benzoin yield from *S. benzoin* and *S. paralleloneurum* maximizes after about 3 years of tapping and remains at this level up to the age of 17–19 years, when the tree is exhausted and dies. Trees of 5, 7 and 9 years old when tapped for 3 months yielded 49 g, 61 g, and 79 g, respectively, but the difference was not statistically significant.

In Laos, the yield of a *S. tonkinensis* tree is 2–3 kg of balsam per harvest in regenerating forest and 0.8–1.5 kg in old secondary forest with very high tree-to-tree variation. The per hectare yield is 15–25 kg per year. Trees observed to be poor-yielding in the first year are not tapped in subsequent years. Trees with thick, rough, reddish bark are reputed to give higher yields than those with thin, grey bark but this may simply be a reflection of older, bigger trees yielding more than younger, smaller ones. Climatic factors, altitude and the height on the tree at which tapping is carried out affect yields. Intrinsic, genetic variation between different natural populations is also possible.

Handling after harvest In Indonesia, more balsam appears to run down the tree, rather than being trapped between the cut bark and the stem, than is the case in Laos, and this results in a large number of different types and qualities of Sumatra benzoin. Darker, dirtier grades are produced, which do not have equivalents in Laos. After hand cleaning sorting gives the following types of balsam:

- 'mata kasar' ('big eye'), first quality
- 'mata halus' ('soft eye'), second quality, 1–2 cm, yellowish white
- 'jurus/jarir', brown with yellowish white pieces, mixed with bark and other impurities
- 'tahir', similar to 'jurus' and usually mixed with it
- 'barbar/laklak' which is the bark that has been removed from the other grades during cleaning
- 'abu', ('dust'), produced from broken 'almonds', 'jurus' and 'tahir'.

'Abu' and 'barbar' are usually mixed with 'jurus' and 'tahir' before sale. The best quality whole pieces ('almonds') are graded according to size: grade 1 for the larger pieces and grade 4 for dust/small particles.

In Laos, pieces of bark and other extraneous matter are removed from the benzoin soon after collection. Most is then sorted and graded according to size, using a sequence of sieves, resulting in four grades. Each pile of sieved benzoin is then further cleaned to remove pieces of bark which have escaped earlier cleaning. When an order is received, the cleaned, graded benzoin is re-packed in cotton-lined jute sacks, each sack being put in a plywood box and placed in a larger wooden crate for export. In contrast to Siam benzoin from Laos, which is sold only in its whole, cleaned form, most Sumatra benzoin enters world trade in a processed form known as 'block benzoin'. Essentially, block benzoin consists of light-coloured pieces embedded in a much darker matrix. However, the light-coloured pieces of benzoin are present only in the higher grades; in the majority of cases they are pieces of 'damar' (resin from *Dipterocarpaceae*). Damar is considerably cheaper than benzoin and readily available from Indonesia and elsewhere. It acts as a binder to make blocks of benzoin that are easier to transport and handle. Most benzoin intended for incense is traded in this form, and damar improves the burning quality as does the presence of powdered bark, although the scent of damar is inferior. The British Pharmacopoeia specification (which relates to Sumatra benzoin) requires damar to be absent and there is a test to check this. Preparation of block benzoin involves adding damar to low grade benzoin according to a well-tried formula, and cooking it briefly in hot water. The wet mixture is then transferred to shallow wooden boxes lined with cotton, and surplus water is squeezed out. The boxes are set aside to cool so that their content solidifies.

Genetic resources As only planted benzoin trees are tapped there seems to be no risk of genetic erosion. FAO has started a tree improvement programme for *S. tonkinensis* in Laos.

Breeding Currently no improved planting stock is used. A screening programme aiming at the identification of superior material in terms of balsam quality and yield from different wild provenances (e.g. 'Toba styrax' from *S. paralleloneurum*) could greatly enhance production. Two provenance trials of *S. tonkinensis* were planted in 1997 in Laos and these indicate clear provenance differences in survival and height growth. It is intended to assess balsam yield and quality when the trees are old enough to be tapped.

Prospects Demand for both Sumatra and Siam benzoin appears to be firm and is spread amongst the flavour, fragrance and pharmaceutical industries. Provided international prices do not decline markedly, and the resource base is secure, prospects for benzoin are likely to remain promising. Measures should be taken to ensure that the price paid to the collectors remains economically interesting. Otherwise, they may turn to more profitable activities to generate income.

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D.S.H. Hoesen

3 Minor species producing exudates

Araucaria bidwillii Hook.

ARAUCARIACEAE

Vernacular names Bunya pine, bunya-bunya (En). Philippines: bunya pine. Thailand: son nam (Central), bunya-bunya.

Distribution Australia (Coast District of Queensland); introduced and planted in South-East Asia and other tropical and subtropical regions mainly as an ornamental.

Uses The resin exuding from wounds is quite hard and brittle and has a pleasant odour. It can be used like incense and be employed in making perfumes and unguents. In Australia the seeds are valued as food or eaten roasted as a snack. Locally the tree is of commercial value as a Christmas tree. The wood can be used for timber like that of other *Araucaria* species, especially for interior work. In South-East Asia *A. bidwillii* is mainly planted as an ornamental tree.

Observations Large, usually monoecious, evergreen tree up to 45 m tall and up to 1.5 m in diameter; bark up to 15 cm thick, rough, dark brown to black, resinous, outer bark scaling off in thin layers. Leaves clustered at the end of branches, needle-like, entire, sessile, glossy green, discolorous, on sterile twigs lanceolate, 13–50 mm × 5–10 mm, apex a long, stiff point; on fertile shoots and higher branches leaves are shorter (up to 25 mm) and incurved. Inflorescence a cone; pollen cones cylindrical, up to 17 cm × 1 cm, situated towards the end of the branches in groups of 15–20; seed cones situated terminally on a shoot with modified leaves, ellipsoidal, up to 30 cm × 22 cm, weighing 4–8 kg, scales with thick, woody wings, apex scales with long, recurved point, cones disintegrating when mature and each cone containing about 150 seeds. Seed pear-shaped, 5–7 cm × 3 cm, seedcoat fused with its scale; germination hypogeal, cryptocotylar. *A. bidwillii* prefers a moist but well-drained, fertile soil, but it will grow on poorer soils when moisture conditions are favourable. In south-eastern Queensland it prefers the higher elevations (800–1000 m altitude), with annual rainfall of about 1000 mm and a temperature range from below 0°C up to 30°C. Its growth is rapid and it does not suffer from serious diseases or pests. The seeds were so important as food resource for the Australian aborigines that the right to collect the seeds from certain trees used to be claimed by individual families who passed on this right from father to son. Bunya pine produces a heavy cone crop only once every 3 years.

Selected sources 3, 4, 9, 11, 13, 15, 16, 25, 39.

Balanophora elongata Blume

BALANOPHORACEAE

Synonyms *Balanophora ungeriana* Valeton.

Vernacular names Indonesia: 'perud' followed by the vernacular name of the host, e.g. perud cantigi, perud ramo giling, perud panggang (Javanese, Sundanese).

Distribution Indonesia (Sumatra, Java, abundant in West Java). Var. *ungeriana* (Valeton) B.Hansen only occurs on Mt. Salak and Mt. Gede (West Java).

Uses *B. elongata* contains so much wax that it is used to make small candles or torches. Whole plants are macerated and heated until the pulp sticks to small bamboo strips which are then sold as candles. The wax can also be obtained by cooking the plant. All parts of the plant are also used as an aphrodisiac.

Observations Dioecious, fleshy root parasite, without chlorophyll, red to brown, with basal tubers from which stems arise. Tubers repeatedly branched, with scattered tessellate warts; tuber branches cylindrical, 3–8 cm × 1–1.5 cm. Stem in male plants up to 20 cm long, shorter in female plants, 5–8 mm in diameter. Leaves 7–20, arranged spirally, imbricate, gradually increasing in size upwards, elliptical-obtuse, up to 4 cm × 2 cm, reddish to yellowish, partly concealing the spadix-like inflorescence. Male inflorescence spicate, 3–5 cm long; pedicel 3–7 mm long; flower 4(–5)-merous, subtended by short truncate bracts; tepals about 4 mm long; stamens forming a synandrium with fertile part 2 mm long and 20–30 vertical locules opening longitudinally. Female inflorescence spicate, ellipsoidal to subspherical, 3–4 cm × 2–3 cm; bracts transformed to minute, more or less club-shaped spadicles; female flowers on main axis of inflorescence as well as on lower part of spadicles, perianth absebt; largest flowers with pistil 1.3 mm long, styles much longer than the spadicles. *B. elongata* flowers throughout the year and is found in evergreen forest at 1000–3000 m altitude. Two varieties are distinguished: var. *elongata* and var. *ungeriana* (Valeton) B.Hansen, the latter with tubers which are not elongated and with coarsely longitudinally striate leaves. The roots of various tree and shrub species have been recorded as host of *B. elongata* var. *elongata*, e.g. *Schefflera aromatica* (Blume) Harms, *Vaccinium laurifolium* (Blume) Miq., *V. lucidum* (Blume) Miq. and various *Ficus* species, but only *Ficus* species have been recorded as hosts of var. *ungeriana*. Due to its rare occurrence, the candles and the wax have never been traded commercially.

Selected sources 5, 21, 23.

Balanophora fungosa J.R.Forst. & G.Forst.

BALANOPHORACEAE

Synonyms *Balanophora gigantea* Wall. ex Fawc., *B. globosa* Jungh., *B. indica* (Arn.) Griff.

Vernacular names Indonesia: perud puspa. Thailand: khanun din (general), kok maak paasee (northern), bua phut (peninsular).

Distribution From India, throughhout South-East Asia to eastern Australia, New Caledonia, New Hebrides, Fiji and the Marianas.

Uses *B. fungosa* contains so much wax that it is used to make small candles or torches. Whole plants are macerated and heated until the pulp sticks to small bamboo strips which are then sold as candles. The wax can also be obtained by cooking the plant. All parts of the plant are also used as an aphrodisiac.

Observations Monoecious or dioecious, tuberous root parasite, without chlorophyll, yellow to orange-yellow or red, 1–22 cm long. Tubers single or fused into a clump 10–15 cm wide, branching from the base; single tuber subspherical or depressed, 1–3 cm in diameter, surface coarsely tessellate with polygons 5–7 mm across. Leaves 10–30, usually arranged spirally, imbricate, closely appressed to the stem and the lower part of the inflorescence, 2–3 cm long. In monoecious plants (subsp. *fungosa*) the male flowers (2–20) are situated just below the female part of the inflorescence, they are 4–5-merous with ovoid-ellipsoidal synandrium; female part of inflorescence subspherical to ovoid, 1–3.5 cm in diameter, largest flowers about 1 mm long. In dioecious plants (subsp. *indica* (Arn.) B.Hansen), the male inflorescence is ellipsoidal and 2–12 cm long with expanded flowers, the female inflorescence variously subellipsoidal, 1–8 cm long, largest flowers with pistil 1.5–2 mm long. *B. fungosa* flowers throughout the year and is found in dense primary forest up to 1000 m altitude. It parasitizes many forest tree species, e.g. *Diospyros maritima* Blume, *Macaranga tanarius* (L.) Müll.Arg. and *Hibiscus tiliaceus* L. Several subspecies and varieties have been distinguished on the basis of differences in inflorescences. In West Java var. *globosa* (Jungh.) B.Hansen with depressed subspherical inflorescences (only female ones observed) up to 4 cm in diameter occurs in the evergreen forest at 1500–2000 m altitude, often with *Schima wallichii* (DC.) Korth. ('puspa') as host, but it is also found on various other tree species. Because the species is rare, candles and wax have never been traded commercially.

Selected sources 5, 21, 23.

Castilla elastica Sessé

MORACEAE

Synonyms *Castilla costaricana* Liebm., *C. panamensis* O.F.Cook, *Ficus gummifera* (Miq.) Miq. Note: The erroneous genus name *Castilloa* sometimes occurs in the literature.

Vernacular names Mexican rubber (En). Philippines: castilloa rubber tree.

Distribution *C. elastica* occurs naturally from Mexico through Panama to western Colombia and western Ecuador. Subsp. *elastica* occurs naturally from Mexico to north-western Costa Rica but has been introduced into many tropical areas; subsp. *costaricana* (Liebm.) C.C.Berg occurs naturally from Costa Rica to south-western Colombia and has been introduced in a few other countries, but is cultivated in Indonesia; subsp. *gummifera* (Miq.) C.C.Berg occurs naturally from Ecuador to south-western Colombia. *C. elastica* was introduced in Bogor in 1876.

Uses The rubber, obtainable from the latex, can be used like para rubber. The latex from this tree was probably being processed into rubber as early as 1600 BC in Ancient Mesoamerica. Because quality and yield are less than from para rubber, there are no longer any commercial plantations.

Observations Monoecious or dioecious tree, up to 30 m tall with low buttresses, exuding white latex when wounded; twigs clothed with soft hairs, dimorphic, some falling off ('self pruning'), the persistent ones never producing flowers. Leaves pendulous, distichous on caducous twigs, arranged spirally on persistent twigs; stipules fully amplexicaul, connate, 2–12 cm long, yellow strigose, margins white-tomentellous; petiole 2(–10) cm long; blade ovate to oblong, 15–40(–55) cm × 5–20(–30) cm, base cordate, margin entire or shallowly dentate, apex acuminate, beneath with soft hairs and with about 20 pairs of prominent secondary veins, leaves on persistent twigs smaller than those on caducous twigs. Inflorescences capitate, peduncled, many-flowered, cup-shaped; male heads 1–3 cm in diameter, often 4 together, on peduncle 1.5 mm long; female heads solitary, subsessile, smaller than male head; male flowers without perianth, stamen 1; female flowers with ovoid perianth, 4-lobed, style 2-branched. Infructescence 3–5 cm in diameter, red to orange or pink, with pyramidal, hairy apex; fruit ellipsoidal, about 1 cm long. Seed brownish. *C. elastica* is found in forests up to 850 m altitude, often along streams, in clearings, or at forest margins. Three subspecies have been distinguished on the basis of distribution pattern and indumentum type. *C. elastica* can be easily propagated by seed and by cuttings from the persistent branches. Many years after the plantations in Java had been cleared the plants were still producing shoots from coppice. In trials *C. elastica* grew faster than para rubber. Although there were fairly extensive plantations in Peninsular Malaysia and Central and East Java, the yield and the quality of the rubber proved to be inferior to para rubber. Moreover, in Peninsular Malaysia plantations were severely damaged and even destroyed by a number of diseases and pests and trees did not stand up to tapping very well. One litre latex yields about 200 g rubber. The mean annual rubber yield from trees in Java was 150 g.

Selected sources 2, 7, 8, 10, 11, 22, 23, 27, 40, 42.

Chonemorpha verrucosa (Blume) D.J.Middleton

APOCYNACEAE

Synonyms *Chonemorpha elastica* Merr., *Rhynchodia rhynchosperma* (Wall.) K.Schum., *R. verrucosa* (Blume) Woodson.

Vernacular names Peninsular Malaysia: kedamba. Philippines: goma, lisid (Apayao). Thailand: mok khruea (central).

Distribution India, Bhutan, China, Burma (Myanmar), Thailand, Laos, Vietnam, Indonesia and the Philippines.

Uses The latex yields a high quality rubber which used to fetch a high price and was extensively collected, for example in the southern Philippines, particularly in the Sulu Archipelago.

Observations Big woody liana, up to 70 m long. Leaves opposite; petiole up to 2 cm long; blade elliptical to obovate, 9–24 cm × 4–12 cm, rounded to cuneate at base, apex sharp acuminate to caudate, papery to coriaceous. Inflorescence a terminal panicle, 3–10 cm long; flowers 5-merous, white, fragrant; corolla tubular, tube 4–7 mm long, lobes 7–14 mm long. Fruit a pair of follicles, each one thin cylindrical, about 15 cm × 0.5 cm. Seed with a long beak and topped with a coma. *C. verrucosa* occurs in forests and thickets, up to 1500 m altitude. A sample of the latex from the Philippines contained 92% rubber and about 4% of resin; it was not very sticky but had good elasticity and tenacity.

Selected sources 10, 11, 27, 34, 42.

Fagraea auriculata Jack

LOGANIACEAE

Synonyms *Fagraea borneensis* Scheff., *F. curranii* Merr., *F. imperialis* Miq.

Vernacular names Indonesia: bira-bira, terentang langit (Sumatra), ki terong (Sundanese). Malaysia: pelir musang, sagam (Peninsular). Philippines: nato, tumakos (Manobo), nonok (Bisaya).

Distribution Southern Burma (Myanmar), Thailand, Cambodia, southern Vietnam, Malaysia, Indonesia (Sumatra, Java, Bali, Kalimantan, the Moluccas, Sumbawa, Flores), Brunei, the Philippines.

Uses The clear, very sticky fluid present under the rind of the fruit has been used as a good quality glue, but also as a birdlime. Plant forms with large flowers are grown as ornamentals.

Observations Epiphytic, more rarely terrestrial, very variable shrub or climber, sometimes becoming a tree up to 20 m tall when older; twigs often sharply quadrangular and each ridge crowned by a small acute spine. Leaves opposite, simple, entire, thickly coriaceous; petiole 2–8 cm long, at the base with 2 suborbicular auricles that are appressed to the twig and provide shelter to ants; blade oblanceolate to oblong or obovate, 9–40(–60) cm × 4–25 cm, base broadly cuneate to narrowly acute, almost decurrent, apex rounded to acute. Flowers solitary or 2–7 in a terminal cyme, bisexual, actinomorphic, 5-merous; pedicel up to 5 cm long with 1–2 pairs of appressed bracteoles; calyx campanulate, 2–7.5 cm long, usually divided to near the base; corolla wide trumpet-shaped, tube 5–15 cm long, lobes contorted, overlapping to the right, rounded, the whole up to 30 cm in diameter, fleshy, leathery, creamy-white; stamens inserted in the throat, alternating, not or hardly exserted, anthers thick, 1–2 cm long, bifid to about the middle; pistil with superior, ellipsoidal ovary, tapering into the quadrangular style, stigma discoid and subconcave. Fruit a berry dehiscing with 4 lobes, oblong-ellipsoidal to ovoid, 6–15 cm long, yellow-brown, pulp orange to red with many seeds. Seed irregularly angular, minutely warty, brown. *F. auriculata* is found in primary and secondary rain forest, often along clearings, river banks, sometimes in mangrove swamps, from sea-level up to 1900 m altitude. It flowers throughout the year and the flowers are protandrous; pollination is by insects and birds. Seed is dispersed by birds and ants. The species has been subdivided into 3 subspecies, mainly on the basis of size of the flowers and the auricles.

Selected sources 5, 11, 23, 29.

Ficus bracteata (Wall. ex Miq.) Miq.

MORACEAE

Vernacular names Malaysia: getah taban rimba (Peninsular).

Distribution Malaysia, Singapore, Indonesia (Sumatra, Kalimantan).

Uses The latex coagulates to a substance with characteristics similar to gutta-percha. The timber is soft and rather light, pale reddish-brown, splitting easily.

Observations Strangling fig-tree containing latex; young branches, stipules, leaf undersides and figs covered with red-brown woolly hairs. Leaves alternate; petiole 3.5 cm long; blade oblong, 22–28 cm × 10–12 cm, base cordate, apex bluntly pointed, secondary veins 7–9 pairs, 3-veined at base, veins prominent below, inconspicuous above. Inflorescence a fig, arranged in sessile clusters with large persistent bracts, depressed globose, orange. *F. bracteata* grows in lowland forest.

Selected sources 11, 26, 27, 36, 45.

Ficus consociata Blume

MORACEAE

Vernacular names Indonesia: karet binasah (Sumatra, Lampung), kiyara kowang (Sundanese), kayu ara seher (western Kalimantan). Malaysia: pianggu antan (Peninsular). Thailand: sai-yai (south-eastern).

Distribution Burma (Myanmar), Thailand, Cambodia, Malaysia (Peninsular), Singapore, Indonesia (Sumatra, Java, Kalimantan).

Uses The latex contains a large amount of resin which destroys most of the elasticity that its rubber might have. Nevertheless it used to be an important source of rubber in Indonesia. A certain variety (var. *murtoni* King) was cultivated in southern Sumatra for rubber tapping because wild trees there had been tapped to death. It is stated that the bark is very rich in tannin and that the bark cloth is suitable for binding books.

Observations Strangling epiphytic fig when young, gradually turning into a large tree, up to 40 m tall with trunk diameter of 2 m, containing latex; all younger parts usually densely covered with crisp hairs or patently brown pilose, gradually becoming glabrescent. Leaves alternate; petiole 2–5 cm long; blade elliptical to obovate, 10–22 cm × 4–10 cm, base rounded to cordate and 3-veined, apex acuminate, secondary veins in 5–10 pairs, prominent below. Inflorescence a fig, usually occurring in pairs in the axils of higher leaves and subtended by 3 large, ovate-acute bracts 1.5 cm long; fig depressed-globose, up to 1.5 cm in diameter, red-orange. *F. consociata* occurs in humid lowland forest, up to 1000 m altitude; it is rare in Java. In Peninsular Malaysia and Sumatra the usual variety is var. *murtoni*.

Selected sources 5, 11, 23, 26, 27, 36, 42, 45.

Ficus curtipes Corner

MORACEAE

Synonyms *Ficus obtusifolia* Roxb.

Vernacular names Thailand: hai linmaa, hai luang (northern), sai hin (peninsular).

Distribution From north-eastern India throughout continental South-East Asia to Indonesia (Sumatra). It is rare in north-western Peninsular Malaysia.

Uses The latex is said to be of fairly good quality for rubber production but in Malesia the tree is too rare to be of any economic importance.

Observations Starting as an epiphytic fig, eventually becoming a big tree, up to 40 m tall with trunk diameter of 1 m, containing latex. Leaves alternate; petiole up to 1.5 cm long; blade elliptical-oblong to obovate, 10–18 cm × 5–7 cm, base cuneate, apex rounded to truncate with numerous secondary veins which fuse at the margin to form a distinct intramarginal vein. Inflorescence a fig, arranged in axillary pairs, subtended by 3 persistent bracts; fig globose, 7 mm in diameter, yellow to yellow-pink, sessile. *F. curtipes* is closely allied to *F. elastica* Roxb. and preferably grows in per-humid lowland and hill forest.

Selected sources 11, 27, 36, 45.

Ficus lowii King

MORACEAE

Distribution Malaysia, Indonesia (Kalimantan), Brunei.

Uses The latex has been used for birdlime.

Observations Stout, woody, climbing, epiphytic fig containing latex. Leaves alternate; petiole up to 4 cm long; blade oblong to elliptical, 12–24 cm × 6–10 cm, base rounded to cuneate and 3-veined, margin rolled inwards, apex long pointed, secondary veins 6–7 pairs and conspicuous below, undersurface of leaf slightly glaucous. Inflorescence a sessile fig, globose, 1.5 cm in diameter, red or yellow, usually several crowded together. *F. lowii* occurs in hill forest but is rather rare.

Selected sources 11, 27, 36, 45.

Ficus padana Burm.f.

MORACEAE

Synonyms *Ficus elegans* Hassk., *F. toxicaria* L.

Vernacular names Indonesia: hamberang (Sundanese), dedek, kebeg (Javanese).

Distribution Indonesia (West Java).

Uses After boiling the latex yields a kind of light grey wax which in Java is used in batik making. The bark can be used for tying. The leaves are used as fodder for livestock and the figs are eaten by humans. The latex is said to cure haematuria.

Observations Tree, 6–15 m tall, widely but not strongly branched, trunk up to 30 cm in diameter, containing milky latex. Leaves arranged spirally; petiole up to 18 cm long; blade ovate to obovate, 18–36 cm × 10–25 cm, base cordate, entire or palmately 5–7-lobed, shallowly serrate-dentate, whitish or yellowish tomentose below. Inflorescence a fig, axillary, depressed globose, 4–5 cm in diameter, black-red when ripe, on peduncle 1 cm long, subtended by 3–4 bracts. *F. padana* grows in western Java in young secondary forest, often gregariously, up to 1500 m altitude. In tea plantations it is sometimes a noxious weed, growing inside tea shrubs from where it is difficult to eradicate.

Selected sources 5, 6, 23, 27.

Ficus retusa L.

MORACEAE

Synonyms *Ficus truncata* Miq.

Vernacular names Malaysia: ara jejawi (Peninsular). Philippines: balete (Tagalog), marabutan (Bagobo).

Distribution From India and southern China, throughout South-East Asia, to Australia and New Caledonia.

Uses The latex has been used to produce rubber, although three quarters of the latex is resin. The powdered adventitious roots are used in Peninsular Malaysia to treat toothache. In India roots and leaves are applied to wounds and bruises, bark and leaves for headache, juice from the leaves externally for colic and juice from the bark internally for liver disease.

Observations Tree up to 18 m tall, with aerial roots and milky latex; twigs with prominent projections of stipular rings and petiolar scars. Leaves alternate; stipules large and persistent; petiole up to 2 cm long; blade oblanceolate to narrowly obovate, 5–15 cm × 3–6 cm, base narrowed and 3-veined, apex rounded to bluntly pointed, secondary veins 5–8 pairs, all veins prominent below. Inflorescence an axillary fig, subglobose to obovoid, 1 cm in diameter, sessile, yellow-red, often in pairs and crowded. *F. retusa* grows in open lowland forest, brushwood and near rivers.

Selected sources 5, 11, 27, 36, 45.

Funtumia elastica (P.Preuss) Stapf

APOCYNACEAE

Synonyms *Kickxia elastica* P.Preuss.

Vernacular names West African rubber tree, Lagos silk rubber tree (En).

Distribution Originating in tropical Africa; it has been introduced and cultivated pantropically, including South-East Asia. Around 1900 there were large plantations in Ghana, Nigeria and Cameroon.

Uses The bark contains a white latex which coagulates readily and produces about one-third of its weight of pure rubber. Before the arrival of *Hevea* rubber, this was the most promising rubber tree in many tropical regions, primarily in West Africa. The rubber is of good quality compared with para rubber, but its yield is much smaller and plantations suffer much more from insect damage. At present it is economically of no importance. In Africa some parts of the tree are also used medicinally: the bark as astringent, the leaves against diarrhoea and to cure whooping-cough, the latex to treat fungal infections and sores. The seed has been used to adulterate *Strophanthus* seed in the production of strophantin. The floss of the fruits is used like kapok, to stuff cushions. The wood is white and soft, not durable, used for carving household utensils like spoons and bowls; it burns well and is a good firewood.

Observations Tree, up to 30 m tall with not straight, cylindrical, unbuttressed bole; bark pale with grey patches and dark brown twigs, containing white latex. Leaves opposite, glabrous; petiole up to 1 cm long; blade oblong-elliptical, up to about 20 cm × 8 cm, margins undulate, with characteristic domatia in the axils of the 7–11 pairs of prominent lateral veins below. Flowers in axillary, many-flowered cymes, 5-merous, white to yellowish; peduncle 1 cm long; pedicel 3–5 mm long; calyx 5 mm long, deeply divided, segments on the inside with 2 glands; corolla salver-shaped, tube 7–9 mm long, segments oblong, about 5 mm long. Fruit composed of 2 divaricating woody follicles about 15 cm × 5–7 cm. Seed fusiform, about 1.5 cm long, narrowed into a slender point at the base, at apex beaked with white, silky hairs. *F. elastica* occurs naturally in deciduous forest and is a rapid grower. *F. africana* (Benth.) Stapf is rather similar to and often co-occurs with *F. elastica* but its latex will not coagulate and is even not suited to be mixed with better latex.

Selected sources 5, 11, 12, 23, 27, 35.

Garcinia merguensis Wight

GUTTIFERAE

Synonyms *Garcinia lanceolata* Ridl.

Vernacular names Malaysia: lulai, kandis burong (Peninsular). Thailand: nuan (northern), yaang khao (south-eastern), ka nuan (peninsular).

Distribution Burma (Myanmar), Cambodia, Thailand, Malaysia (Peninsular), Singapore.

Uses In Malaysia the latex is collected and mixed with twice its volume of turpentine and boiled 3 times to make a pale brown-yellow varnish. *Melipona* and *Trigona* bees collect the latex to line their nests. The latex contains a large proportion of free resin acids and a comparatively small amount of resin esters and is quite different from gamboge obtained from *G. morella* (Gaertn.) Desr. It is not available in commercial quantities. The fruit is edible. The wood is red-yellow, flexible and light, but is little used.

Observations Dioecious shrub or small tree up to 12 m tall, exuding whitish-yellowish latex from the inner bark when wounded. Leaves opposite; petiole about 0.5 cm long; blade lanceolate to elliptical, 5–15 cm × 1–5 cm, base long tapering, apex acuminate, secondary veins prominent, parallel, 4–6 mm apart. Inflorescence a short axillary raceme with 3–6 flowers; flowers 4-merous, small, about 3 mm in diameter on a stout pedicel 5 mm long; male flowers with stamens in 4 bundles round a central mushroom-like pistillode. Fruit a subglobose, thinly woody berry, 13 mm in diameter, tipped by a conspicuous disk-like stigma 3 mm wide and with a subpersistent calyx. *G. merguensis* is common in lowland to lower montane forest, sometimes on limestone, up to 1500 m altitude.

Selected sources 11, 23, 36, 45.

Garcinia morella (Gaertn.) Desr.

GUTTIFERAE

Synonyms *Garcinia gaudichaudii* Planch. & Triana, *G. gutta* Wight, *G. lateriflora* Blume.

Vernacular names Indian gamboge tree (En). Malaysia: kandis (Peninsular). Philippines: maladambo (Tagalog), ugau (Bikol), kandis (Manobo).

Distribution From Sri Lanka and India throughout northern South-East Asia.

Uses After wounding the bark exudes a brilliant golden-yellow resinous sap, called gamboge, which can be used in watercolours because it emulsifies well in water. It can also be used for dyeing and as colouring agent for varnishes, lacquer, paints and ink. Gamboge is a drastic purgative, an emetic and a vermifuge but nowadays is rarely used medicinally. Sap from the root is said to be used to heal cuts.

Observations Tree, up to 20 m tall and trunk diameter 50 cm but usually much smaller, glabrous in all parts. Inner bark up to 1 cm thick, white to pale yellow, containing plenty of brilliant yellow, sticky latex. Leaves opposite, coriaceous, entire; petiole up to 2 cm long, foveola conspicuous with prominent margins; blade obovate to oblanceolate, 9–24 cm × 5–10 cm, base tapering, apex usually obscurely acuminate, lower surface with 7–8 very prominent pairs parallel, slender lateral veins 8–14 mm apart. Flowers subsessile, axillary, solitary (female) or 2–3 together (male), per tree unisexual or bisexual; sepals 4, 5 mm long; petals 4, elliptical, 5–8 mm long, fleshy, white to pink; stamens in male flowers in a monadelphous central column with free red anthers; female flowers with sessile peltate stigma, base of ovary surrounded by about15 free staminodes. Fruit a globose berry, up to 3.5 cm in diameter, at base surrounded by the persistent sepals, at apex crowned by the flat tuberculate stigma, smooth, yellowish; exocarp thin, fruit pulp edible, acid-sweet, containing 2–3 seeds. Seed kidney-shaped, laterally compressed. *G. morella* occurs in dry and humid forest. Trees can be tapped when they are 10 years old by making a spiral incision and collecting the latex in small bamboo containers. In dry zones the trees are often stunted and the leaves less fleshy.

Selected sources 5, 11, 17, 24, 25, 36.

Geodorum nutans (Presl) Ames

ORCHIDACEAE

Synonyms *Arethusa glutinosa* Blanco, *Dendrobium nutans* Presl, *Geodorum semicristatum* Lindley.

Vernacular names Philippines: kula (Tagalog), bandabok (Bisaya), lubi-lubi (Panay Bisaya).

Distribution Widely distributed in the Philippines and in Taiwan.

Uses The tuberous roots contain a substance which is used as a glue, especially in musical instruments like mandolin and guitar. Medicinally the tuberous parts are used as an emollient poultice.

Observations Terrestrial orchid up to 70 cm tall with underground fleshy rhizome which thickens into globose, pluri-articulate pseudo-bulbs and a shoot with 2–4 large leaves. Leaves erect, articulate, petiolate, convolutive, firmly folded along the mid-vein, narrow and pointed, up to 35 cm × 7 cm. Flowering shoots 20–25 cm long, leafless, ending in a raceme with a top nodding at first but straightening later; flowers numerous, pale pink to purple, about 1 cm long; sepals and petals slightly differing; lip immobile, at right angles to the short column foot and forming a shallow pouch with it; anther proclined with 2 basal appendages; pollinia 2 on a common stipe. *G. nutans* grows in thickets and open locations up to 300 m altitude. To prepare the glue the rhizomes are first cooked and then finely grated. The glue is said to have a great tenacity. Several other Philippine orchids are used for the same purpose. *G. citrinum* Jacks. (from Peninsular Malaysia) and *G. purpureum* R.Br. (from Peninsular Malaysia and Java) can be used similarly.

Selected sources 5, 10, 11, 25.

Hymenaea verrucosa Gaertn.

LEGUMINOSAE

Synonyms *Trachylobium verrucosum* (Gaertn.) Oliv.

Vernacular names Zanzibar copal (trade name), East African copal, Madagascar copal (En).

Distribution Native in Kenya, Tanzania, Mozambique, Madagascar, Mauritius and Seychelles. Introduced and cultivated pantropically, including South-East Asia.

Uses All parts, but particularly the bark, yield a valuable resin which is used like the resin of *Hymenaea courbaril* L. The fruits and the wood are also used the same way. The hard fossil resin, dug from the ground where it fell from trees long since disappeared, is more valuable than the soft fresh resin and is the hardest of all copals.

Observations Tree, up to 24(–40) m tall. Leaves alternate, 2-foliolate; petiole 8–18 mm long, petiolules 3–5 mm long, twisted; leaflet blade elliptical to broadly falcate, 3–13 cm × 2–7 cm, asymmetrical at base. Inflorescence paniculate, up to 35 cm long, with short dense hairs; pedicel 2–9 mm long; flowers small, white; calyx tubular with 4 lobes, tube 2 mm long, lobes ovate, 7–11 mm × 4–6 mm, appressed puberulous outside, silvery sericeous inside; petals clawed and subequal, up to 2 cm long; stamens 10. Fruit an ellipsoidal-cylindrical pod, up to 5 cm × 3 cm, coarsely verrucose-rugose, reddish-brown, 1–3-seeded. Seed ellipsoidal, 13–18 mm × 9–12 mm, dark brown. In its natural area *H. verrucosa* is common in coastal evergreen forest. The fossilized resin is pale yellow to reddish and in East Africa it has a peculiar, characteristic, roughened surface called 'gooseskin'. The best areas to find fossilized resin are near rivers and streams. The soil is dug out to a depth of about 1 m and the resin, usually found in the form of flat or disk-like pieces, picked out and later roughly cleaned. The fruits contain approximately 20% resin, but this is not easily obtained or extracted.

Selected sources 5, 11, 25.

Ichnocarpus serpyllifolius (Blume) P.I.Forst.

APOCYNACEAE

Synonyms *Ficus serpyllifolia* Blume, *Micrechites tenuifolia* Ridl., *Trachelospermum philippinense* Elmer.

Vernacular names Malaysia: kayu naga, gerip tembaga. Thailand: yan ta suea.

Distribution Thailand (peninsular), Malaysia, Singapore, Indonesia, Brunei, the Philippines.

Uses Before the arrival of para rubber in South-East Asia a non-commercial rubber used to be prepared from the latex.

Observations Woody climber containing white latex. Leaves opposite; petiole up to 1.5 cm long; blade orbicular, elliptical or obovate, 3–12 cm × 1–6 cm, 1–3 times as long as wide, base cuneate to rounded, apex usually short blunt acuminate. Inflorescence axillary and terminal cymes aggregated into a panicle up to 12 cm long; flowers 5-merous, cream; corolla tubular, tube up to 5 mm long, lobes up to 2 mm long. Fruit consisting of 2 spreading follicles, each about 2–7 cm × 0.5 cm. Seed flat, 1–3 cm × 1–2 mm, with grey-brown coma up to 5 cm long. *I. serpyllifolius* occurs in forests up to 1300 m altitude.

Selected sources 11, 32, 34.

Leuconotis eugenifolius A.DC.

APOCYNACEAE

Synonyms *Leuconotis cuspidatus* Blume.

Vernacular names Indonesia: pulai akar (Sumatra, Palembang), karet murai burung (Bengkulu), akar lutung wahai (Kalimantan). Malaysia: cheret murai (Peninsular).

Distribution Malaysia, Indonesia (Sumatra, Kalimantan), Brunei.

Uses The latex coagulates into a good quality rubber which was formerly traded from Borneo as 'manuyan biyok'. The fruit is edible. Medicinally the latex is used to treat yaws (applied on the skin) and with it is drunk salt as a cure for worms.

Observations Climbing, evergreen shrub, containing milky latex. Leaves opposite; petiole about 1 cm long; blade elliptical, up to 10 cm × 3 cm, acuminate at apex. Inflorescence a cyme, several together on an axillary peduncle; flowers 4-merous, about 1 cm long, orange-yellow; corolla tubular, lobes short. Fruit a globose berry, 1–2 cm in diameter. *L. eugenifolius* is common in rain forest and peat forest at low altitudes. The latex contains a very poisonous alkaloid.

Selected sources 11, 20, 23, 24, 30.

Leuconotis griffithii Hook.f.

APOCYNACEAE

Vernacular names Peninsular Malaysia: akar gerip puteh, akar gerit puteh, akar getah sundek.

Distribution Malaysia (Peninsular), Indonesia (Sumatra), Thailand.

Uses The latex produces a fair quality rubber.

Observations Climbing shrub containing latex, branches glabrous. Leaves opposite; petiole 1–3 cm long; blade elliptical to oblong, 5–14 cm × 2–6 cm, base rounded to cuneate, apex blunt acuminate. Inflorescence a cyme, several together on a robust, axillary peduncle in total about 5 cm long; flowers 4-merous, yellow to orange; corolla tubular, tube up to 7 mm long, lobes up to 4 mm long. Fruit an ellipsoidal to pear-shaped berry, up to 3.5 cm × 2 cm, usually with only 2 seeds of about 1 cm length. *L. griffithii* occurs in evergreen forest. In Peninsular Malaysia *L. maingayi* Dyer ex Hook.f. (vernacular name: 'akar gerip nasi') resembles *L. griffithii* but is much stouter; its latex is of comparable quality.

Selected sources 11, 20, 24, 30, 34.

Madhuca aristulata (King & Gamble) H.J.Lam

SAPOTACEAE

Synonyms *Bassia aristulata* King & Gamble.

Distribution Malaysia (Peninsular).

Uses The latex is said to give a good quality gutta-percha.

Observations Tree, up to 15 m tall. Leaves scattered, loosely clustered; petiole up to 6 cm long; blade oblong-elliptical, 20–50 cm × 7–18 cm, base rounded, apex bluntly pointed, secondary veins 19–25(–35) pairs mostly inarching to form a prominent intramarginal vein. Flowers in axillary clusters, 2–11 together, about 1 cm in diameter; sepals 4, about 1 cm long; corolla tubular, 8-lobed, tube about 1 cm long and inside densely filled with woolly hairs; stamens about 25, in 3 whorls, about 7 mm long. Fruits and seeds are unknown. *M. aristulata* is a rare species flowering in April or October.

Selected sources 11, 28, 43, 45.

Madhuca ovata H.J.Lam

SAPOTACEAE

Synonyms *Bassia forbesii* King, *Madhuca forbesii* (King) Moore.

Vernacular names Indonesia: regis itam, balam sudu (Sumatra). Malaysia: nyatoh balak, nyatoh balong kayam (Peninsular).

Distribution Indonesia (Sumatra, Java), Malaysia (Peninsular).

Uses The tree produces a kind of gutta-percha. The fragrance of the flowers resembles that of *Jasminum sambac* (L.) Aiton.

Observations Tree, up to 25 m tall with slender branches. Leaves alternate; petiole up to 3 cm long; blade oblong-ovate to elliptical, 8–20 cm × 4–8 cm, base cuneate, apex acuminate, secondary veins 10–15 pairs. Inflorescence an axillary cluster with 3–8 flowers; flowers bisexual, 4-merous, white, fragrant; calyx 4 mm long with 2 inner and 2 outer lobes; corolla tubular, tube 1 mm long, lobes 8–10, narrow, 4 mm long; stamens 16–20, in 2 whorls, about 3 mm long. Fruit an ovoid to obovoid berry, about 2 cm × 0.5 cm, ferruginously puberulous. Seed ellipsoid-fusiform, about 1.5 cm × 3 mm. *M. ovata* is a rather rare tree of primary forest, in Java flowering in October, occurring up to about 1100 m altitude.

Selected sources 11, 28, 43.

Madhuca rupicola (King & Gamble) H.J.Lam

SAPOTACEAE

Synonyms *Bassia rupicola* King & Gamble.

Vernacular names Malaysia: nyatoh. Thailand: puduwa.

Distribution Malaysia (Peninsular, Sarawak), Thailand.

Uses The white latex produces a sticky and inferior quality gutta-percha. The fruits are said to be edible.

Observations Tree, up to 18 m tall. Leaves scattered; petiole up to 2.5 cm long; blade elliptical to obovate-oblong, 10–20 cm × 3–8 cm, cuneate at base, obtusely acuminate at apex, secondary veins 8–12 pairs. Inflorescence an axillary cluster of 3–5 cream-coloured flowers; calyx of 2 pairs of sepals, up to 0.5 cm long; corolla tubular and 8-lobed, up to 7 mm long, lobes 4 mm long, tube woolly between the stamens; stamens 16, in 2 whorls, 3 mm long. Fruit unknown. *M. rupicola* grows in evergreen forest, up to 500 m altitude; in Peninsular Malaysia flowering is in March, in Thailand in July.

Selected sources 11, 43.

Manihot glaziovii Müll.Arg.

EUPHORBIACEAE

Vernacular names Ceara rubber tree (En). Caoutchoutier de Céara (Fr). Indonesia: singkong karet (Indonesian), sampeu karet (Sundanese), tela karet (Javanese). Malaysia: pokok chat.

Distribution *M. glaziovii* originates from north-eastern Brazil between the southern degrees of latitude 0–10. It is occasionally cultivated pantropically, including South-East Asia.

Uses In the early 1900s the latex was collected commercially to produce rubber, but eventually para rubber from *Hevea* ousted all other rubber sources. In Africa the leaves are used as a vegetable. In Indonesia *M. glaziovii* scions are grafted on cassava rootstocks (*M. esculenta* Crantz) to increase the yield of storage roots (Mukibat method). The plant is also planted as an ornamental. In breeding work in cassava, *M. glaziovii* has been used as a source to improve vigour and resistance to drought, to mosaic virus disease and to bacterial disease.

Observations Deciduous, monoecious shrub or small tree, up to 15 m tall, trunk 20–30 cm in diameter at base, containing copious latex, bearing tuberous roots. Leaves alternate, peltate, often with a bluish-white bloom; petiole 20(–45) cm long; blade palmately 3(–5) lobed, median lobe obovate about 15(–25) cm × 7(–10) cm, entire, lateral lobes prominently asymmetrical and curved upwards. Inflorescence a terminal panicle, about 30 cm long, profusely branched, many flowered, with setaceous bracts and bracteoles; female flowers restricted to the base of the upper 2/3 of the inflorescence, pedicel up to 2 cm long, flowers large, tepal 1.5 cm long, cleft to the base into 5 strap-shaped lobes, greenish-yellow with purplish tinge, disk prominent, stigma trifid and many-lobed; male flowers in the apical part of the inflorescence, large, tepal 1.5 cm long, cleft 1/3 way down into 5 lobes, green-yellow with purplish pigmentation, disk prominent, stamens 10 in 2 whorls of 5. Fruit a capsule, 2 cm long, dehiscing septicidally. Seed rounded, 1.5 cm in diameter, with trapeziform caruncle. In its native area *M. glaziovii* occurs up to 750 m altitude in a pronounced seasonal climate with a half year rainy season and a half year dry season. The latex is harvested in the dry season, when the plant is leafless and older than 5 years. In South-East Asia it only grows well in the driest areas. In large-scale experimental plantings in East Africa around 1900, a 4-year-old tree yielded about 0.1 kg rubber per year, and about 0.4 kg when 7 years old. In general, the rubber had a high resin content. In Java *M. glaziovii* has been tried on a large scale as well, but the soils and climate were much better suited for *Hevea* rubber.

Selected sources 11, 23, 27, 37, 38, 41, 42.

Melodinus orientalis Blume

APOCYNACEAE

Vernacular names Indonesia: areuy ki kadanca (Sundanese). Malaysia: getah ujul.

Distribution Malaysia (Peninsular), Indonesia, Thailand (peninsular).

Uses The latex is yellow-green, blackening when exposed to air; it is said to be highly poisonous and turns into an inferior kind of sticky rubber, used to adulterate good quality rubber. The bark has a useful short fibre similar to the one in pineapple leaves.

Observations A woody climber up to 60 m long with glabrous branchlets containing latex. Leaves opposite; petiole up to 1 cm long; blade elliptical, 6–12 cm × 2–4 cm, base cuneate, apex acuminate. Inflorescence an axillary cyme, in clusters up to 2 cm long; flowers 5-merous, fragrant, white; corolla tubular, tube about 5 mm long, lobes 2 mm long. Fruit a hard-walled, solitary globose berry, 6–7 cm in diameter. Seed flattened ellipsoid, 1–1.5 cm long. *M. orientalis* grows in hill forest, usually at 700–1400 m altitude. In Thailand and Indo-China another 2 species occur, possibly with similar uses and with edible fruits: *M. cambodiensis* Pierre ex Spire (synonym: *M. monogynus* auct. non Roxb.) and *M. cochinchinensis* (Lour.) Merr.

Selected sources 5, 11, 20, 23, 34.

Mesua lepidota T.Anderson

GUTTIFERAE

Synonyms *Kayea lepidota* (T.Anderson) Pierre, *K. parviflora* Ridl.

Vernacular names Malaysia: penaga bayan, penaga tikus (Peninsular).

Distribution Malaysia (Peninsular), Indonesia (Sumatra).

Uses Upon wounding, all parts, but especially the bark, exude an aromatic resin that can be used as a varnish after dilution with turpentine. The wood is a heavy hardwood, possibly used like penaga from *Mesua ferrea* L. (ironwood tree) for heavy construction, because both species are rather similar. An oil for lighting and perfumery can be extracted from the seeds. The oil is also used in traditional medicine for poulticing wounds and to treat skin eruptions. The tree is also a pleasing ornamental and shade tree along roadsides and in parks bearing fragrant flowers.

Observations Tree, up to 20 m tall with trunk diameter of 40 cm; bole fluted at base, bark adherent scaly; inner bark pink-brown with translucent to clear, yellow, varnish-like exudate. Leaves opposite, simple, entire; petiole about 5 mm long; blade oblong-elliptical, 8–15 cm × 3–5 cm, base wedge-shaped, margin slightly recurved, apex acuminate. Inflorescence a terminal or axillary umbel consisting of 1–3-flowered racemes, up to 6 cm long; flowers bisexual, on a pedicel with small paired bracts; sepals 4, decussate, rounded, 5 mm in diameter; petals 4, very narrowed at base with a roundish apical part about 8 mm in diameter, white or pink. Fruit a globose capsule, 2.5 cm in diameter, thick and woody, seated on the persistent, usually reflexed, thick-woody sepals. *M. lepidota* grows in lowlands and plains, sometimes in seasonal swamp forest. A form occurring in the hills of Peninsular Malaysia with smaller leaves and flowers has been distinguished as var. *parviflora* (Ridl.) Whitmore.

Selected sources 11, 24, 36, 45.

Musa acuminata Colla

MUSACEAE

Synonyms *Musa malaccensis* Ridl., *M. truncata* Ridl., *M. zebrina* Van Houtte ex Planch.

Vernacular names Indonesia: pisang batu (Indonesian), gedang klutuk (Javanese), cau batu (Sundanese).

Distribution The origin is not very well known but it is thought that the primary gene centre is Peninsular Malaysia and possibly also the immediately adjacent areas. At present it is distributed from India to Malesia.

Uses The underside of the leaf blade bears a thick white wax layer, which can be collected by scraping. It is then liquidized by heating and cleaned by filtering, after which it solidifies into a hard white wax with a high melting point (about 80°C). One of the uses of this hard wax is in the batik industry. The wild *M. acuminata* has played an important role in the development of the edible banana cultivars; it contributed the AA genome. The rhizomatous roots are sometimes eaten in times of food shortage and the leaves are used for wrapping of food and packing, just like those of other bananas. The inflorescence is sometimes eaten like a vegetable. Mature fruits, full of seeds, are not edible, but in Java young fruits (astringent to the taste) are used as a flavouring for the sauce of fruit salad ('rujak').

Observations Tufted, rhizomatous, 4–30-stemmed, erect herb, 4–9 m tall. Pseudostem (consisting of numerous completely convolute leaves) slender, 3–7 m tall. Leaves oblong from an acute or obtuse base, acutely passing into the petiole, 2–2.7 m × 40–75 cm, green or purplish-green, usually pruinose on the lower surface. Inflorescence racemiform, on a pubescent peduncle arising from the rhizome through the pseudostem; bracts dark purple; female hands 4–10, 12–26-flowered; male hands 12–23-flowered, compound tepal about 4 cm × 1.2 cm, creamy-white, free tepal about half as long, filaments about 1 cm, anthers 1.5 cm long. Fruit a berry, up to about 13 cm long, usually curved, 5-sided in cross-section, glabrous to covered with soft hairs, yellow with red blotches, pulp yellow-white. Seed angular but flat on one face, 6–7 mm × 3 mm, dark brown. *M. acuminata* occurs in light forest, forest borders and ravines in not too dry regions. It is very variable and, for example in Java, 3 formas have been distinguished although intermediates also exist. Particularly forma *cerifera* Backer has a very densely white pruinose leaf underside and the berry is covered with soft hairs. The wax yield per plant is about 200 g and 100 leaves yield about 0.5 kg pure wax. The wax layer is said to be thicker on plants growing in mountainous areas.

Selected sources 5, 11, 17, 23, 38.

Myroxylon balsamum (L.) Harms

LEGUMINOSAE

Synonyms *Myroxylon pereirae* (Royle) Klotzsch, *M. toluiferum* Kunth, *Toluifera balsamum* L.

Vernacular names Tolu balsam (var. *balsamum*), Peru balsam (var. *pereirae*) (En).

Distribution The native area is northern South America (Colombia, Venezuela, Peru). Introduced and cultivated pantropically, including South-East Asia. Commercially most important in Columbia, El Salvador, Nicaragua and Honduras.

Uses Tolu or Peru balsams are oleoresin exudates obtained from wounded trees. Tolu balsam is a brownish-yellow, plastic solid when fresh, but becomes harder, and eventually brittle, on exposure to air. Peru balsam is a dark brown, very viscous liquid, with a typically 'balsamic' odour, somewhat resembling vanilla. Both balsams are used in perfumery, but only rarely in their natural form; more commonly a prepared oil or 'resinoid' is used. The oil or extract is generally used as a fixative in fragrance applications. There is some use as a flavouring in drinks and sweets, and in incense. Both balsams contain mixtures of cinnamic and benzoic acid esters and these confer some mild antiseptic properties on the balsams, in addition to fragrance properties. Tolu balsam is used as an expectorant and as a flavouring compound in cough mixtures and other pharmaceutical preparations, often in combination with other balsams, although, today, many Tolu syrups described in national pharmacopoeia are synthetic mixtures rather than ones which contain genuine balsam. Peru balsam is used in some pharmaceutical preparations for treating skin disorders. The wood is also useful for timber (like mahogany or cedar) and the tree is also grown as an ornamental or as shade tree.

Observations Tree, up to 40 m tall with a wide spreading crown, trunk up to 1 m in diameter, bark resiniferous. Leaves alternate, imparipinnate, 5–11-foliolate, axis 6–15 cm long; leaflets ovate-oblong, 3–14 cm × 1–7 cm, subcoriaceous, lustrous, with pellucid lines and dots. Inflorescence a raceme; pedicel 1.5 cm long, flowers 1–1.5 cm long, white. Fruit an indehiscent, light brown pod, 6–12 cm × 2–3 cm × 1 cm, style tip noticeably situated below curved upper edge where also the seed is situated, basal portion alate, sterile, 4–7 cm long. Seed 1(–2), reniform, up to 2 cm long, light brown. *M. balsamum* grows scattered in forest, preferably with annual rainfall of about 2000 mm and mean annual temperature of 21–28°C. It is subdivided into 3 varieties: var. *balsamum* (fruit 8–11 cm × 2–3 cm, margins parallel, leaflets glabrous and acuminate; this var. produces the Tolu balsam); var. *pereirae* (Royle) Harms (fruit 6–9 cm × 1.5–2.5 cm, straight or curved, leaflets smaller than of other varieties; this var. produces the Peru balsam); var. *punctatum* (Klotzsch) Harms (fruit 8–12 cm × 2.5–3 cm, straight, leaflets abundantly punctate but with very few pellucid lines; this var. produces no balsam). Tolu balsam is harvested by cutting V-shaped notches through the bark and collecting the exuding balsam into cups which are regularly emptied. As many as 20 V-notches are cut in each tree, taking care not to girdle the tree. Peru balsam is harvested differently and there are 2 methods. In the 'cascara' or 'bark' process the bark is scorched for 10 minutes; 8 days later the bark is soft and pieces of about 30–60 cm × 30 cm are cut off at intervals. The remaining bark is crushed and treated with hot water to let the balsam flow, after which the balsam is separated from the water. In the 'panal' or 'trapo' process the trees are beaten on 4 sides, then scorched with a torch to cause the bark to separate from the trunk (some intermediate pieces are left uninjured). After about 1 week the bark drops off and the balsam starts exuding from the wood and is collected in rags that are wrapped around the exposed wood parts; saturated rags are renewed and the balsam is extracted by boiling with water. In the 1940s annual exports of Tolu balsam (mainly from Colombia) and Peru balsam (from El Salvador) were around 80 t and 100 t, respectively. Few recent data are available, but Indian imports of Tolu balsam in the late 1980s/early 1990s were usually about 10 t per year, of which Indonesia, Malaysia, Singapore and Thailand were occasional minor suppliers (assuming this to be genuine Tolu balsam).

Selected sources 11, 14, 17, 19, 23, 25, 44.

Sindora galedupa Prain

LEGUMINOSAE

Synonyms *Galedupa indica* Lam., *Pahudia galedupa* Backer ex K.Heyne.

Vernacular names Indonesia: kayu galadupa (South Sulawesi), kayu gowa, ai kowa (Moluccas, Seram).

Distribution Indonesia (Lesser Sunda Islands, Sulawesi, Moluccas).

Uses After the bark of *S. galedupa* has been pounded, the tree exudes a black, sticky balsam, which after a long time hardens to a hard resin. Although itself not very aromatic, this balsam (the basis for the 'dupa' of the Makassarese people), served to stick together other wood and resin parts and to strengthen their aroma. The timber is possibly used like sepetir, a medium-heavy hardwood from *Sindora* species.

Observations Tree, up to 25 m tall. Leaves alternate, compound, usually 4-jugate; petiole up to 3 cm long, rachis 8–14 cm long; leaflets elliptical to ovate or obovate, 4–13 cm × 3–7 cm, base usually unequally sided, apex acute to obtuse, usually glabrous. Inflorescence paniculate, up to 17(–37) cm long; flowers dirty yellow or light brown, fragrant; calyx lobes lanceolate, about 1 cm long; petals about 6 mm long; stamens 9 (2 fertile, 7 sterile) and 1 staminode. Fruit a flattened, suborbicular to ellipsoidal pod, 6–10 cm × 5 cm, at almost a right angle on a fruit stalk 1 cm long, smooth, with a very short beak, 1–2-seeded. Seed suborbicular to broadly ellipsoidal, about 2 cm × 1.8 cm, compressed, with a small aril. *S. galedupa* grows in lowland forest, flat country, often below 100 m altitude. It flowers in April–July and fruits in April–December.

Selected sources 11, 18, 23.

Urceola brachysepala Hook.f.

APOCYNACEAE

Synonyms *Urceola imberbis* (Elmer) Merr., *U. maingayi* Hook.f., *U. philippinensis* Merr.

Vernacular names Indonesia: akar gerip putih (Malay), gembor (Sundanese), serapat hitam (West Kalimantan). Peninsular Malaysia: akar gerit jantan. Philippines: hinggiu-kalabau, dugtong-ahas (Tagalog).

Distribution Malaysia, Singapore, Indonesia (Sumatra, Java, Kalimantan), Brunei, the Philippines.

Uses The latex present in the bark of the stem makes a good kind of rubber. Formerly this latex was collected in Indonesia by making cuts in the bark. The latex was mixed with that of other species and made into rubber.

Observations A big, woody, extremely variable climber containing white to yellowish latex; twigs glabrous to densely puberulent. Leaves opposite; petiole up to 3 cm long; blade ovate to elliptical, 2–22 cm × 1–13 cm, 1–3 times as long as wide, base cuneate to subcordate, apex acuminate. Inflorescence a terminal or axillary cymose panicle 1–12 cm long; flowers 5-merous, bisexual; corolla tubular, tube 1–2 mm long, lobes valvate in bud, urceolate and greenish-white when open, about 1 mm long and wide. Fruit a pair of follicles, each follicle linear to fusiform, 7–27 cm × 3–10 mm. Seed flattened ellipsoid, 8–15 mm × 1–3 mm, coma 2–5 cm long, pointing towards the end of the fruit. *U. brachysepala* occurs in widely differing habitats from cliffs to primary forest or swamp forest, up to 1000 m altitude. In an experimental plantation in Indonesia plants 8 years old produced about 25 g rubber when tapped like para rubber trees. Elsewhere in Indonesia, plants with stem diameter of about 10 cm were said to produce 300 g rubber by carving the stem; sometimes the whole stem is cut into sections about 30 cm long and the exuded coagulated latex at the ends is collected.

Selected sources 11, 23, 27, 33, 42.

Urceola elastica Roxb.

APOCYNACEAE

Synonyms *Tabernaemontana elastica* (Roxb.) Spreng., *Urceola brachysepala* Hook.f. var. *pilosa* Boerl.

Vernacular names Indonesia: akar gerip tembaga (Malay), tahoi tabu (Sumatra, Lampung). Malaysia: akar gegerit jantan (Peninsular).

Distribution Malaysia, Indonesia (Sumatra, Java, Kalimantan), Brunei.

Uses Before the introduction of the para rubber tree this liana was the oldest known rubber producer from Asia. It produced a good quality rubber and would certainly have been cultivated on a large scale had not all latex producing plants been overshadowed by *Hevea brasiliensis* (Willd. ex Juss.) Müll.Arg.

Observations Robust liana, up to 180 m long and 50 cm stem diameter at base, with densely brown puberulent branchlets, containg latex. Leaves opposite; petiole up to 3 cm long; blade elliptical to obovate, 3–20 cm × 1.5–9 cm, about 2 times as long as wide, base weakly cordate to obtuse, margins often slightly inrolled, apex acuminate, puberulent beneath. Inflorescence an axillary or terminal cymose panicle up to 20 cm long; flowers 5-merous; corolla tubular, greenish-white, lobes valvate in bud, urceolate when open, tube 1–2 mm long, lobes about 1 mm × 0.5 mm. Fruit a pair of divergent follicles, follicle linear to fusiform, up to 26 cm × 1.5 cm. Seed flattened ellipsoidal, up to 20 mm × 4 mm bearing a coma up to 6 cm long. *U. elastica* occurs in primary, secondary or disturbed forest, up to 800 m altitude.

Selected sources 11, 23, 27, 33, 42.

Urceola lucida (Wall. ex G.Don) Benth. ex Kurz

APOCYNACEAE

Synonyms *Urceola esculenta* (A.DC.) Benth. ex Kurz, *U. reticulata* King & Gamble.

Vernacular names Malaysia: akar gegerit puteh (Peninsular). Thailand: tang tiu (northern), thian ruesee (central), thee ngoh (peninsular).

Distribution Burma (Myanmar), Thailand, Malaysia (Peninsular), Singapore, Indonesia (Sumatra).

Uses The latex produces a good kind of rubber but the flow of latex is scanty.

Observations Liana with subglabrous branchlets, containing latex. Leaves opposite; petiole up to 3 cm long; blade obovate to elliptical, up to 26 cm × 11 cm, about 1–2 times as long as wide, base weakly cordate to obtuse, apex acuminate to caudate. Inflorescence an axillary or terminal cymose panicle up to 30 cm long; flowers 5-merous, white; corolla urceolate to campanulate, tube up to 1.5 mm long, lobes valvate in bud, about 1 mm long. Fruit a pair of follicles, follicle dagger-shaped, tapering, up to 11 cm × 2 cm. Seed flattened ellipsoidal, about 15 mm × 4 mm, coma 3–5 cm long. *U. lucida* grows in evergreen or deciduous, primary or secondary forest up to 1000 m altitude.

Selected sources 11, 27, 33, 42.

Urceola micrantha (Wall. ex G.Don) D.J.Middleton

APOCYNACEAE

Synonyms *Ecdysanthera micrantha* (Wall. ex G.Don) A.DC., *E. utilis* Hayata & Kawakami, *Parabarium spireanum* Pierre ex Spire.

Vernacular names Thailand: katang katiu (eastern), yaang yuet (northern).

Distribution From India, Nepal, Burma (Myanmar) and Thailand throughout Indo-China to Peninsular Malaysia, China, Taiwan and Japan.

Uses Before the arrival of the para rubber the latex was considered for commercial exploitation. In a sample originating from Burma (Myanmar) 11.5% resin had been found in the latex.

Observations Liana with finely puberulent branches which contain latex. Leaves opposite; petiole up to 2 cm long; blade elliptical to ovate, 3–18 cm × 1–6 cm, about 2–4 times as long as wide, base cuneate to rounded, apex acuminate. Inflorescence consisting of axillary and terminal cymes forming a panicle up to 18 cm long; flowers 5-merous, white to greenish-white; corolla campanulate, tube up to 1.5 mm long, lobes overlapping to the right in bud, about 1 mm long. Fruit a pair of divergent follicles, linear, up to 25 cm × 1 cm. Seed flattened ellipsoidal, up to 18 mm × 4 mm, coma up to 6 cm long. *U. micrantha* occurs in evergreen or secondary forest up to 1500 m altitude. It is very variable and widespread.

Selected sources 11, 27, 33, 42.

Urceola torulosa Hook.f.

APOCYNACEAE

Synonyms *Urceola malaccensis* Hook.f.

Vernacular names Malaysia: akar gerit-gerit, akar serapat (Peninsular).

Distribution Malaysia, Singapore, Indonesia (Sumatra, Kalimantan), Brunei.

Uses The latex produces a good quality rubber.

Observations Liana with puberulent branchlets. Leaves opposite; petiole up to 2.5 cm long; blade ovate to elliptical, up to 18 cm × 7 cm, 2–5 times as long as wide, base rounded to cuneate, apex acuminate. Inflorescence consisting of axillary and terminal congested cymes, 2–6 cm long; flowers 5-merous; corolla tubular, tube up to 2 mm long, lobes less than 1 mm long. Fruit a pair of torulose follicles, follicle 5–45 cm × 3–7 mm. Seed flattened ellipsoidal, up to 11 mm × 5 mm, coma up to 3 cm long. *U. torulosa* occurs in evergreen primary or secondary forest up to 500 m altitude. The torulose fruits are characteristic.

Selected sources 11, 27, 33, 42.

Willughbeia angustifolia (Miq.) Markgr.

APOCYNACEAE

Synonyms *Willughbeia apiculata* Miq., *W. elmeri* Merr., *W. rufescens* Dyer ex Hook.f.

Vernacular names Indonesia: jotan (Batak), jantahan, langgitan (West Kalimantan). Malaysia: gerit-gerit.

Distribution Thailand, Malaysia, Indonesia (Sumatra, Kalimantan, Buru), Brunei, Nicobar Islands.

Uses From the latex a sticky rubber of inferior quality is prepared which has been used to adulterate (up to half/half) better quality rubber-latex or, more often, gutta-percha. The stems are also used for binding. The latex is used medicinally to cure serious ulcers. The fruits are said to be edible.

Observations Woody climber, up to 60 m long, with glabrous branchlets, producing latex. Leaves opposite; petiole up to 2 cm long; blade elliptical, ovate or oblong, 3–14 cm × 1–4 cm, 2–4 times as long as wide, base rounded to cuneate, apex obtuse to acuminate. Inflorescence an axillary cyme (rarely a fascicle of 3), up to 2 cm long, with 5–19 flowers; flowers 5-merous, actinomorphic, bisexual, white to greenish; corolla tubular, tube inflated, up to 3 mm long, lobes up to 4.5 mm long. Fruit a fleshy, globose berry, 2–10 cm in diameter, pale green, yellow, orange or reddish, indehiscent. Seed compressed ovoid, about 2 cm × 1 cm, coma absent. *W. angustifolia* is rather variable in leaf shape, size and venation. Its small inflated corolla tube and short delicate inflorescence are rather distinctive.

Selected sources 20, 23, 27, 31, 34.

Willughbeia coriacea Wall.

APOCYNACEAE

Synonyms *Willughbeia firma* Blume, *W. minutiflora* (Pierre) K.Schum., *W. nodosa* (Pierre) K. Schum.

Vernacular names Borneo rubber (En). Indonesia: getah susu (south-western Sumatra), dango, tampirik (south-eastern Kalimantan). Malaysia: akar gegerit besi, akar garu. Thailand: khui, aa-kaa kue-loh (peninsular).

Distribution Thailand, Malaysia, Indonesia (Sumatra, Java, Kalimantan), Brunei.

Uses Until about 1900 expectations of *W. coriacea* were great and in many places plantations were started because the latex yielded a good quality rubber: the best of all the lianas. As soon as the para rubber tree appeared however, it overshadowed all other latex producers and commerial interest in other latex sources disappeared. Medicinally the latex and dried powdered fruits are used to cure ulcers. The bark is used to cure headache and to stop bleeding and a decoction of the root is applied against dysentery. Ripe fruits are edible.

Observations Woody, glabrous climber, stem up to 30 m long and 10 cm in diameter, containing latex. Leaves opposite; petiole up to 4 cm long; blade elliptical to obovate, 3–30 cm × 1–10 cm, base cuneate to rounded, apex acute to acuminate. Inflorescence an axillary cyme, up to 3 cm long, with 3–25 flowers; flowers 5-merous, bisexual, white or yellow, rarely tinged with red; corolla tubular, tube up to 8 mm long, lobes 4–10 mm long. Fruit a globose to ellipsoidal berry, up to 12 cm × 7 cm, green, yellow or orange. Seed compressed ovoid, about 1 cm long and wide; coma absent. *W. coriacea* occurs in primary and secondary forest, up to 1600 m altitude, in well drained soils not suffering from stagnant water. The plant grows slowly and yields little compared to the para rubber tree. A 6 -year-old liana yielded 0.1 kg rubber, a 14-year-old one 2 kg. The rubber is white and very elastic when pure and is difficult to mix with latex of other species; adulterations can easily be seen when the rubber is cut. The loss from latex to rubber is about 50% (a great portion is resin).

Selected sources 5, 11, 20, 23, 27, 31, 34, 42.

Willughbeia edulis Roxb.

APOCYNACEAE

Synonyms *Willughbeia cochinchinensis* (Pierre) K.Schum., *W. curtisiana* (Pierre) K.Schum., *W. dulcis* Ridl.

Vernacular names Malaysia: aguh, akar jitan, buah padang (Peninsular). Thailand: ka tang ka tiu (central), khui (peninsular), khui chaang (south-eastern). Vietnam: d[aa]y gu[oos]i ta.

Distribution Nicobar Islands, India, Bangladesh, Burma (Myanmar), Thailand, Vietnam, Cambodia, Laos, Malaysia (Peninsular).

Uses Before the coming of para rubber the latex of *W. edulis* was used to make rubber, although its latex is of inferior quality because it soon becomes resinous and hard. The edible fruit, although full of latex, is said to be soft and sweet. In Cambodia the stem is used in medicines against dysentery, liver complaints and yaws.

Observations Woody climber with glabrous branches containing latex. Leaves opposite; petiole up to 2 cm long; blade elliptical or oblong, 3–25 cm × 1–12 cm, 1–5 times as long as wide, base cuneate to rounded, apex acuminate. Inflorescence an axillary cyme, up to 3 cm long, sometimes 2 in a single leaf axis, with 3–12 flowers; flowers 5-merous; corolla tubular, tube up to 7 mm long, lobes 4–14 mm long. Fruit a globose to ovoid berry, up to 6 cm in diameter, yellow or orange. Seed compressed ovoid, up to about 1.5 cm long.

Selected sources 5, 11, 20, 27, 31, 34.

Willughbeia flavescens Dyer ex Hook.f.

APOCYNACEAE

Synonyms *Urnularia flavescens* (Hook.f.) Stapf, *Willughbeia beccarii* (Pierre) K.Schum., *W. stapfii* Merr.

Vernacular names Malaysia: getah gerip puteh, akar tengkang merah (Peninsular).

Distribution Malaysia, Indonesia (Sumatra, Kalimantan), Brunei.

Uses The latex turns into an inferior kind of rubber-like birdlime. Before the advent of para rubber it was of some commercial importance in Malaysia.

Observations Woody liana, up to 30 m long, usually glabrous, containing latex. Leaves opposite; petiole up to 2 cm long; blade elliptical to oblong, 4–16 cm × 2–6 cm, about 2–3 times as long as wide, base rounded to cuneate, apex acuminate to subcaudate. Inflorescence an axillary cyme, up to 5 cm long, with 11–17 flowers; flowers 5-merous, yellow or reddish-yellow; corolla tubular, tube inflated, up to 3.5 mm long, lobes elliptical, up to 3 mm long. Fruit a globose berry, up to 5 cm in diameter. Seed compressed ovoid, about 2 mm long.

Selected sources 11, 20, 27, 31.

Willughbeia grandiflora Dyer ex Hook.f.

APOCYNACEAE

Synonyms *Ancylocladus glaucinus* Pierre, *Willughbeia glaucina* (Pierre) K.Schum.

Vernacular names Malaysia: akar jitan (Peninsular).

Distribution Southern Thailand, Malaysia, Indonesia (Kalimantan), Brunei.

Uses The latex yields a kind of rubber. Because the liana is rather rare, its latex and rubber have never been exploited commercially.

Observations Large woody liana up to 40 m long with puberulent branchlets, containing latex.

Leaves opposite; petiole up to 3 cm long; blade elliptical to ovate, 4–16 cm × 2–9 cm, about 2 times as long as wide, base rounded to obtuse, apex rounded to short acuminate. Inflorescence an axillary cyme, up to 5 cm long with 8–20 flowers; flowers 5-merous, white, creamy or greenish; corolla tubular, tube up to 15 mm long, lobes oblong, up to 2.5 cm long. Fruit a globose berry, only immature ones are known. *W. grandiflora* only grows in peat swamp forest.

Selected sources 11, 20, 27, 31, 34.

Willughbeia oblonga Dyer ex Hook.f.

APOCYNACEAE

Synonyms *Ancylocladus oblongus* (Hook.f.) Kuntze.

Vernacular names Malaysia: akar kuop-kuop, akar semarang (Peninsular).

Distribution Malaysia (Peninsular).

Uses In Peninsular Malaysia, the Jakuns formerly used the latex to glue poison to their arrows.

Observations Woody climber with glabrous branches, containing latex. Leaves opposite; petiole up to 1 cm long; blade elliptical, 6–16 cm × 3–7 cm, about 2 times as long as wide, base acute to rounded, apex obtuse to blunt acuminate. Inflorescence an axillary cyme, up to 2 cm long, with 3–8 flowers; flowers 5-merous, bisexual; corolla tubular, tube up to 8 mm long, lobes ciliate. Fruit a cylindrical berry, about 5 cm × 1.5 cm. Seed flattened, rounded, about 1 mm long.

Selected sources 11, 20, 27, 31.

Willughbeia tenuiflora Dyer ex Hook.f.

APOCYNACEAE

Synonyms *Ancylocladus tenuiflorus* (Hook.f.) Kuntze.

Vernacular names Malaysia: akar getah gerip, akar jitan, akar segerang (Peninsular).

Distribution Malaysia (Peninsular), Singapore, Indonesia (Sumatra).

Uses The plant produces abundant yellowish latex which, however, gives an inferior rubber. It is hardly flexible but becomes so in hot water. Formerly this latex was mixed with latex of other species to produce a better quality rubber and to adulterate gutta-percha. The fruits are edible. The latex has been used to cure scabies and other skin diseases.

Observations Large woody liana with glabrous to pubescent branches, containing abundant latex. Leaves opposite; petiole up to 2 cm long; blade elliptical, oblong or obovate, 5–20 cm × 2–8 cm, about 2–3 times as long as wide, base cuneate, apex acuminate. Inflorescence an axillary cyme, up to 4 cm long with 8–18 flowers; flowers 5-merous, white, bisexual; corolla tubular, tube up to 15 mm long, lobes oblong and up to 2 cm long. Fruit a pear-shaped berry, 6–15 cm long, 5–12 cm wide. Seed compressed ovoid, about 2 cm long. *W. tenuiflora* grows in primary and secondary forest, up to 1500 m altitude, on well-drained soils.

Selected sources 11, 20, 23, 27, 31, 42.

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4 Plants producing exudates, but with other primary use

List of species in other commodity groups (parenthesis), which are also used as an exudate. Synonyms in the indented lines.

Acacia farnesiana (L.) Willd. (essential-oil plants)
    Acacia smallii Isely
    Mimosa farnesiana L.
    Vachellia farnesiana (L.) Wight & Arn.
Acacia nilotica (L.) Willd. ex Delile (dye and tannin-producing plants)
    Acacia arabica (Lam.) Willd.
Aganosma marginata (Roxb.) G.Don (medicinal and poisonous plants)
    Aganosma acuminata G.Don
Agathis robusta (Moore) Bailey (timber trees)
    Agathis palmerstonii (F.Muell.) Bailey
Agrostistachys borneensis Becc. (timber trees)
    Agrostistachys latifolia (Hook.f.) Pax & K.Hoffm.
    Agrostistachys leptostachya Pax & K.Hoffm.
    Agrostistachys longifolia (Wight) Trimen, non (Müll.Arg.) Kurz
Ailanthus altissima (Mill.) Swingle (medicinal and poisonous plants)
    Ailanthus glandulosa Desf.
    Ailanthus vilmoriniana Dode
Ailanthus triphysa (Dennst.) Alston (timber trees, medicinal and poisonous plants)
    Ailanthus imberbiflora F.Muell.
    Ailanthus malabarica DC.
    Ailanthus philippinensis Merr.
Albizia lebbeck (L.) Benth. (forages, timber trees)
    Acacia speciosa (Jacq.) Willd.
    Inga leucoxylon Hassk.
Albizia procera (Roxb.) Benth. (timber trees, auxiliary plants)
    Acacia procera (Roxb.) Willd.
    Mimosa elata Roxb.
    Mimosa procera Roxb.
Alstonia angustiloba Miq. (timber trees, medicinal and poisonous plants)
    Alstonia calophylla Miq.
    Paladelpha angustiloba (Miq.) Pichon
Alstonia iwahigensis Elmer (medicinal and poisonous plants)
Alstonia scholaris (L.) R.Br. (timber trees, medicinal and poisonous plants)
    Echites pala Ham.
    Echites scholaris L.
    Tabernaemontana alternifolia Burm.
Alstonia spatulata Blume (timber trees, medicinal and poisonous plants)
    Alstonia cuneata Wall. ex G.Don
Altingia excelsa Noronha (timber trees)

Anacardium occidentale L. (edible fruits and nuts)
Anodendron candolleanum Wight (fibre plants)
Anodendron paniculatum A.DC. (fibre plants)
  Anodendron manabriatum Merr.
  Anodendron moluccanum Miq.
  Anodendron tenuiflorum (Miq.) Miq.
Anisoptera thurifera (Blanco) Blume (timber trees)
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr. (timber trees)
  Conocarpus latifolia Roxb. ex DC.
Antiaris toxicaria Lesch. (timber trees, medicinal and poisonous plants)
  Antiaris africana Engl.
  Antiaris macrophylla R.Br.
  Antiaris welwitschii Engl.
Ardisia fuliginosa Blume (medicinal and poisonous plants)
Artocarpus altilis (Parkinson) Fosberg (edible fruits and nuts)
  Artocarpus camansi Blanco
  Artocarpus communis J.R.Forst. & G.Forst.
Artocarpus elasticus Reinw. ex Blume (timber trees, fibre plants)
  Artocarpus blumei Trécul
  Artocarpus kunstleri King
Artocarpus fretessii Teijsm. & Binnend. (timber trees)
  Artocarpus dasyphyllus Miq.
  Artocarpus leytensis Elmer
  Artocarpus paloensis Elmer
Artocarpus heterophyllus Lam. (edible fruits and nuts)
  Artocarpus brasiliensis Gomez
  Artocarpus maxima Blanco
  Artocarpus philippensis Lam.
Artocarpus horridus Jarrett (timber trees)
  Artocarpus communis J.R.Forst. & G.Forst. var. *pungens* J.J.Sm. ex K.Heyne
Artocarpus integer (Thunb.) Merr. (edible fruits and nuts)
  Artocarpus champeden (Lour.) Stokes
  Artocarpus integrifolia L.f.
  Artocarpus polyphema Pers.
Artocarpus kemando Miq. (timber trees)
  Artocarpus brunneifolius S.Moore
Artocarpus ovatus Blanco (timber trees)
  Artocarpus acuminatissimus Merr.
  Artocarpus cumingiana Trécul
Artocarpus rigidus Blume (edible fruits and nuts)
  Artocarpus asperula Gagnep.
  Artocarpus calophylla Kurz
  Artocarpus cuspidatus Griff.
  Artocarpus kertau Zoll. ex Miq.
  Artocarpus varians Miq.
Artocarpus scortechinii King (timber trees)
Artocarpus sericicarpus Jarrett (edible fruits and nuts, timber trees)
Artocarpus teysmannii Miq. (timber trees)

Artocarpus peduncularis Kurz
Artocarpus treculianus Elmer (timber trees)
Artocarpus nigrescens Elmer
Artocarpus ovatifolia Merr.
Artocarpus sorsogonensis Elmer ex Merr.
Asclepias curassavica L. (medicinal and poisonous plants)
Avicennia officinalis L. (timber trees)
Avicennia obovata Griff.
Avicennia oepata Ham.
Azadirachta indica A.Juss. (timber trees, auxiliary plants)
Antelaea azadirachta (L.) Adelb.
Melia azadirachta L.
Melia indica (A.Juss.) Brandis
Baeckea frutescens L. (medicinal and poisonous plants)
Bambusa bambos (L.) Voss (bamboos)
Arundo bambos L.
Bambusa arundinacea (Retz.) Willd.
Bambusa spinosa Roxb.
Bauhinia purpurea L. (ornamental plants)
Benincasa hispida (Thunb. ex Murray) Cogn. (vegetables)
Benincasa cerifera Savi
Cucurbita hispida Thunb. ex Murray
Buchanania latifolia Roxb. (edible fruits and nuts)
Buchanania lanzan Spreng.
Butea monosperma (Lam.) Taub. (dye and tannin-producing plants)
Butea frondosa Roxb. ex Willd.
Calamus paspalanthus Becc. (rattans)
Calotropis gigantea (L.) W.T.Aiton (medicinal and poisonous plants)
Asclepias gigantea L.
Calotropis procera (Aiton) W.T.Aiton (medicinal and poisonous plants)
Asclepias procera Aiton
Canarium acutifolium (A.DC.) Merr. (timber trees)
Canarium album (Lour.) Raeusch. (edible fruits and nuts)
Canarium australianum F.Muell. (timber trees)
Canarium balsamiferum Willd. (timber trees)
Canarium englerianum Hochr.
Canarium longissimum Hochr.
Canarium rooseboomii Hochr.
Canarium decumanum Gaertn. (timber trees)
Canarium littorale Blume (timber trees)
Canarium purpurascens Benn.
Canarium rufum Benn.
Canarium tomentosum Blume
Canarium megalanthum Merr. (timber trees)
Canarium oleosum (Lam.) Engl. (timber trees)
Canarium laxiflorum Decne.
Canarium microcarpum Willd.
Canarium pimela Leenh. (edible fruits and nuts)
Pimela nigra Lour.

Canarium pilosum Benn. (edible fruits and nuts, timber trees)
 Canarium grandiflorum Benn.
 Canarium hirtellum Benn.
 Canarium motleyanum Engl.
Canarium pseudodecumanum Hochr. (timber trees)
Canarium sumatranum Boerl. & Koord. (timber trees)
Canarium sylvestre Gaertn. (timber trees)
 Canarium appendiculatum Lauterb.
 Canarium branderhorstii Lauterb.
 Canarium simplicifolium Engl.
Canarium vrieseanum Engl. (edible fruits and nuts, timber trees)
 Canarium dolichophyllum Merr.
 Canarium tongcalingii Elmer
 Canarium williamsii C.B.Rob.
Carica papaya L. (edible fruit and nuts)
Ceiba pentandra (L.) Gaertn. (fibre plants)
Cerbera manghas L. (timber trees, medicinal and poisonous plants)
 Cerbera linnaei Montrouz.
 Cerbera odollam auct. non Gaertn.
Cerbera odollam Gaertn. (timber trees, medicinal and poisonous plants)
 Cerbera manghas auct. non L.
 Cerbera lactaria Buch.-Ham. ex Spreng.
Chonemorpha fragrans (Moon) Alston (fibre plants)
 Chonemorpha macrophylla G.Don
Chrysophyllum cainito L. (edible fruits and nuts)
Cinnamomum iners Reinw. ex Blume (timber trees)
 Cinnamomum eucalyptoides T.Nees
 Cinnamomum nitidum Blume
 Cinnamomum paraneuron Miq.
Combretum sundaicum Miq. (medicinal and poisonous plants)
Cryptostegia grandiflora R.Br. (fibre plants)
Dacryodes rostrata (Blume) H.J.Lam (edible fruits and nuts, timber trees)
 Canarium cuspidatum (Blume) Merr.
 Canarium kadondon Benn.
 Hemisantiria rostrata (Blume) H.J.Lam
 Santiria samarensis Merr.
Daemonorops didymophylla Becc. (rattans)
Daemonorops draco (Willd.) Blume (rattans)
Daemonorops micracantha (Griff.) Becc. (rattans)
 Daemonorops draconcella Becc.
Daemonorops propinqua Becc. (rattans)
Daemonorops rubra (Reinw. ex Blume) Blume (rattans)
Delonix regia (Bojer ex Hook.) Raf. (ornamental plants)
Dictyosperma album (Bory) H.Wendl. & Drude ex Scheff. (ornamental plants)
Diospyros hasseltii Zoll. (edible fruits and nuts, timber trees)
 Diospyros brachiata King & Gamble
 Diospyros horsfieldii Hiern
Diospyros malabarica (Desr.) Kostel. (dye and tannin-producing plants, timber trees)

Diospyros embryopteris Pers.
Diospyros globularia (Miq.) Koord. & Valeton
Diospyros glutinifera Roxb.
Diospyros toposia Buch.-Ham. (timber trees)
Diospyros collinsae Craib
Diospyros foveo-reticulata Merr.
Diospyros incisa Buch.-Ham. ex Wall.
Dipterocarpus baudii Korth. (timber trees)
Dipterocarpus duperreana Pierre
Dipterocarpus pilosus auct. non Roxb. p.p.
Dipterocarpus scortechinii King
Dipterocarpus caudatus Foxw. (timber trees)
Dipterocarpus chartaceus Symington (timber trees)
Dipterocarpus skinneri auct. non King
Dipterocarpus confertus Slooten (timber trees)
Dipterocarpus cornutus Dyer (timber trees)
Dipterocarpus costatus Gaertn.f. (timber trees)
Dipterocarpus artocarpifolius Pierre ex Laness.
Dipterocarpus insularis Hance
Dipterocarpus parvifolius Heim
Dipterocarpus crinitus Dyer (timber trees)
Dipterocarpus hirtus Vesque
Dipterocarpus tampurau auct. non Korth.
Dipterocarpus dyeri Pierre (timber trees)
Dipterocarpus hasseltii Blume (timber trees)
Dipterocarpus balsamiferus Blume
Dipterocarpus subalpinus Foxw.
Dipterocarpus tampurau Korth.
Dipterocarpus kunstleri King (timber trees)
Dipterocarpus exalatus Slooten ex Wood
Dipterocarpus speciosus Brandis
Dipterocarpus lowii Hook.f. (timber trees)
Dipterocarpus undulatus Vesque
Dipterocarpus palembanicus Slooten (timber trees)
Dipterocarpus sublamellatus Foxw. (timber trees)
Dipterocarpus validus Blume (timber trees)
Dipterocarpus affinis Brandis
Dipterocarpus lasiopodus Perkins
Dipterocarpus warburgii Brandis
Dipterocarpus verrucosus Foxw. ex Slooten (timber trees)
Dipteryx odorata (Aubl.) Willd. (spices)
Baryosma tonga Gaertn.
Coumarouna odorata Aubl.
Dipteryx tetraphylla Spruce ex Benth.
Dischidia imbricata (Blume) Steudn. (medicinal and poisonous plants)
Dischidia nummularia R.Br. (medicinal and poisonous plants)
Dischidia gaudichaudii Decne.
Dryobalanops beccarii Dyer (timber trees)
Dryobalanops oocarpa Slooten

Dryobalanops lanceolata Burck (timber trees)
  Dryobalanops kayanensis Becc.
Dryobalanops sumatrensis (J.F.Gmel.) Kosterm. (timber trees)
  Dryobalanops aromatica Gaertn.f.
  Dryobalanops camphora Colebr.
Eucommia ulmoides Oliv. (medicinal and poisonous plants)
Euphorbia antiquorum L. (medicinal and poisonous plants)
Euphorbia atoto G.Forst. (medicinal and poisonous plants)
  Chamaesyce atoto (G.Forst.) Croizat
  Euphorbia halophila Miq.
  Euphorbia laevis Poir.
Euphorbia barnhartii Croizat (medicinal and poisonous plants)
  Euphorbia trigona Roxb. non Mill.
Euphorbia cyathophora Murray (medicinal and poisonous plants)
  Euphorbia heterophylla L. var. *cyathophora* (Murray) Griseb.
  Poinsettia cyathophora (Murray) Klotzsch & Garcke
  Poinsettia graminifolia (Michx.) Millsp.
Euphorbia hirta L. (medicinal and poisonous plants)
  Chamaesyce hirta (L.) Millsp.
  Chamaesyce pilulifera (L.) Small
  Euphorbia pilulifera L.
Euphorbia neriifolia L. (medicinal and poisonous plants)
  Euphorbia ligularia Roxb.
Euphorbia plumerioides Teijsm. ex Hassk. (medicinal and poisonous plants)
Euphorbia prostrata Aiton (medicinal and poisonous plants)
  Chamaesyce prostrata (Aiton) Small
Euphorbia thymifolia L. (medicinal and poisonous plants)
  Chamaesyce thymifolia (L.) Millsp.
Euphorbia tirucalli L. (medicinal and poisonous plants)
  Euphorbia media N.E.Br.
  Euphorbia rhipsaloides Lem.
  Euphorbia scoparia N.E.Br.
Fagraea berteriana A.Gray ex Benth. (timber trees)
  Fagraea affinis S.Moore
  Fagraea novae-guineae Cammerl.
  Fagraea sair Gilg & Gilg-Ben.
Ficus adenosperma Miq. (timber trees, medicinal and poisonous plants)
  Ficus chaetophora Warb.
  Ficus pauper King
  Ficus turbinata Ridl.
Ficus altissima Blume (fibre plants)
Ficus ampelas Burm.f. (medicinal and poisonous plants)
  Ficus blepharosepala Warb.
  Ficus kingiana Hemsl.
  Ficus soronensis King
Ficus bauerleni King (medicinal and poisonous plants)
  Ficus hollrungii Lauterb. & K.Schum.
  Ficus laurentina Diels
  Ficus mespiloides King

Ficus benghalensis L. (timber trees, medicinal and poisonous plants)
    Ficus banyana Oken
    Ficus indica L.
    Ficus lasiophylla Link
Ficus botryocarpa Miq. (vegetables, medicinal and poisonous plants)
    Ficus barnesii Merr.
    Ficus linearifolia Elmer
    Ficus mindorensis Merr.
Ficus calopilina Diels (medicinal and poisonous plants)
    Ficus setistyla Warb.
Ficus dammaropsis Diels (vegetables, medicinal and poisonous plants)
    Dammaropsis kingiana Warb.
Ficus edelfeltii King (fibre plants)
Ficus fulva Reinw. ex Blume (fibre plants)
Ficus hispida L.f. (medicinal and poisonous plants)
    Ficus letaqui Lév. & Vaniot
    Ficus poilanei Gagnep.
Ficus microcarpa L.f. (timber trees, medicinal and poisonous plants)
    Ficus cairnsii Warb.
    Ficus prolixa Vieill. & Depl.
    Ficus retusa auct. non L.
    Ficus retusiformis Lév. & Vaniot
Ficus nasuta Summerh. (medicinal and poisonous plants)
Ficus pachyrrachis Lauterb. & K.Schum. (medicinal and poisonous plants)
    Ficus grandis King non Miq.
    Ficus hypoglauca Lauterb. & K.Schum.
    Ficus pachythyrsa Diels
Ficus pumila L. (medicinal and poisonous plants)
    Ficus repens Hort. var. *lutchuensis* Koidz.
    Ficus scandens Lam.
    Ficus stipulata Thunb.
Ficus pungens Reinw. ex Blume (vegetables, medicinal and poisonous plants)
    Ficus kalingaensis Merr.
    Ficus myriocarpa Miq.
    Ficus ovalifolia Ridl.
Ficus racemosa L. (edible fruits and nuts, timber trees)
    Ficus glomerata Roxb.
    Ficus semicostata F.M.Bailey
    Ficus vesca F.Muell. ex Miq.
Ficus religiosa L. (medicinal and poisonous plants)
    Ficus caudata Stokes
    Ficus peepul Griff.
    Ficus superstitiosa Link
Ficus rumphii Blume (medicinal and poisonous plants)
    Ficus conciliorum Oken
    Ficus cordifolia Roxb.
    Ficus damit Gagnep.
Ficus septica Burm.f. (medicinal and poisonous plants)
    Ficus casearia F.Muell. ex Benth.

Ficus hauili Blanco
Ficus kaukauensis Hayata
Ficus subcuneata Miq. (timber trees, medicinal and poisonous plants)
Ficus formosa Summerh.
Ficus stoechotricha Diels
Ficus trichoneura Diels non Summerh.
Ficus sublimbata Corner (medicinal and poisonous plants)
Ficus variegata Blume (timber trees)
Ficus cordifolia Blume
Ficus laevigata Blanco
Ficus sum Gagnep.
Ficus virens Aiton (timber trees)
Ficus carolinensis Warb.
Ficus glabella Blume
Ficus infectoria Roxb.
Hoya alba Kostel. (medicinal and poisonous plants)
Hoya coronaria Blume (medicinal and poisonous plants)
Hoya elegans Kostel. (medicinal and poisonous plants)
Hoya latifolia G.Don (medicinal and poisonous plants)
Hoya rumphii Blume (medicinal and poisonous plants)
Hoya sussuela Merr. (medicinal and poisonous plants)
Hunteria zeylanica (Retz.) Gardner ex Thwaites (medicinal and poisonous plants)
Hunteria corymbosa Roxb.
Garcinia cowa Roxb. (timber trees, vegetables)
Garcinia lobulosa Wall. ex T.Anderson
Garcinia roxburghii Wight
Garcinia umbellifera Roxb.
Garcinia hanburyi Hook.f. (dye and tannin-producing plants)
Garcinia morella (Gaertn.) Desr. var. *pedicellata* Hanbury
Gluta renghas L. (timber trees)
Gluta velutina Blume (timber trees)
Gluta coarctata (Griff.) Hook.f.
Hopea beccariana Burck (timber trees)
Balanocarpus ovalifolius Ridl.
Hopea intermedia King
Hopea bracteata Burck (timber trees)
Balanocarpus bracteatus (Burck) Merr.
Balanocarpus curtisii King
Hopea minima Symington
Hopea dasyrrhachis Slooten (timber trees)
Hopea dryobalanoides Miq. (timber trees)
Hopea borneensis Heim
Hopea micrantha King non Hook.f.
Hopea sarawakensis Heim
Hopea dyeri Heim (timber trees)
Hopea intermedia King p.p.
Hopea micrantha Burck non Hook.f. p.p.
Hopea pierrei Brandis non Hance

Hopea ferrea Laness. (timber trees)
  Balanocarpus anomalus King
  Hopea anomala (King) Foxw.
Hopea ferruginea Parijs (timber trees)
  Hopea micrantha Dyer non Hook.f. p.p.
Hopea gregaria Slooten (timber trees)
Hopea helferi (Dyer) Brandis (timber trees)
  Hopea dealbata Hance
Hopea johorensis Symington (timber trees)
Hopea mengarawan Miq. (timber trees)
Hopea myrtifolia Miq. (timber trees)
Hopea nutans Ridl. (timber trees)
Hopea odorata Roxb. (timber trees)
Hopea pedicellata (Brandis) Symington (timber trees)
  Hopea pierrei Ridl. non Hance p.p.
  Hopea siamensis Heim
Hopea pierrei Hance (timber trees)
Hopea sangal Korth. (timber trees)
  Hopea curtisii King
  Hopea globosa Brandis
  Hopea lowii Dyer ex Brandis
  Hopea sericea (Korth.) Blume
Jatropha curcas L. (medicinal and poisonous plants)
  Curcas indica A.Rich.
  Curcas purgans Medik.
  Jatropha afrocurcas Pax
Jatropha gossypiifolia L. (medicinal and poisonous plants)
  Jatropha elegans (Pohl) Klotzsch
Jatropha multifida L. (medicinal and poisonous plants)
  Adenoropium multifidum (L.) Pohl
  Jatropha janipha Blanco
Kibatalia arborea (Blume) G. Don (timber trees, medicinal and poisonous plants)
  Hasseltia arborea Blume
  Kickxia arborea (Blume) Blume
  Tabernaemontana ovalis Miq.
Lactarius spp. (cryptogams)
Lannea coromandelica (Houtt.) Merr. (ornamental plants)
  Lannea grandis (Dennst.) Engl.
Laurentia longiflora (L.) Peterm. (ornamental plants)
Lepidozamia hopei Regel (ornamental plants)
Lepidozamia peroffskyana Regel (ornamental plants)
Limonia acidissima L. (edible fruits and nuts)
  Feronia elephantum Correa
  Feronia limonia (L.) Swingle
Litsea glutinosa (Lour.) C.B.Rob. (timber trees)
  Litsea chinensis Lam.
  Litsea geminata Blume
  Litsea glabraria A.Juss.

Leucaena leucocephala (Lam.) de Wit (forages, auxiliary plants)
Leucaena glauca (Willd.) Benth.
Leucaena latisiliqua (L.) Gillis
Macaranga diepenhorstii (Miq.) Müll.Arg. (timber trees)
Macaranga grandifolia (Blanco) Merr. (medicinal and poisonous plants)
Macaranga indica Wight (timber trees)
Macaranga tanarius (L.) Müll.Arg (dye and tannin-producing plants, timber trees)
Madhuca korthalsii (Pierre ex Burck) H.J.Lam (timber trees)
Bassia braceana King & Gamble
Madhuca malaccensis (C.B.Clarke) H.J.Lam (timber trees)
Bassia malaccensis (C.B.Clarke) H.J.Lam
Madhuca penangiana (King & Gamble) H.J.Lam (timber trees)
Bassia penangiana King & Gamble
Mammea americana L. (edible fruits and nuts)
Manilkara zapota (L.) P.Royen (edible fruits and nuts)
Achras zapota L. p.p.
Nispero achras (Mill.) Aubrév.
Melicope latifolia (DC.) T.G.Hartley (timber trees)
Euodia latifolia DC.
Moringa oleifera Lam. (vegetables)
Guilandina moringa L.
Moringa polygona DC.
Moringa pterygosperma Gaertn.
Neobalanocarpus heimii (King) P.Ashton (timber trees)
Balanocarpus heimii King
Neolitsea vidalii Merr. (timber trees)
Odontadenia macrantha (Roem. & Schult.) Markgr. (ornamental plants)
Odontadenia speciosa Benth.
Osmoxylon umbelliferum (Lam.) Merr. (essential-oil plants)
Aralia umbellifera Lam.
Palaquium barnesii Merr. (timber trees)
Madhuca barnesii (Merr.) Baehni
Palaquium hexandrum (Griff.) Baill. (timber trees)
Croixia hexandra (Griff.) Baehni
Palaquium hispidum H.J.Lam (timber trees)
Croixia hispida (H.J.Lam) Baehni
Palaquium maingayi (C.B.Clarke) King & Gamble (timber trees)
Croixia maingayi (C.B.Clarke) Baehni
Palaquium philippense (Perr.) C.B.Rob. (timber trees)
Madhuca philippensis (Perr.) Baehni
Palaquium quercifolium (de Vriese) Burck (timber trees)
Croixia quercifolia (de Vriese) Baehni
Palaquium macrophyllum (de Vriese) Pierre ex Dubard
Palaquium stellatum King & Gamble (timber trees)
Bassia watsoni Ridl.
Madhuca watsoni (Ridl.) H.J.Lam
Palaquium walsurifolium Pierre ex Dubard (timber trees)
Papaver somniferum L. (medicinal and poisonous plants)

Papaver hortense Hussenot
Papaver officinale C.C.Gmel.
Papaver setigerum DC.
Parameria laevigata (Juss.) Moldenke (medicinal and poisonous plants)
Parameria barbata (Blume) K.Schum.
Parameria glandulifera (Wall. ex G.Don) Benth. ex Kurz
Parartocarpus venenosus (Zoll. & Moritzi) Becc. (edible fruits and nuts, timber trees)
Parartocarpus triandra (J.J.Sm.) J.J.Sm.
Parartocarpus woodii (Merr.) Merr.
Parashorea lucida (Miq.) Kurz (timber trees)
Shorea lucida Miq.
Shorea subpeltata Miq.
Payena acuminata (Blume) Pierre (timber trees)
Madhuca acuminata (Blume) Baehni
Payena sericea (Blume) H.J.Lam non Miq.
Payena dasyphylla (Miq.) Pierre (timber trees)
Bassia caudata Ridl.
Madhuca caudata (Ridl.) H.J.Lam
Payena lucida (Wall. ex G.Don) A.DC. (timber trees)
Madhuca lucida (Wall. ex G.Don) Baehni
Payena dasyphylla (Miq.) Pierre var. glabrata King & Gamble
Payena glutinosa Pierre
Payena obscura Burck (timber trees)
Payena havilandii King & Gamble
Pedilanthus tithymaloides (L.) Poit. (ornamental plants)
Pentaspadon motleyi Hook.f. (timber trees)
Pentaspadon minutiflora B.L.Burtt
Pentaspadon moszkowskii Lauterb.
Pentaspadon officinalis Holmes ex King
Phyllanthus acidus (L.) Skeels (medicinal and poisonous plants)
Cicca acida (L.) Merr.
Phyllanthus acidissimus (Blanco) Müll.Arg.
Phyllanthus distichus (L.) Müll.Arg.
Phyllocladus hypophyllus Hook.f. (timber trees)
Phyllocladus major Pilger
Phyllocladus protractus (Warb.) Pilger
Pimelodendron amboinicum Hassk. (timber trees)
Daphniphyllum conglutinosum Hemsl.
Pimelodendron papuanum Warb.
Pinus caribaea Morelet (timber trees)
Plumeria rubra L. (ornamental plants)
Plumeria acuminata Aiton
Plumeria acutifolia Poir.
Pottsia laxiflora (Blume) Kuntze (fibre plants)
Pouteria kaernbachiana (Engl.) Baehni (timber trees)
Planchonella kaernbachiana (Engl.) H.J.Lam
Pouteria malaccensis (C.B.Clarke) Baehni (timber trees)
Lucuma malaccensis (C.B.Clarke) Dubard

Sideroxylon malaccense C.B.Clarke
Xantolis malaccensis (C.B.Clarke) Baehni
Prosopis juliflora (Swartz) DC. (auxiliary plants)
Mimosa juliflora Swartz
Prosopis vidaliana Naves
Raphia farinifera (Gaertn.) Hyl. (fibre plants)
Raphia pedunculata P.Beauv. (fibre plants)
Saccharum officinarum L. (plants yielding non-seed carbohydrates)
Semecarpus cassuvium Roxb. (edible fruits and nuts, timber trees)
Sesbania grandiflora (L.) Poir. (forages)
Agati grandiflora (L.) Desv.
Aeschynomene grandiflora (L.) L.
Robinia grandiflora L.
Shorea acuminata Dyer (timber trees)
Shorea assamica Dyer (timber trees)
Shorea globifera Ridl.
Shorea koordersii Brandis ex Koord.
Shorea philippinensis Brandis
Shorea balangeran (Korth.) Burck (timber trees)
Hopea balangeran Korth.
Parashorea balangeran (Korth.) Merr.
Shorea bracteolata Dyer (timber trees)
Shorea curtisii Dyer ex King (timber trees)
Shorea faguetiana Heim (timber trees)
Shorea ridleyana King p.p.
Shorea glauca King (timber trees)
Shorea henryana Pierre (timber trees)
Shorea sericeiflora Fischer & Hutch.
Shorea hypochra Hance (timber trees)
Shorea crassifolia Ridl.
Shorea maritima Pierre
Shorea laevis Ridl. (timber trees)
Shorea ciliata Ridl. non King
Shorea laevifolia (Parijs) Endert
Shorea rogersiana Raizada & Smitinand
Shorea lamellata Foxw. (timber trees)
Shorea leprosula Miq. (timber trees)
Hopea maranti Miq.
Shorea maranti (Miq.) Burck
Shorea longisperma Roxb. (timber trees)
Parashorea longisperma (Roxb.) Kurz
Shorea resina-nigra Foxw.
Shorea macroptera Dyer (timber trees)
Shorea bailloni Heim
Shorea sandakanensis Symington
Shorea materialis Ridl. (timber trees)
Shorea mecistopteryx Ridl. (timber trees)
Shorea chrysophylla Ridl.
Shorea quadrinervis Slooten (timber trees)

Shorea retinodes Slooten (timber trees)
Shorea roxburghii G.Don (timber trees)
  Shorea cochinchinensis Pierre
  Shorea floribunda (Wall.) Kurz
  Shorea talura Roxb.
Shorea selanica (DC.) Blume (timber trees)
  Engelhardtia selanica (DC.) Blume
  Hopea selanica (DC.) Wight & Arn.
Shorea smithiana Symington (timber trees)
Shorea virescens Parijs (timber trees)
Sindora beccariana Backer ex de Wit (timber trees)
Sindora coriacea Maingay ex Prain (timber trees)
Sindora javanica (Koord. & Valeton) Backer ex K.Heyne (timber trees)
Sindora leiocarpa Backer ex K.Heyne (timber trees)
Sindora siamensis Teijsm. ex Miq. (timber trees)
  Sindora cochinchinensis Baill.
Sindora wallichii Graham ex Benth. (timber trees)
Stemmadenia donnell-smithii (Rose) Woodson (ornamental plants)
Streblus asper Lour. (timber trees, medicinal and poisonous plants)
  Diplothorax tonkinensis Gagnep.
  Streblus monoicus Gagnep.
Streptocaulon baumii Decne. (medicinal and poisonous plants)
Tabernaemontana aurantiaca Gaud. (medicinal and poisonous plants)
  Tabernaemontana novoguineesis Scheff.
Tabernaemontana corymbosa Roxb. ex Wall. (medicinal and poisonous plants)
  Ervatamia hirta (Hook.f.) King & Gamble
  Pagiantha peninsularis Kerr
  Tabernaemontana hirta Hook.f.
Tabernaemontana dichotoma Roxb. ex Wall. (medicinal and poisonous plants)
  Ervatamia dichotoma (Roxb.) Burkill
  Ervatamia polyneura King & Gamble
Tabernaemontana macrocarpa Jack (medicinal and poisonous plants)
  Tabernaemontana megacarpa Merr.
  Tabernaemontana plumeriaefolia (Elmer) Merr.
Tabernaemontana pandacaqui Poir. (medicinal and poisonous plants)
  Ervatamia pandacaqui (Poir.) Pichon
  Tabernaemontana orientalis R.Br.
  Tabernaemontana cumingiana A.DC.
Tabernaemontana pauciflora Blume (medicinal and poisonous plants)
  Tabernaemontana dinhensis Pit.
  Tabernaemontana harmandiana Pierre ex Pit.
  Tabernaemontana malaccensis Hook.f.
  Tabernaemontana polysperma Merr.
  Tabernaemontana sralensis Pierre ex Pit.
Tabernaemontana rostrata Roxb. ex Wall. (medicinal and poisonous plants)
  Ervatamia cylindrocarpa King & Gamble
  Ervatamia rostrata (Roxb. ex Wall.) Markgr.
  Tabernaemontana crispa auct. non Roxb.

Tabernaemontana sphaerocarpa Blume (medicinal and poisonous plants)
 Ervatamia sphaerocarpa (Blume) Burkill
 Tabernaemontana fagraeoides Miq.
 Tabernaemontana javanica Miq.
Taraxacum officinale Weber ex F.H.Wigg. (medicinal and poisonous plants)
Thevetia peruviana (Pers.) K.Schum. (medicinal and poisonous plants, ornamental plants)
 Cascabela thevetia (L.) Lippold
 Cerbera peruviana Pers.
 Thevetia nereifolia Juss. ex Steud.
Tinomiscium petiolare Hook.f. & Thomson (medicinal and poisonous plants)
 Tinomiscium philippinense Diels
 Tinomiscium phytocrenoides Kurz ex Teijsm. & Binnend.
 Tinomiscium tonkinense Gagnep.
Triomma malaccensis Hook.f. (timber trees)
 Canarium mahassan Miq.
 Triomma macrocarpa Backer ex Thorenaar
Uncaria homomalla Miq. (spices)
 Uncaria parviflora (Ridl.) Ridl.
 Uncaria quadrangularis Geddes
 Uncaria tonkinensis Havil.
Vallaris solanacea (Roth) Kuntze (vegetables)
 Vallaris heynei Spreng.
Vanilla griffithii Rchb.f. (edible fruits and nuts)
Vatica dulitensis Symington (timber trees)
Vatica odorata (Griff.) Symington (timber trees)
Vatica rassak (Korth.) Blume (timber trees)
 Vatica celebensis Brandis
 Vatica moluccana Burck
 Vatica papuana Dyer
Voacanga foetida (Blume) Rolfe (medicinal and poisonous plants)
 Orchipeda foetida Blume

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Acronyms of organizations

- CIFOR: Center for International Forestry Research (Bogor, Indonesia).
- DGIS: Directorate-General for International Cooperation of the Netherlands Ministry of Foreign Affairs (Den Haag, the Netherlands).
- EU: European Union (Brussels, Belgium).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- FPRDI: Forest Products Research and Development Institute (College, Laguna, the Philippines).
- FRIM: Forest Research Institute Malaysia (Kepong, Malaysia).
- ICRAF: International Centre for Research in Agroforestry (Nairobi, Kenya).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- IPGRI: International Plant Genetic Resources Institute (Rome, Italy).
- IRD (formerly ORSTOM): Institut de Recherche pour le Développement (Montpellier, France).
- LIPI: Indonesian Institute of Sciences (Jakarta, Indonesia).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- RRIM: Rubber Research Institute of Malaysia (Kuala Lumpur, Malaysia), presently: Malaysian Rubber Board.
- TISTR: Thailand Institute of Scientific and Technological Research (Bangkok, Thailand).
- UNITECH: Papua New Guinea University of Technology (Lae, Papua New Guinea).
- WU (formerly WAU): Wageningen University (Wageningen, the Netherlands).

Glossary

accrescent: increasing in size with age

acid number: a measure of the acidity, expressed as the amount (in mg) of KOH required to neutralize one gram of material

actinomorphic: radially symmetrical; applied to flowers which can be bisected in more than one vertical plane

acumen: the point of an acuminate leaf; the drip-tip

acuminate: ending in a narrowed, tapering point with concave sides

acute: sharp; ending in a point with straight or slightly convex sides

aerial root: any root that grows above the ground

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)

alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled

ambrosia beetle: a general name for beetles of the families *Platypodidae* and *Scolytidae* that tunnel in wood but feed principally on fungi that develop in their tunnels

amplexicaul: stem-clasping, when the base of a sessile leaf or a stipule is dilated at the base, and embraces the stem

analgesic: relieving pain; not sensitive to pain; an agent alleviating pain without causing loss of consciousness

anaphylaxis: a general term, originally applied to the situation in which exposure to a toxin resulted not in immunity (prophylaxis), but in hypersensitivity; extended to include all cases of systemic anaphylaxis in response to foreign antigens and to include a range of experimental models

anastomosis: cross connection of branches or roots; union of one vein or parenchyma band with another, the connection forming a reticulation

annular: used of any organs disposed in a circle

anther: the part of the stamen containing the pollen

anthesis: the time the flower is expanded, or, more strictly, the time when pollination may take place

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*

apex (plural apices): the tip or summit of an organ

apical: at the apex of any structure

apiculate: ending abruptly in a short point

apophysis: in conifers, the swollen top of the scales of a female cone

appressed: lying flat for the whole length of the organ

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)

arillate: possessing an aril

armed: bearing some form of spines

ascending: curving or sloping upwards

auct.: auctorum (Latin); of authors

auct., non: auctorum, non (Latin); of authors, not ... (author name); used after a scientific name when this name is erroneously applied by several authors to material actually belonging to a different species than the species described by the mentioned author

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

bark: the tissue external to the vascular cambium collectively, being the secondary phloem, cortex and periderm

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

berry: a juicy indehiscent fruit with the seeds immersed in pulp, usually several-seeded without a stony layer surrounding the seeds

bisexual: having both sexes present and functional in the same flower

blade: the expanded part, e.g. of a leaf or petal

bole: the main trunk of a tree, generally from the base up to the first main branch

boxing: a tapping technique in which a hole ('box') is cut into the wood of a standing tree

bract: a reduced leaf subtending a flower, flower stalk or the whole or part of an inflorescence

breeding: the propagation of plants or animals to improve certain characteristics

broadcast: to sow seed scattered, not in lines or pockets

bronchitis: inflammation of the bronchial tubes

bud: the nascent state of a flower or branch, often applied to those primordial vegetative or reproductive branches that are enclosed in a prophyll 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

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

caducous: falling off

callus: small hard outgrowth at the base of spikelets in some grasses; tissue that forms over cut or damaged plant surface

calyx: the outer envelope of the flower, consisting of sepals, free or united

cambium (plural cambia): a layer of nascent tissue between the sapwood and bark, adding elements to both

campanulate: bell-shaped

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 headlike clusters as in some inflorescences

capsule: a dry dehiscent fruit composed of two or more carpels and either splitting when ripe into valves, or opening by slits or pores

carminative: expelling gas from the stomach and intestines

carpel: one of the foliar units of a compound pistil or ovary; a simple pistil has only one carpel

caruncle: an outgrowth of a seed near the hilum

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

chlorophyll: green pigment in plants which absorbs light for photosynthesis

ciliate: with a fringe of hairs along the edge

claw: the basal, narrow part of a petal or sepal

cleft: cut halfway down

clone: a group of plants originating by vegetative propagation from a single plant and therefore of the same genotype

colic: a paroxysm of acute abdominal pain localized in a hollow organ or tube and caused by spasm, obstruction, or twisting

collar: the boundary between the above- and underground portions of the axis of a plant

column (botany): a cylindrical body, e.g. a tube of connate stamen filaments or the central axis of a fruit

coma: the hairs at the end of some seeds; a tuft of leafy bracts or leaves at the top of an inflorescence (e.g. pineapple, *Curcuma* inflorescence)

comose: tufted

concave: hollow

cone: the fruit of a pine or fir tree (gymnosperms), largely made up of imbricated scales

conical: having the shape of a cone (cone-shaped)

connate: united or joined

connective (botany): tissue between the pollen sacs of an anther

conspecific: belonging to the same species

contiguous: touching but not united, directly bordering
contorted: twisted or bent
copal: a recent or fossil resin from various trees
coppice: a small wood which is regularly cut at stated intervals, the new growth arising from the stools
cordate: heart-shaped, as seen at the base of a leaf, etc., which is deeply notched
coriaceous: of leathery texture
corolla: the inner envelope of the flower consisting of free or united petals
corona: any appendage or extrusion between the corolla and stamens
corrugate, corrugated: wrinkled
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: with flowers arranged in a corymb
cotyledon: seed-leaf, the primary leaf; dicotylous embryos have two cotyledons and monocotylous embryos have one
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
cross-pollination: the transfer of pollen from one flower to the stigma of a flower of another plant which is not of the same clone
crown: the aerial expanse of a tree, not including the trunk
crustaceous: of hard but brittle texture
cryptocotylar: of germination, condition in which the cotyledons remain enveloped in the persistent fruit wall and/or testa
cultivar: an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety
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
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: with flowers arranged in a cyme
damar: a soft, clear to yellow resin used largely in varnishes and printing inks
damping-off: a disease of seeds or seedlings caused by fungi which cause various effects, from failure to germinate to the dying off of the seedling
deciduous: shedding, applied to leaves, petals, etc.
decoction: a medicinal preparation made by boiling parts of a plant in water
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
dehiscent: opening spontaneously when ripe, e.g. of capsules, anthers
deltoid: shaped like an equal-sided triangle
density: weight (kg) per volume (m^3) at a certain moisture content
dentate: margin prominently toothed with the pointed teeth directed outwards
diarrhoea: a profuse, frequent, and loose discharge from the bowels
dieback: the dying off of parts of the above-ground structure of the plant, generally from the top downward
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)
dippled: of the bark surface, with depressions or indentations
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
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
distal: situated farthest from the place of attachment
distichous: regularly arranged in two opposite rows on either side of an axis
diuretic, diureticum: an agent increasing the urinary discharge
domatium (plural domatia): a modified projection that provides shelter for other organisms
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
drupe: a fleshy one-seeded indehiscent fruit with the seed enclosed in a strong endocarp
drupelet: a small drupe
dysentery: any of various intestinal diseases characterized by inflammation, abdominal pain, toxaemia, and diarrhoea with bloody, mucous faeces
ectomycorrhiza: see mycorrhiza
ellipsoid: a solid which is elliptic in outline
elliptical: oval in outline but widest about the middle
emarginate: notched at the extremity
embryo: 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)
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
emetic: an agent that induces vomiting
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
enrichment planting: a term embracing various measures for improving the percentage of desirable species in a natural forest
entire (botany): with an even margin without teeth, lobes, etc.
epiderm, epidermis: the true cellular skin or covering of a plant below the cuticle
epigeal: above the ground; in epigeal germination the cotyledons are raised above the ground
epithelial cell: cell in the layer of secretory parenchymatous cells that surround an intercellular canal or cavity
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
ester number: a measure of the neutral components of a material, calculated by taking the difference between the saponification number and the acid number
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
exudate: the secreted substance
exudation: the discharging of a substance
falcate: sickle-shaped
fascicle: a cluster of flowers, leaves, etc., arising from the same point
ferruginous: rust-coloured
fertile (botany): capable of completing fertilization and producing seed; producing seed capable of germination; having functional sexual organs
fertilization (biology): union of the gametes (egg and sperm) to form a zygote
fibrous: composed of or including 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
flaccid: withered and limp
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: dry nourishment for domesticated animals, especially coarse, dried plants (hay, straw, leaves)
foliolate: 2-, 3-, 4- etc., with 2-, 3-, 4- leaflets
follicle: a dry, unicarpellate fruit, dehiscing by the ventral suture to which the seeds are attached
fossil resin: resin dug from the ground near a resin-producing tree (see also recent resin)
free: neither adhering nor united
fungicide: an agent that destroys fungi or inhibits their growth
fusiform: spindle-shaped; tapering towards each end from a swollen centre
genetic erosion: the decline or loss of genetic variability
geniculate: abruptly bent so as to resemble the knee-joint
genus (plural genera): a natural group containing one or more distinct species
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
glandular: having or bearing secreting organs or glands
glaucous: pale bluish-green, or with a whitish bloom which rubs off
globose: spherical or nearly so
graft: a union of different individuals by apposition, the rooted plant being termed the stock, the portion inserted the scion
grafting: the process of inserting a scion, which consists of a piece of stem and two or more buds of the plant to be propagated, into another plant (rootstock) with the intention that it will unite and grow
gregarious: growing in associated groups or clusters but not matted; at the same time
growth ring: the layer of wood formed during one growing season
gum: a colloidal polysaccharide substance that is gelatinous when moist but hardens on drying and is exuded by or extracted from plants
gutta-percha: the coagulated latex from certain trees of the family *Sapotaceae*
gynoecium: the female part or pistil of a flower, consisting, when complete, of one or more ovaries with their styles and stigmas
habit: external appearance or way of growth of a plant
habitat: the kind of locality in which a plant grows
hardwood: the wood of an angiospermous tree as distinguished from that of a coniferous tree
hastate: with more or less triangular basal lobes diverging laterally
head: a dense inflorescence of small crowded often stalkless flowers (a capitulum)
heartwood: wood from the inner portion of a tree in which the cells are dead and no longer engaged in sap conduction and food storage
heath forest: = kerangas
hemi-: prefix, meaning half
herb: any vascular plant which is not woody
hilum: the scar left on a seed indicating its point of attachment
hirsute: with rather coarse stiff hairs
hoop mark: a ring-shaped marking, often used to denote such a mark around a tree trunk
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
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
hypocotyl: the young stem below the cotyledons
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
in vitro: outside the living body and in an artificial environment
indehiscent: not opening when ripe
indigenous: native to a particular area or region
indumentum: a covering, as of hairs, scales, etc.
inferior: beneath, lower, below; an inferior ovary is one which is situated below the sepals, petals and stamens
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
infructescence: a ripened inflorescence in the fruiting stage
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; transferring e.g. mycorrhiza or rhizobia in the growing medium to promote growth
insecticide: an agent that destroys insects
internode: the portion of the stem between two nodes
intramarginal: of a vein, running near and parallel with the margin
intrastaminal: within the stamens
iodine number: a measure of the degree of unsaturation of the acids in a material
joint, jointed: an articulation (e.g. a node); articulated
jugate: connected or yoked together; e.g. in leaves 1-n-jugate: with 1-n pairs of leaflets
keel: a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla (carina); the principal vein of a sepal or glume
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

lamina: see blade
laminate, laminated: consisting of plates or layers
lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex
laryngitis: inflammation of the larynx
lateral: on or at the side
latex: a plant juice, usually white and sometimes sticky, being a suspension of organic matter
laticifer: a latex-bearing cell or vessel
laticiferous: latex-bearing
laxative: having a tendency to loosen or relax; a drug making the bowels loose and relieving constipation
leaflet: one part of a compound leaf
lenticel: lenticular masses of loose cells protruding through fissures in the periderm on stems, fruits and roots, usually arising beneath individual stomata and their main function is gaseous exchange
lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres
linear: long and narrow with parallel sides
lingulate: tongue-shaped
liniment: an oily liquid preparation to be used on the skin
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
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
lorate: strap-shaped
Lyctus: a lyctid or bostrychid beetle damaging wood by characteristic round holes of about 1-3 mm in diameter with the wood reduced to flour-like dust
lysigenous: formed by degeneration and breaking down of cell walls in centre of mass
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
marcotting: = air layering
membranous: thin and semi-transparent, like a fine membrane
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.
microsporophyll: a leaf-like organ bearing or subtending a sporangium which produces microspores
midrib: the main vein of a leaf which is a continuation of the petiole
moisture content: the weight of water expressed as a percentage of the dry weight
monadelphous: of stamens, united into one group by their filaments
monoclonal: belonging to one clone
monocotyledon: angiosperm having a single cotyledon or seed-leaf
monoecious: with unisexual flowers, but male and female flowers borne on the same plant
monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches
moulding: of wood or plywood, shaping by cutting and/or pressing into various contours
mucilage: a gelatinous substance that is similar to gum but that swells in water without dissolving and forms a slimy mass
mucro: a sharp terminal point
mucronate: ending abruptly in a short stiff point
mycorrhiza: a symbiotic association of roots with a fungal mycelium which may form a layer outside the root (ectotrophic) or within the outer root tissue (endotrophic)
nodule: a small knot or rounded body, often in roots of leguminous plants, where bacteria of the genus *Rhizobium* are active in the fixation of nitrogen from the air
nut: a one to many-seeded indehiscent fruit with a hard dry pericarp or shell
ob-: prefix, indication inverse or opposite condition (obtriangular, obcordate, etc.)
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: solid and reversely egg-shaped
obtuse: blunt or rounded at the end
oleoresin: a natural plant product consisting of a viscous mixture of essentially essential oil and non-volatile solids
oligotrophic: providing inadequate nutrients or with a low supply of nutrients
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
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: that part of the pistil, usually the enlarged base, which contains the ovules and eventually becomes the fruit
ovate: egg-shaped in outline; a flat surface which is scarcely twice as long as broad with the widest portion below the middle
ovoid: a solid object which is egg-shaped (ovate in section)
ovule: the immature seed (egg) in the ovary before fertilization
palmate: of leaflets, leaf-lobes or veins, with the different elements arising from the same point
palmatifid: palmately lobed
panicle: an indeterminate branched racemose inflorescence
paniculate: resembling a panicle
pantropical: distributed throughout the tropics
parenchyma: ground tissue composed of thin-walled, relatively undifferentiated cells, e.g. the pith and mesophyll
paripinnate: a pinnate leaf with all leaflets in pairs
pedicel: the stalk of an individual flower
peduncle: the stalk of an inflorescence or partial inflorescence
pellucid: translucent
peltate: of a leaf, with the stalk attached to the lower surface, not at the edge
pendulous: drooping; hanging down from its support
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
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
petiolate: having a petiole
petiole: the stalk of a leaf
petiolule: the stalk of a leaflet
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
pilose: hairy with rather long soft hairs
pinhole borer: generally an ambrosia beetle damaging wood producing a worm-hole of up to about 1.5 mm across which is generally darkly stained and without bore-dust
pinnate: arranged in pairs along each side of a common axis
pioneer species: a species able to establish itself on bare ground, starting primary succession, often showing rapid growth and producing large amounts of diaspores
pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of one or more ovaries, styles and stigmas
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
plagiotropic: having an oblique or horizontal direction of growth
plicate: folded to and fro, like a fan
plumose: feather-like with fine hairs
plumule: the primary bud of an embryo or germinating seed
pneumatophore: used of air vessels of any description; a root often functioning as a respiratory organ in swampy conditions
pod: a dry fruit composed of a single carpel and dehiscing by sutures, like in legumes; a general term for a dry dehiscent fruit
podzol: a zonal soil having an organic mat and a thin organic-mineral layer above a grey leached layer resting on a dark illuvial horizon
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
polyclonal: belonging to more than one clone
polymorphic, polymorphous: with several or various forms; variable as to habit
poultice: a soft, usually heated and sometimes medicated mass spread on cloth and applied to sores or other lesions
primary vegetation: the original, undisturbed plant cover
progeny: offspring
protandrous: of flowers, shedding pollen before the stigma is receptive
provenance: a collection of pollen, seed or propagules from a certain restricted locality
pruning: cutting off the superfluous branches or

shoots of a plant for better shape or more fruitful growth
puberulent: covered with down or fine hairs
puberulous: minutely pubescent
pubescent: covered with soft short hairs
pulp: the soft fleshy part of the fruit; mechanically ground or chemically digested wood used in manufacturing paper and allied products
punctate: marked with dots or translucent glands
pungent: bearing a sharp point; causing a sharp or irritating sensation
purgative: a medicine causing vigorous evacuation from the bowels
pustular, pustulate: with blister-like prominences
pyrene: a nutlet or kernel; the stone of a drupe or similar fruit
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: with flowers arranged in a raceme
rachis (plural rachides): the principal axis of an inflorescence or a compound leaf beyond the peduncle or petiole
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
ramification: branching
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
recalcitrant: of seeds, not tolerating desiccation or temperatures below 10°C
recent resin: resin obtained by tapping (see also fossil resin)
rechipping: enlargement of the tapping panel by cutting away a narrow strip of bark
recurved: bent or curved downward or backward
reflexed: abruptly bent or turned downward or backward
reforestation: the planting of a formerly forested area with forest trees
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
reticulate: netted, as when the smallest veins of a leaf are connected together like the meshes of a net
rheumatism: any of various painful conditions of the joints and muscles
rhizome: an underground stem which is distinguished from a root by the presence of nodes, buds, and leaves or scales
rind: the tough outer layer of the fruit
rosin: the non-volatile fraction of pine resin
root sucker: a shoot originating from adventitious buds on the roots
rootstock: see rhizome; a stock for grafting consisting of a root and part of the main axis
rudimentary: of organs, imperfectly developed and non-functional
rufous: reddish
rugose: wrinkled
rugulose: somewhat wrinkled
samara: an indehiscent winged fruit
sapling: a young tree of more than 1.5 m tall and with a bole of less than 10 cm in diameter
saponification number: a measure of the total amount of acids and the extent of esterification, expressed as the amount (in mg) of KOH required to saponify one gram of material
sapwood: the outer layers of wood adjacent to the bark which in the living tree contain living cells and reserve materials
scabies: a contagious skin disease caused by certain mites that burrow under the skin and deposit eggs, causing intense itching
scabrid, scabrous: rough to the touch
scale: a thin scarious body, often a degenerate leaf or a trichome of epidermal origin
scarification: of seed, the cutting or softening of the wall of a hard seed to hasten germination
scion: the plant which is being propagated vegetatively in grafting; the part of the plant above the graft union
scurf: abnormal skin condition in which small flakes or scales become detached
secondary vegetation: a plant cover that has been disturbed by natural causes or by man
secondary venation: the collection of veins of a leaf blade branching off from the midrib in pinnately veined leaves, or from the main veins in palmately veined ones
seed orchard: a plantation of selected trees, isolated to reduce pollination from outside, cultivated for the production of seed
seed: the reproductive unit formed from a fertilized ovule, consisting of embryo and seed-coat, and, in some cases, also endosperm
seedling: the juvenile plant, grown from a seed

semi-: prefix, meaning half or incompletely, e.g. semi-inferior
sepal: a member of the outer series of perianth segments
septicidal: dehiscing along the septa of the ovary
sericeous: silky
serrate: toothed like a saw, with regular pointed teeth pointing forwards
serrulate: serrate with minute teeth
sessile: without a stalk
shrub: a woody plant which branches from the base, all branches being equivalent (see also tree)
simple (botany): not compound, as in leaves with a single blade
sinuate: with a deep wavy margin
slash: a cut or stroke along the stem of a tree to reveal exudates and colours of bark and sapwood
sore: a place in the body where the skin is ruptured or bruised; it can be tender or painful; an ulcer or wound
spatulate: spoon-shaped
specific gravity: ratio of the weight of a volume of material to the weight of an equal volume of water of 4°C, in wood measured at 0% moisture content
spherical: globular
spicate: spike-like
spike: a simple indeterminate inflorescence with sessile flowers along a single axis
spine: a short, stiff, straight, sharp-pointed hard structure usually arising from the wood of a stem
spinescent: ending in a spine or sharp point
spiral: as though wound round an axis
stain: discoloration or variation from natural colour due to fungi, chemical action or other causes
stamen: one of the male reproductive organs of a flower; a unit of the androecium
staminode: an abortive or rudimentary stamen without or with an imperfect anther
stellate: star-shaped, as of hairs with radiating branches, or of petals arranged in the form of a star
sterile: 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)
stigma: the portion of the pistil which receives the pollen
stipe: the stalk supporting a carpel or gynoecium
stipitate: borne on a stipe or short stalk
stipule: a scale-like or leaf-like appendage at the base of a petiole
stoma (plural stomata): a breathing pore or aperture in the epidermis
stone: the hard endocarp of a drupe containing the seed or seeds
striate: marked with fine longitudinal parallel lines, as grooves or ridges
strigose: with short stiff hairs lying close along the surface
strobile (plural strobili): cone, an assemblage of imbricate sporophylls arranged in a cone-shaped structure in horsetails, club mosses and conifers
stump: seedling with trimmed roots and shoot and used as planting stock; also 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
stylopodium: enlargement or swelling at the base of the style
sub-: prefix, meaning somewhat or slightly (e.g. subacute), or below (e.g. subterranean) or less than, imperfectly
subfamily: a taxonomic rank between the family and the tribe denoting a part of a family
subspecies: a taxonomic rank between a variety and a species denoting a group of individuals with certain characteristics separating them from other members of the species
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
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
tangential: lengthwise, in a plane at right angles to the radius but not passing through the pith
tapping: the removal of bark and/or wood in order to cause exudation
tapping panel: the part where bark and/or wood has been removed while tapping
taproot: the primary descending root, forming a direct continuation of the radicle
taungya system: an agroforestry method where a forest crop is raised in conjunction with a temporary agricultural crop

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)
tepal: a segment of a perianth, applied when no distinction between sepals and petals can be made
terete: cylindrical; circular in transverse section
terminal: borne at the end or apex
termite: ant-like organism of the order *Isoptera* damaging wood by characteristic irregular honeycombing or wide channels with dry bore-dust or dust cemented together
terrestrial: on or in the ground
tertiary venation: generally the collection of the smallest veins of a leaf blade
tessellate: marked with a fine chequered pattern, like a mosaic
testa: the outer coat of the seed
thinning: removing trees, stems or plants from immature or mature stands in order to stimulate the growth of the remaining trees, stems or plants
throat: of a corolla, the orifice of a gamopetalous corolla
tissue culture: a body of tissue growing in a culture medium outside the organism
tomentose: densely covered with short soft hairs
tomentum: pubescence
transverse: straight across; of tertiary veins, connecting the secondary veins, not necessarily in a perpendicular way
traumatic duct: canal formed in response to injury, generally irregular in outline
tree: a perennial woody plant with a single evident trunk (cf. shrub)
tribe (plural tribae): a taxonomic rank between the family and the genus
trifoliolate: with three leaflets
trigonous: three-angled, with plane faces
truncate: cut off more or less squarely at the end
trunk: the main stem of a tree apart from its limbs and roots
tuberculate: covered with warty protuberances
turbinate: top-shaped
turpentine: the volatile fraction of pine resin
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)
umbo: a protuberance on the swollen top of the scale of a coniferous female cone or on the top of a fruit
unarmed: devoid of thorns, spines or prickles
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
unilocular: one-celled
unisexual: of one sex, having stamens or pistils only
urceolate: urn-shaped
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
variety: a botanical variety which is a subdivision of a species (an agricultural or horticultural variety is referred to as a cultivar)
vein: 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: the arrangement of the veins in a leaf
veneer: a thin sheet of wood
vermifuge: a drug serving to destroy or expel parasitic worms of the intestine
verrucose: warty
verticillate: in a whorl with several elements arising at the same node
vessel (anatomy): a continuous tube formed by superposition of numerous cells whose common walls are perforated or have broken down
vestigial: small and imperfectly developed
viability: ability to live, grow and develop
viscid: sticky
vitreous: transparent, glassy
warty: covered with firm roundish excrescences
waterlogged: flooded with water, generally for a period of at least a few weeks
whorl: arrangement with more than two organs of the same kind arising at the same level
wildling: a seedling taken from natural regeneration to serve as planting stock
wing: any membraneous expansion attached to an organ; a lateral petal of a papilionaceous corolla
wood: the hard, compact, fibrous substance between pith and bark
woolly: clothed with long and tortuous or matted hairs
zygomorphic: irregular and divisible into equal halves in one plane only

Sources of illustrations

Photo 1: original photo by S. Massalt and E. Boer.

Photo 2: Suhardi, Sosef, M.S.M., Laming, P.B. & Ilic, J., 1993. Pinus L. In: Soerianegara, I. & Lemmens, R.H.M.J. (Editors): Plant resources of South-East Asia No 5(1). Timber trees: major commercial timbers. Pudoc Scientific Publishers, Wageningen, the Netherlands. p. 351.

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Styrax benzoin: Koorders, S.H. & Valeton, T., 1916. Atlas der Baumarten von Java [Atlas of the tree species of Java]. Vol. 4. P.W.M. Trap, Leiden, the Netherlands. Fig. 252 (fruit); Perkins, J., 1907. Styracaceae. In: Engler, A. (Editor): Das Pflanzenreich [The plant kingdom]. Wilhelm Engelmann Verlag, Leipzig, Germany. Fig. 7, p. 59 (flowering branch, flower). Redrawn and adapted by P. Verheij-Hayes.

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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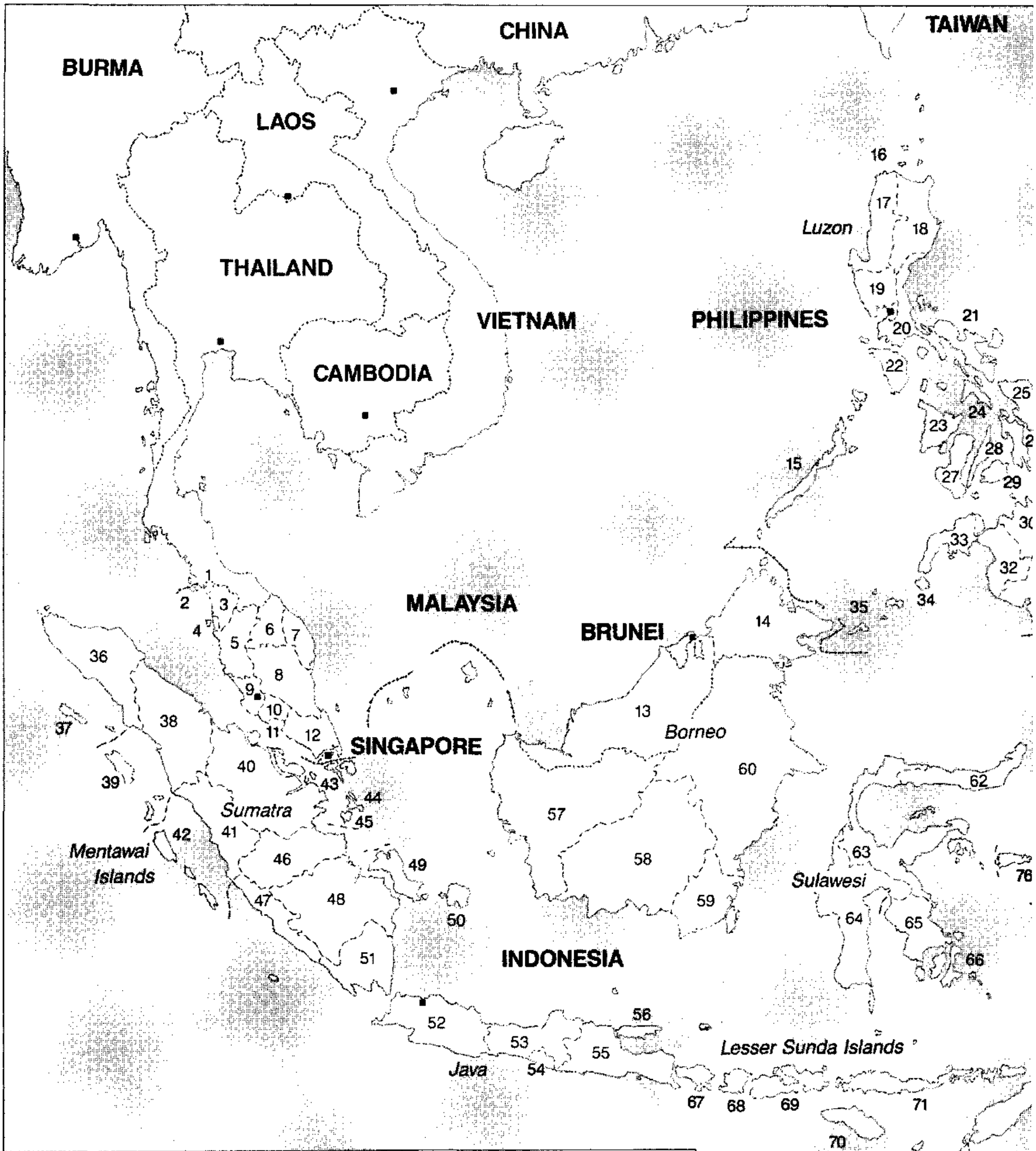

MAP OF SOUTH-EAST ASIA FOR PROSEA

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
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Bohol *i* 29
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