Plant Resources of South-East Asia

No 5(1)

Timber trees: Major commercial timbers

I. Soerianegara and R.H.M.J. Lemmens (Editors)

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Foreword

In South-East Asia timber trees constitute a major element of the natural vegetation, and timber exploitation plays an important role in most economies. If not properly controlled, the excessive utilization by logging, shifting cultivation and other human activities may lead to the total destruction of tropical forests.
Fortunately, efforts to protect, conserve and sustainably use tropical forests are gaining worldwide support. Not only better methods for the sustainable use of forest resources are being introduced and developed, but also generation of alternative sources of income for local populations is envisaged.
In addition to improved management of natural forests, cultivation of valuable timber species should also be encouraged. Commercialization of other forest products (e.g. rattans, edible fruits and nuts, resin and other exudates, medicines, fibres, essential oils, dyes and tannins) on a sustainable basis may generate additional income for local communities and may protect forests from destruction.
The cultivation of various tree species requires knowledge concerning ecological requirements, methods of propagation, seed production and longevity, growth and development, diseases and pests, productivity, geographic distribution and variability, vernacular names, and correct scientific name. In order to commercialize non-timber products, information is required on the quantity of harvestable products, season of harvest, area and density of tree stands, and value and possibilities for trade of each product. Correct identification of wood and tree species is necessary to promote the conservation of tropical rain forest, and, in the case of export and import restrictions, the conservation of species threatened with extinction.
All these efforts must start from the same sound basis: up-to-date knowledge of trees and forests. Against this background, the publication of the Prosea Handbook volumes on timber trees is of utmost importance, since they provide the state-of-the-art of our knowledge. We sincerely hope that this first volume on timbers will provide a useful tool for those active in education, research, extension and industry, and also for policy-makers committed to the sustainable use of timbers and forests in South-East Asia and other parts of the world.
We are grateful for the specific grants made available for this work by the Commission of the European Communities, the Tropenbos Foundation and the International Tropical Timber Organization.
Finally, may we express our appreciation of the efforts of all authors, editors, associate editors and Prosea personnel for making this important publication, Prosea 5(1): 'Timber trees: Major commercial timbers', a reality.

Jakarta, July 1993

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1 Introduction

1.1 Definitions

This volume deals with timbers of South-East Asia. The term 'timber' is generally used for wood other than fuelwood, following primary conversion, in forms suitable for construction (especially for building houses, bridges and ships) and comparatively large in size. It is also used as a general term for forest crops and stands (hence the term 'standing timber').
'Wood' is the hard, compact and fibrous substance between pith and bark of trunk and branches of a tree. Wood consists technically of the aggregated xylem elements intersected with the rays in many plants. In these definitions, the wood of a tree may be used as timber.
A 'tree' is a perennial plant with a single woody self-supporting stem or trunk which is usually unbranched for some distance above the ground and crowned with a head of branches and foliage. Foresters, when considering a tree mainly as a source of timber, often add to this definition a minimum height (4 m) and a minimum diameter of the trunk (7.5 cm) at breast height (1.5 m). Trees are very important elements of the landscape, not only by forming forests but because they are very common and predominant elements of the rural and semi-urban landscape of most tropical countries.
A 'forest' is defined as a large tract covered with trees, having a closed canopy and often with undergrowth. A natural forest is an extensive plant community of trees, shrubs and herbs in all stages of growth and decay having the quality of self-perpetuation or of developing into an ecological climax.

1.2 Role of timber trees

1.2.1 Timber production and trade

Timber is very important in South-East Asian countries in the present stage of their economic development. Malaysia and Indonesia are well in the lead of the exporting countries of tropical timber. In Malaysia the annual export value of tropical hardwood (logs, sawn timber and plywood) in the period 1985–1987 averaged almost US$ 2000 million, in Indonesia in the same period almost US$ 1750 million, which made timber the second most important export product after oil. From 1988–1992 the value of the exported timber was increased by levies; moreover, several tropical countries prohibited the export of non-processed wood, to favour the domestic wood-processing industry. This has made prices of exported timber increase considerably in recent years, and the export of sawn timber, veneer and plywood is currently an very important source of foreign exchange. For instance, from 1988 to 1989 the value of the ex-

Table 1. Annual export (in million US$) of tropical timber for five South-East Asian countries. Various sources.

	Indonesia (1989)	Malaysia (1992) Pen.	Sabah	Sarawak	total	Papua New Guinea (1992)	the Philippines (1992)	Thailand (1991)
Logs	–	–	347	1202[1]	1549	169	1.5	–
Sawn timber	623	535	612	199[1]	1346	0.5	14	54
Veneer	–	3	147[1]	31[1]	181	–	12	12
Plywood	2694	258	86[1]	151	495	–	60	1.5
Total	3317	796	1192	1583	3571	169.5	87.5	67.5

1. Estimated by extrapolation of statistics over part of the year (9 months).

port of plywood in Indonesia increased by 27%. In 1990 the 108 Indonesian plywood manufacturers exported plywood at an estimated value of US$ 3000 million. The total production of plywood in Indonesia is about 8 million m^3/year.
The annual export value of timber in the Philippines is much less, averaging about US$ 230 million in the period 1985–1987. The contribution of timber from Papua New Guinea on the world market has increased in recent years, but in Thailand, which was once an important exporter of timber, timber imports nowadays exceed timber exports (in 1991 Thailand imported tropical timber to a value of US$ 644 million, exporting timber to a value of only US$ 68 million). Singapore is an important intermediate port in timber trade; in the period 1985–1987 it marketed timber with a value of about US$ 370 million annually.
Export values of timber and wood products in South-East Asia are listed in Table 1. The export of logs is very important in Sarawak and Papua New Guinea and the export of sawn timber in Indonesia, Sabah and Peninsular Malaysia. Plywood is the main export product from Indonesia and it has some importance in Peninsular Malaysia and the Philippines.
The demand for tropical timber continues to grow. The increase in the domestic timber requirements of the developing countries in South-East Asia is estimat-

Table 2. Major trade groups of sawn timber in Indonesia, and volume and value of exports in 1989.

Trade group (sawn timber)	Volume (m^3)	Value (mln US$)
Meranti (*Shorea*)	1 408 000	301
Kapur/keruing (*Dryobalanops/Dipterocarpus*)	463 000	99
Pulai (*Alstonia*)	90 000	18
Teak (*Tectona grandis*)	46 000	29
Other timbers	685 000	175
Total	2 692 000	622

ed to be 6–10% a year. In 1989 the production of sawn timber in Indonesia was 10.2 million m^3, whereas the export was only 2.7 million m^3 (26%). On the other hand, in 1988 Sarawak exported more than 92% of the logs it produced, and Sabah more than 77%. The main importers of Malaysian and Indonesian timber are Japan (46%), other countries in East Asia (42%), the European Community (7%) and the United States (3%). In the period 1987–1990 Japan imported annually about 17 million m^3 of timber (both processed and unprocessed) from South-East Asia, which is about 20% of the total Japanese import. In the same period the European Community imported annually about 2.5 million m^3 of timber from South-East Asia.

Table 3. Major trade groups in Peninsular Malaysia (sawn timber) and Sabah (sawn timber and logs), and volume and value of exports in 1992.

Trade group	Peninsular Malaysia		Sabah	
	volume (m^3)	value (mln US$)	volume (m^3)	value (mln US$)
Red meranti (*Shorea*)	497 000	210	1 608 000	324
White meranti/mersawa (*Shorea, Parashorea*)	42 000	15	892 000	166
Balau/red balau (*Shorea*)	22 000	5	395 000	94
Yellow meranti (*Shorea*)	–	–	372 000	67
Keruing (*Dipterocarpus*)	190 000	37	494 000	87
Kapur (*Dryobalanops*)	80 000	13	365 000	55
Tualang (*Koompassia excelsa*)	71 000	10	139 000	17
Kempas (*Koompassia malaccensis*)	49 000	9	52 000	6
Merbau (*Intsia*)	63 000	23	35 000	7
Binuang (*Octomeles sumatrana*)	–	–	95 000	8
Mempisang (*Annonaceae*)	–	–	68 000	7
Bintangor (*Calophyllum*)	–	–	59 000	10
Medang (*Lauraceae*)	–	–	52 000	4
Kauri (damar minyak) (*Agathis*)	4 000	2	46 000	20
Perupok (*Lophopetalum*)	–	–	50 000	13
Magas (*Duabanga moluccana*)	–	–	42 000	4
Jelutong (*Dyera costulata*)	19 000	8	23 000	4
Kadam (*Anthocephalus chinensis*)	–	–	41 000	4
Rubberwood (*Hevea brasiliensis*)	39 000	9	–	–
Mengkulang (*Heritiera*)	23 000	8	15 000	3
Melunak (*Pentace*)	–	–	38 000	4
Macang (*Mangifera*)	–	–	38 000	6
Merawan (*Hopea*)	–	–	32 000	4
Nyatoh (*Sapotaceae*)	8 000	3	23 000	4
Keranji (*Dialium*)	–	–	31 000	3
Pulai (*Alstonia*)	–	–	30 000	3
Sepetir (*Sindora*)	8 000	2	20 000	3
Bayur (*Pterospermum*)	–	–	24 000	2
Kembang semangkok (*Scaphium*)	–	–	23 000	2
Other timbers	1 080 000	181	284 000	29
Total	2 195 000	535	5 386 000	960

Timber is usually graded into trade groups. The importance of timber trade groups varies with country, depending on the natural distribution areas of the timber species, since the most important groups are still harvested from natural forest. For Indonesia, the major timber trade groups (sawn timber) and their statistics for 1989 are listed in Table 2. Table 3 lists the most important groups and their statistics in 1992 for Peninsular Malaysia and Sabah. No statistics on trade groups for Sarawak are available, but the most important ones are meranti (*Shorea* spp.), keruing (*Dipterocarpus* spp.), kapur (*Dryobalanops* spp.) and ramin (*Gonystylus* spp.).
The major timber trade groups in Papua New Guinea are listed in Table 4. No export statistics are available.
The timber export in the Philippines is for the greater part confined to red lauan (*Shorea negrosensis*). The quantity of this timber (sawn) exported was about 750 000 m^3 with a value of US$ 125 million in 1989, and 49 000 m^3 with a value of US$ 10.5 million in 1990. Other important trade groups are white lauan (*Shorea contorta*) and apitong (*Dipterocarpus*), but their volumes and export value are much less (in 1989 about 45 000 m^3 with a value of US$ 6 million for white lauan, and about 1600 m^3 with a value of US$ 200 000 for apitong).
Teak (*Tectona grandis*) is by far the most important export timber of Thailand. The quantity exported in 1990 (processed) was 25 000 m^3. Other export timbers, although of much less importance, are pra-du (*Pterocarpus macrocarpus*) and para rubber (*Hevea brasiliensis*), which were exported (processed) in 1990 in amounts of about 8000 m^3 and 320 m^3, respectively.

Table 4. Major trade groups in Papua New Guinea.

Conifers: *Araucariaceae* (*Agathis*, *Araucaria*) and *Podocarpaceae*
Fagaceae: *Castanopsis*, *Lithocarpus* and *Nothofagus*
Ebony (*Diospyros*)
Kerosene wood (*Cordia*)
Teak (*Tectona grandis*, planted)
Rosewood (*Pterocarpus indicus*)
Black bean (*Castanospermum australe*)
Kwila (*Intsia*)
Planchonella (*Pouteria*)
PNG walnut (*Dracontomelon*)
Mersawa (*Anisoptera*)
Kalofilum (*Calophyllum*)
Taun (*Pometia pinnata*)
Terminalia (*Terminalia*)
Vitex (*Vitex*)
Wau beech (*Elmerrillia*)
Basswood (*Endospermum*)
Kamarere (*Eucalyptus deglupta*)
Hopea (*Hopea*)
Erima (*Octomeles sumatrana*)
Malas (*Homalium*)
Amberoi (*Pterocymbium*)

1.2.2 Wood used for non-timber purposes

Wood is also used for purposes other than timber, e.g. for pulp and paper and as firewood. The consumption of paper is burgeoning. The prognosis made by FAO in 1986 for 1990 was exceeded by 10%, resulting in a worldwide consumption of paper in 1990 of almost 250 million t. A further increase is expected in the coming years. This demand has resulted in plans for the establishment of new pulp mills and of plantations to supply them, mainly in Indonesia.

Many people depend on firewood as their chief source of fuel, and in parts of South-East Asia the average user burns well over 1 t of firewood each year (National Academy of Sciences, 1980). With increasing human population and decreasing wooded areas, there is growing pressure on the forest for firewood (and timber for domestic use).

Excluded from this volume are plant species used primarily for paper-making (to be dealt with in the Prosea Vol. 17: 'Fibre plants'), and species whose primary use is firewood and allied applications (to be treated in Prosea Vol. 11: 'Auxiliary plants in agriculture and forestry').

1.3 Grouping of timber trees

In 1989 a Prosea Timber Task Force was appointed to elucidate the large commodity group of timber trees and to propose how this group could best be treated in the Prosea Handbook. The Timber Task Force consisted of: I. Soerianegara (IPB, Indonesia), F.S.P. Ng and K.M. Kochummen (both FRIM, Malaysia); its advisers were R.J. Johns (Prosea Programme Leader Papua New Guinea) and S. Kadarsan (Prosea Programme Leader Indonesia); the coordinator was J.S. Siemonsma (Prosea Regional Coordinator South-East Asia). In May 1990, this Task Force presented its report. A classification according to commercial importance was proposed: the major commercial timbers of South-East Asia would be treated in Vol. 5(1), the minor commercial timbers in Vol. 5(2) and the lesser-known timbers in Vol. 5(3). The choice of genera to be treated in each volume is rather subjective. What is now a lesser-known timber may in the near future prove to be a major commercial timber. Conversely, commercially important timbers may rapidly lose their importance, for instance because of the depletion or conservation of stands. Nevertheless, this approach has important advantages over a complete alphabetical treatment: it enables important and well-known timbers to be dealt with in greater detail than unimportant and lesser-known ones, and omissions from the first two volumes have no serious consequences.

The timber trees in this volume are dealt with primarily by genus rather than by species. This is because trade groups of timber generally correspond more to genera than to species, and information on wood or timber is often not reducible to species. Furthermore, the genus approach reduces the large commodity group to manageable proportions.

After each genus treatment, selected species are described briefly. The selection of the species per genus is essentially based on their importance for the production of timber. However, it often proved difficult to determine the importance of a species on the basis of the availability of information on the use of the timber (e.g. for construction) or of the wood (e.g. for arts and crafts). In the absence of such information (the literature often only refers to genera or trade groups), those species known to reach a medium size (minimum height 20 m, minimum diameter of trunk 50 cm), and which are fairly common, at least locally, are included. Questionable choices are occasionally inevitable.

1.4 Botany

1.4.1 Taxonomy

Throughout Malaysia, Brunei and western Indonesia most lowland rain forests are dominated by a vast variety of tree species of the family *Dipterocarpaceae*. Dipterocarp genera and species represent a particularly valuable contribution to the world's timber resources and are the most important element in the productive forests of South-East Asia. Dipterocarps are particularly important in the Philippines, where they provide 75% of the logs and 94% of the total volume. In Borneo, it is estimated that 67% of the total growing stock consists almost entirely of *Shorea* species, and in Peninsular Malaysia dipterocarps make up 50–60% of the total volume of the growing stock over 30 cm diameter and represent 75% of the commercial volume. In the semi-evergreen forest in northern Thailand the dipterocarps make up 33% of the total growing stock (*Dipterocarpus* and *Hopea*), and the same predominance is found in Vietnam (Unesco, 1974). East of Borneo dipterocarps make up only a very small proportion of the big trees and there are few species.
Other important families for timber in South-East Asia are *Anacardiaceae*, *Apocynaceae*, *Bombacaceae*, *Burseraceae*, *Combretaceae*, *Ebenaceae*, *Euphorbiaceae*, *Fagaceae*, *Flacourtiaceae*, *Guttiferae*, *Lauraceae*, *Leguminosae*, *Magnoliaceae*, *Meliaceae*, *Moraceae*, *Myristicaceae*, *Myrtaceae*, *Rhizophoraceae*, *Rubiaceae*, *Sapindaceae*, *Sapotaceae*, *Sterculiaceae*, *Theaceae*, *Tiliaceae*, *Verbenaceae*, and the Gymnosperm families *Araucariaceae*, *Pinaceae* and *Podocarpaceae*.
The tree species from large areas in South-East Asia are not yet covered by modern floras. Flora Malesiana (van Steenis et al., 1950–), covering Brunei, Indonesia, Malaysia, Papua New Guinea, the Philippines and Singapore, is far from complete. The commercially important timber-producing families which have been covered in Flora Malesiana include *Anacardiaceae*, *Araucariaceae*, *Burseraceae*, *Combretaceae*, *Dipterocarpaceae*, *Fagaceae*, *Flacourtiaceae*, *Leguminosae* (*Mimosoideae*), *Magnoliaceae*, *Pinaceae*, *Podocarpaceae* and *Rhizophoraceae*.
Indonesia has approximately 4000 tree species which are potentially useful for timber. Only about 400 species have current economic value, and about 260 species are classified as commercial timbers. A complete flora of Java is available (Backer & Bakhuizen van den Brink, 1963–1968), but other areas of Indonesia are covered incompletely or not at all.
Over 3000 tree species occur in Peninsular Malaysia. The tree flora of Malaya (Whitmore & Ng, 1972–1989) covers all tree species of Peninsular Malaysia except dipterocarps which were covered earlier by Symington (1941). There are checklists and manuals for the trees of Sarawak, Sabah and Brunei (e.g. Smythies, 1965; Ashton, 1988). A flora of East Malaysia is in preparation.
Papua New Guinea, which together with Irian Jaya (Indonesia) and the Solomon Islands forms a biogeographical region occasionally known as Pa-

puasia, has a mixture of floristic elements from Australasia and Malesia, to which Papua New Guinea belongs. Elements of Australasia are represented among the trees by genera such as *Nothofagus*, *Casuarina* and *Proteaceae*, elements of Malesia by the *Fagaceae* genera *Castanopsis* and *Lithocarpus* and the *Dipterocarpaceae* genera *Anisoptera*, *Hopea* and *Vatica*. Papuasia has well over 2000 species of trees, and some 120 genera are used in the trade for timber. Several endemic timber species of Papua New Guinea are suitable for use in reforestation or have potential for plantation establishment (e.g. *Terminalia brassii*). However, few tree species have been studied in detail, and even studies on the major commercial species are limited. Much research is still required, especially on the lesser-known tree species (Johns, 1989). In Papua New Guinea only field keys and manuals are available for tree identification.

In the Philippines it is estimated that 3500 tree species have economic potential (Meniado et al., 1975). About 350 species are considered to have at least some economic importance. There has never been a good, comprehensive flora of the Philippines. The flora of the Philippines is probably the least known of any country in South-East Asia. Most information is still based upon the work of E.D. Merrill (Merrill, 1923–1926). Recently, a flora of the Philippines project has been started.

About 540 useful tree species are recorded for Thailand, of which 59 are reported as useful timbers (Duriyaprapan et al., 1989). Teak (*Tectona grandis*) and *Dipterocarpaceae* supply most of the commercially important timber. Teak is important in the 5 provinces in the north-west, covering an area of about 3 million hectares. Work on the flora of Thailand is currently in progress. The important timber-producing families that have been dealt with so far include *Ebenaceae*, *Leguminosae* (partly), *Magnoliaceae*, *Pinaceae*, *Podocarpaceae*, *Rhizophoraceae* and *Theaceae*.

About 500 tree species are found in Vietnam. Most of the valuable timbers belong to the families *Cupressaceae*, *Dipterocarpaceae*, *Leguminosae*, *Meliaceae*, *Podocarpaceae* and *Sapotaceae*. Among the families published in the current Flora of Cambodia, Laos and Vietnam (Flore du Cambodge, du Laos et du Viêtnam, 1960–) are *Anacardiaceae*, *Combretaceae*, *Dipterocarpaceae*, *Flacourtiaceae*, *Leguminosae* (partly), *Rhizophoraceae* and *Sapotaceae*.

Approximately 2300 tree species are found in Burma (Myanmar). Only a few of these are extensively used for timber, and the knowledge of tree species is very limited. Teak is the main species producing timber, sometimes occupying over 10% of the area of the economically important deciduous forest. It is even estimated that teak accounts for 10–15% of the total volume of growing stock of the mixed deciduous forests in Burma (Unesco, 1974). Burma has always produced the largest quantity and the best quality teak. Teak and 'padouk' (*Pterocarpus macrocarpus*) are often planted for timber production (San Maung, 1989). The only existing flora of Burma dates from the 19th Century (Kurz, 1877).

It is clear that up-to-date taxonomic information on tree species is limited in many parts of South-East Asia. Taxonomic information is fundamental for an understanding of the threatened tropical rain forest, but even at the most elementary levels of organisms of the forest (i.e. the trees) this kind of information is often lacking or very incomplete. Forestry research should be accompanied by taxonomic research, but this combination is seldom practised.

1.4.2 Morphology

Tree architecture

Hallé, Oldeman & Tomlinson (1978) distinguish 23 architectural models of trees. The models are monoaxial (with a single apical meristem and consequently a single axis), or polyaxial (with several morphologically distinct axes, derived from more than one meristem). The first group (2 models) is represented by palms and comparatively small dicotyledons.
In the polyaxial trees the following types are distinguished:

1. Vegetative axes all equivalent and orthotropic; 4 models are distinguished. Multiple-stemmed palms are particularly important in this group.

2. Vegetative axes differentiated into trunk and branch; 14 models are distinguished. The most important models for timber trees of South-East Asia are briefly described below, and illustrated semi-diagrammatically in Fig. 1.

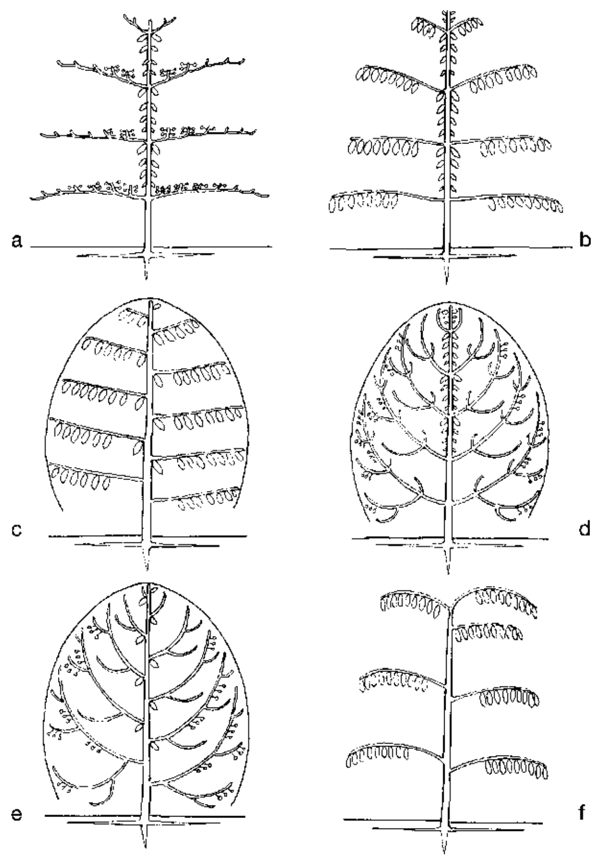


Figure 1. Six architectural models of trees. a, Aubréville's model; b, Massart's model; c, Roux's model; d, Rauh's model; e, Attim's model; f, Troll's model.

- Aubréville's model. Monopodial trunk with rhythmic growth and spiral or decussate phyllotaxis, bearing whorled branch tiers with similar phyllotaxis; branches growing rhythmically but modular, each branch plagiotropic by apposition; inflorescences lateral and modules consequently growing indefinitely. Examples: *Campnosperma brevipetiolatum*, *Endospermum diadenum*, *Fagraea fragrans*, *Palaquium gutta* and *Terminalia catappa*.
- Massart's model. Orthotropic monopodial trunk with rhythmic growth and consequently producing regular tiers of branches at levels established by the growth of the trunk meristem; branches plagiotropic either by leaf arrangement or symmetry, but never by apposition; position of flowers not significant in the definition of the model. Examples: *Ceiba pentandra*, *Dipterocarpus costulatus* and *Shorea ovalis*.
- Roux's model. Orthotropic monopodial trunk meristem showing continuous growth; branches plagiotropic and usually inserted continuously; leaf arrangement spiral on the trunk but usually distichous on the branches; position of the flowers not significant in the definition of the model, but mainly lateral on the branches. Examples: *Dryobalanops sumatrensis*, *Durio zibethinus* and *Hopea odorata*.
- Rauh's model. Monopodial trunk growing rhythmically and so developing tiers of branches which are morphogenetically identical to the trunk; flowers always lateral and having no effect on the growth of the shoot system. One of the most common models. Examples: *Araucaria cunninghamii*, *Artocarpus heterophyllus*, *Pinus merkusii* and *Swietenia macrophylla*.
- Attim's model. Axes with continuous growth, differentiated into a monopodial trunk and equivalent branches; branching either continuously or diffusely; flowers lateral and not affecting shoot construction. Examples: *Casuarina equisetifolia*, *Lumnitzera racemosa*, *Calophyllum* spp., *Ceriops tagal* and *Rhizophora mucronata*.

3. Mixed axes; meristems determining both trunk and branch axis; 3 models are distinguished. The most important model for South-East Asian timber trees is:
- Troll's model. Axes all plagiotropic with continual superposition, mainline axes contributing part trunk, part branch, the proximal part becoming erect; distal part of each axis being a branch with or without determinate growth, bearing lateral axes which often do not form a basal erect portion. The most common model, particularly in *Leguminosae*. Examples: *Albizia lebbeck* and *Pterocarpus indicus*.

Trunk, root system and bark

The trunk is the main stem of a tree. The lower merchantable portion of the trunk is often called 'bole', and the length of the clear bole, up to the first limbs, is of interest for timber production. The bole may be columnar or tapered, straight or crooked. For most timber purposes straight and columnar boles are preferred. Sometimes the bole is fluted. The trunk often has buttresses: large flanges protruding from the lower part of the trunk. They may give support to the trunk in trees with superficial rooting. Buttresses are a valuable guide to the identification of trees in the forest. Plank roots (horizontal roots extending

vertically resulting in wavy, plank-like structures growing away from the base of the trunk, e.g. *Heritiera littoralis*, can be considered as a form of buttress. Aerial roots are particularly common in species growing in swamps. There are several types of aerial roots including stilt roots (branched, looping aerial roots that arise from the trunk and lower branches, e.g. *Rhizophora* spp.), pneumatophores (erect lateral branches of buried horizontal roots which arise above the level of the substrate, e.g. *Avicennia* spp.), and root knees (horizontal roots forming a pronounced loop above the level of the substrate, e.g. *Bruguiera gymnorhiza*.
The bark surface often provides important characters for identification. The bark of some species nearly always has a distinctive colour, e.g. tualang (*Koompassia excelsa*) tinged a delicate fluorescent green. The bark surface may be smooth, dimpled (e.g. kasai (*Pometia pinnata*) has a surface mottled in colour with small round scales), scaly, fissured (e.g. bintangor (*Calophyllum* spp.)) or scrolled (e.g. *Tristaniopsis* spp.). Sometimes the outer bark can be removed to show a prominently coloured 'middle bark' which is the innermost cork layer (e.g. *Lophopetalum* spp. have an ochre or orange middle bark). The inner bark (bast) is of less value for identification, but colour, texture, exudates and smell do provide diagnostic characters.

Wood

In a cross section of the trunk the wood portion often has a distinctive outer and inner layer (see Fig. 2). The outer layer consists of wood that is young and living or physiologically active. It is usually paler than the inner wood, permeable and not durable. This 'sapwood' is separated from the bark by a formative layer of cells called 'cambium'. The central portion of the wood is called 'heartwood'; it is usually darker and less permeable than the surrounding sapwood but sometimes difficult to distinguish. Often resins, gums, tannins or other coloured organic substances are present in the heartwood, which may function as deterrents to fungi and insects. The heartwood is more durable than the sapwood, and because of the presence of extractives, is also heavier after drying. The pith is situated in the very centre of the heartwood and consists of a usually sclerified longitudinal strand of parenchyma tissue. Throughout, the wood is traversed by wood rays running radially from the pith or a more pe-

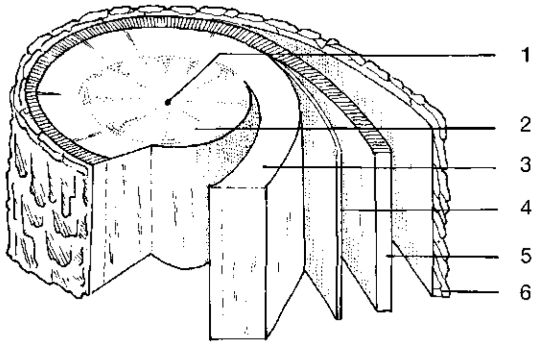


Figure 2. Composition of the trunk. 1, pith; 2, heartwood; 3, sapwood; 4, cambium; 5, inner bark; 6, outer bark.

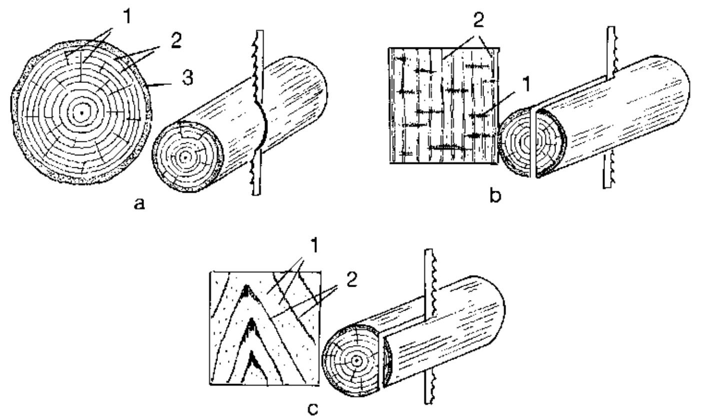


Figure 3. Main saw planes. a, transverse; b, radial; c, tangential; 1, rays; 2, growth rings; 3, bark.

ripheral part of the wood to the cambium and continuing in the bark as phloem rays.

Three major planes are distinguished for sawing or for describing macroscopic or microscopic features (Fig. 3):

- Transverse, end grain, or cross section: the plane perpendicular to the log.
- Radial or quarter-sawn: vertical plane through the central axis of the log (parallel to the rays).
- Tangential, flat-sawn or back-sawn: vertical plane parallel to but not intersecting the longitudinal axis.

The growth of the wood is sometimes discontinuous as a result of less favourable growing conditions. This may result in growth rings in the wood. In the tropics growth rings are often present in trees growing in areas with a pronounced dry season, e.g. teak (*Tectona grandis*). Evergreen trees of the rain forest often lack distinct growth rings, but growth rings are more common in tropical trees than is suggested in the general literature, although they may not be annual (Baas & Vetter, 1989).

1.4.3 Wood anatomy

Detailed standardized accounts of the wood anatomy have been included in all generic treatments because microscopic wood structure is basic to an understanding of wood properties and crucial for timber identification. In a broader context, microscopic wood structure is also crucial for the understanding of processes within the living tree because it fulfils a combination of four vital functions: mechanical support, long-distance transport of water and minerals from the roots to the transpiring leaves and flowers, storage and mobilization of reserve carbohydrates, lipophilic compounds and proteins, and the ability to resist pathogens after wounding or to compartmentalize decay by the formation of various types of barrier zones to micro-organisms.

On a global scale, there are strong correlations between the wood structure and macro-ecology of tree species. Hardwoods of the tropical lowland forests typically have a hydraulically efficient system of wide and simply perforated vessels. Axial parenchyma is often abundant, or its function in storage and defence is taken over by living libriform fibres. Fibres range from thin- to thick-walled, in close correlation with the density and hardness of the timber, and reputedly also in close correlation with the successional status of the species. However, the observation that some fast-growing pioneer species (e.g. *Macaranga*) produce much lighter woods with thin-walled fibres than slow-growing climax species cannot be generalized and has many exceptions.

The descriptive format in this volume follows generally accepted standards. For hardwoods, details are given on growth rings; vessel distribution, frequency, diameter, element length, type of vessel perforation, and lateral wall pitting; fibre length, fibre wall thickness and pitting; axial parenchyma distribution and strand length; ray frequency, size, and composition; mineral inclusions (crystals and/or silica bodies) and their distribution; secretory elements such as resin or gum ducts, laticifers, etc. The terms and definitions adopted are those of the IAWA (International Association of Wood Anatomists) List of Features for Hardwood Identification (IAWA Committee, 1989. IAWA Bulletin n.s. 10: 219–332). For the limited number of South-East Asian softwoods (which, like all conifers, lack vessels), another descriptive format, with emphasis on crossfield pitting and ray parenchyma and ray tracheid cell wall features, has been adopted.

1.4.4 Growth and development

Trunk and branch formation and growth rhythm

The trunk of a tree results from the dominance of one main axis (i.e. one meristem) over all others (Champagnat, 1978). This axis is usually the epicotyledonary axis of the seedling. If the epicotyledonary axis is destroyed, it can be replaced by a shoot from a distal position from the remaining part. There is no branching of the young trunk. In somewhat older individuals, dominance is diminished and several terminal shoots may arise. However, one of these becomes dominant, and the others die. Later, the first persistent branch appears, the first element of the crown. The height of the crown depends not only on the species but also on environment, planting distance, etc.

Saplings of many tropical trees have been reported to remain evergreen and show continuous, monopodial growth for 2–3 years or until they reach a height of several metres (Borchert, 1978). With increasing size, growth is often discontinuous or regularly rhythmic (flushes). Discontinuity of development is the rule in a temperate climate with winter dormancy and in a tropical climate with a pronounced dry season, but it is also common in a more or less uniform tropical climate such as that prevailing in Singapore. Tree species which exhibit continuous growth do exist, but they do not appear to reach exceptional dimensions and are not very common in the tropics. The intervals between growth flushes vary among species, climatic regimes, individual trees within species, and even branches of a given tree (Kramer & Kozlowski, 1979). Little is known about climate-dependent growth or about slow and progressive endogenous changes that are independent of the environment. Much experimental work is needed in order to define the regulatory mechanism of growth rhythms in the tropics.

Tropical trees exhibiting rhythmic growth are usually asynchronous in regard to growth flushes when they are young, but invariably show close synchronism in growth behaviour when mature. This seems to indicate the presence of an external triggering stimulus (Alvim & Alvim, 1978) which may be photoperiodic, thermoperiodic or hydroperiodic.

In young trees the amount of annual shoot growth increases for a number of years but attains a maximum rate relatively early in the life of a tree, and gradually declines thereafter. Height growth of tropical trees may not exceed that of temperate trees, or exceed 2 m a year, particularly in saplings and coppice shoots. Rapid rates of growth are often found in trees growing in the open or at the forest edge. The rate tends to be much slower inside the forest.

The growth of all or most tree species is supported by the existence of mycorrhizae, a symbiotic relationship between the roots and fungi whereby nutrient uptake of the tree roots is facilitated. Most legumes have bacterial nodules which are capable of fixing atmospheric nitrogen to improve soil fertility.

Crown formation

The shapes of tree crowns differ greatly among species occupying different height levels of the tropical forest, the tallest trees having the widest and flattest crowns. In the second layer tree crowns are about as wide as they are high, while in the lower or third layer they are often tapering or conical. The angles of branching tend to be upwardly oriented in upper strata and more horizontally oriented in the third layer. In many species the crown form changes progressively during development when passing through the different forest strata. Crown forms are also greatly modified by site. Aspects of tree form such as branch angle, amount of branching, amount and duration of shoot growth, and degree of apical dominance are genetically controlled, but they can also be modified by the environment (Kramer & Kozlowski, 1979).

Solitary trees tend to have larger crowns than those growing in plantations. In a young, even-aged stand all trees may have more or less similar crown shapes, but with increasing age, competition intensifies as the crowns begin to close the canopy. Trees of some species come to occupy low positions in the canopy whereas these of others become dominant because they are the largest and most vigorous.

Leaf shedding

Leaf shedding of individual trees usually does not occur continuously in evergreen, tropical forests, but there are peaks of leaf abscission. Trees may be bare for a period and flower on the bare crown (deciduous trees), or leaf fall may occur at about the same time as bud-break (leaf exchange); finally, leaf fall may occur well after bud-break and leaves of several flushes sometimes occur together on one tree (evergreen trees). Leaf shedding of many rain forest species is easily induced, even by mild water stress (Kramer & Kozlowski, 1979). Leaf fall is closely related to the local dry season. However, when the rainy season is accompanied by waterlogging of the soil, leaves may drop because of insufficient aeration of the roots. Some species grow or can be grown both in permanently moist and seasonally dry regions (e.g. teak) and their habit may vary from evergreen to deciduous and they may display significant differences in shoot growth patterns. However, a genetically determined lifespan of leaves has also been suggested (Whitmore, 1990).

Wood formation

The wood-producing capacity of a tree depends on the interaction of 3 major components (Kramer & Kozlowski, 1979):
- The rate of photosynthesis per unit of leaf area or of mass or per unit of chlorophyll.
- Structure, duration, exposure and area of canopy.
- Differences in distribution and partitioning of photosynthates among the various organs of the tree, resulting in different ratios of dry matter in the crown, bole and roots.

Of course, the increment in diameter may also be influenced by environmental conditions.
Tree species compete with each other in a forest stand for space, light, nutrients and water. Hence, root competition should be considered when establishing plantations. Some tree species produce toxic substances which may assist in avoidance of competition with other species; such substances consist of phenolic acids, quinones, etc. However, such allelopathy has seldom been demonstrated (e.g. in *Ailanthus*).

Flowering and seeding

Although some tropical trees flower continuously throughout the year (particularly pioneer species), most of them have a distinct flowering season although individuals may flower irregularly. Some species show mass flowering at indefinite intervals, with practically every individual of that species in flower at the same time over a wide area (often when rain and associated cooling follows a period of drought). An example is *Pterocarpus indicus*. Nearly all species and individuals of dipterocarps in a certain area may flower simultaneously at more or less irregular intervals of 2–10 years. The area may be as small as a river valley or as big as north-eastern Borneo. Other trees (e.g. trees of the families *Burseraceae* and *Sapotaceae*) also flower heavily in a good dipterocarp year, and it is possible that a climatic factor is involved. Mass flowerings coincide with exceptionally dry weather, but the exact nature of the trigger has not yet been established (Whitmore, 1990). Some dipterocarps, however, flower and fruit every year, e.g. *Anisoptera thurifera* in New Guinea.
Vigorous, dominant trees produce more seed than intermediate or suppressed trees; trees of the latter category often fail to produce any seed. The seeds of most trees in forests of South-East Asia germinate within a few days of shedding; those that do not germinate within a few weeks usually die. This means that the forest soil does not hold a reservoir of seeds and therefore these trees are vulnerable to extinction by logging if not many seedlings are already established and survive the logging operations. This also means that seeds can only be stored for a short period. Many species of tropical trees have comparatively large seeds, which enables their seedlings to establish under dense shade (because of the large amount of food reserves), waiting for a gap to appear in the

canopy before growing upwards. On the other hand, large seeds have a limited dispersal ability, except when they are dispersed by animals such as birds and bats. Consequently, large quantities of seedlings are found close to the mother trees. Predation of seedlings, e.g. by ants, can be considerable. It is possible that predators are attracted to concentrated stands of seedlings, giving the few furthest dispersed seeds a better chance of survival (Ng, 1978). Mass fruiting of dipterocarps may be advantageous for seed survival.
Those commercially important timber trees which are pioneers have small seeds. Examples are *Alstonia angustiloba* and *Anthocephalus chinensis*.

Longevity

The longevity of trees varies greatly. Trees can become very old, particularly some species from temperate regions, where ages of well over 5000 years have been reported. Tropical trees usually die earlier, but several species can reach a considerable age. Trees show several common symptoms of ageing: decrease of metabolism, decrease in the proportion of photosynthetic to non-photosynthetic tissue, gradual reduction of growth of vegetative and reproductive tissues, increase in dead branches, slow wound healing, increased susceptibility to injury from certain insects and diseases and from unfavourable environmental conditions, and loss of geotropic responses.

Silvicultural treatments

Most silvicultural treatments practised in plantations are successful only insofar as they improve the physiological functioning of trees. In forestry the primary crop is the stem of the tree, and hence the factors which determine the growth rate and form of the stem are of major concern. Much interest has been shown in crown sizes because of their influence on wood production. After the crowns close, the lower branches die and the live-crown ratio (percentage of total tree height occupied by functional branches) decreases. When the live-crown ratio decreases below a critical value (often about 40%), the rate of wood production diminishes greatly. Thinning at this stage may result in increased wood production of single trees because it results in a larger leaf area which is accompanied by more photosynthesis and general physiological activity of the crown. However, thinning may produce a more tapered trunk because the increase of cambial activity and radial growth towards the base of the tree is greater than in the crown. This may be misleading when using the increase of diameter growth at breast height as an indication of the actual increase of total volume of wood. In natural forest, the live-crown ratio is approximately 30% and trees grow comparatively slowly.

1.5 Ecology

1.5.1 Climate

In the tropics, climatic differences are primarily determined by the amount and distribution of rainfall (the absence or presence – and duration – of a dry season), and secondarily by differences in elevation. The climatic types of tropical

Table 5. A comparison of the climatic types defined by Schmidt & Ferguson (1951), Troll (1966) and Whitmore (1984) for South-East Asia.

Q values (Schmidt & Ferguson)	Rainfall type (Schmidt &Ferguson)	Climatic zone (Troll)	Climatic type (Whitmore)
0 – 14.3	A	V_1	perhumid
14.3– 33.3	B	V_1	slightly seasonal
33.3– 60.0	C	V_1, V_2	seasonal
60.0–100.0	D	V_1, V_2	seasonal
100.0–167.0	E	V_2	strongly seasonal
167.0–300.0	F	V_2	strongly seasonal
300.0–700.0	G	–	–
over 700.0	H	–	–

South-East Asia fall into zones V_1 (tropical rainy climate, 9.5–12 humid months per year) and V_2 (tropical humid-summer climate, 7–9.5 humid months per year) as defined by Troll (1966); zone V_3 (wet-and-dry tropical climate, 4.5–7 humid months per year) occurs only in central Thailand. Schmidt & Ferguson (1951) used the following equation to distinguish rainfall types in Indonesia:

$$Q = \frac{\text{average number of dry months}}{\text{average number of wet months}} \times 100$$

Whitmore (1984) produced a climatic map of South-East Asia based on the rainfall types of Schmidt & Ferguson, but simplified it by uniting types C and D, and also E and F (types G and H occur only very locally in Sulawesi). Table 5 compares the climatic types. It should be noted that a sound comparison of the classifications of Schmidt & Ferguson and Troll is not possible, although both classifications are based on the number of humid months per year. This is because Troll defines his climatic types on a global scale and his classification is much less detailed for South-East Asia, or because his definition of a humid month is different from what Schmidt & Ferguson call a wet month. The climatic zones of Troll in Table 5 have been derived by comparing his (global) climatic map with the climatic maps of Indonesia and South-East Asia produced by Schmidt & Ferguson and Whitmore, respectively.

Peninsular Malaysia, most of Sumatra and Borneo, the eastern parts of the Philippines, central Sulawesi and most of New Guinea have rainfall type A (perhumid). Rainfall type B (slightly seasonal) is found in southern peninsular Thailand, some areas in northern, western and southern Sumatra, south-western Java, southern and eastern Borneo (and northern Sabah), the central part of the Philippines, parts of southern, northern and eastern Sulawesi, most of the Moluccas, and parts of New Guinea (particularly in the south). Rainfall type C+D (seasonal) occurs in most of Thailand, Indo-China, a small area of northern Sumatra, northern, central and eastern Java, the western parts of the northern and southern Philippines, parts of Sulawesi and the Moluccas, and parts of Papua New Guinea (but not in the centre and west). Rainfall type E+F (strongly seasonal) is confined to the extreme north of Sumatra, parts of East Java, most of the Lesser Sunda Islands and Timor, two small areas in western Sulawesi, Waigeo Island (Irian Jaya), and a small area around Port Moresby (Papua New Guinea). In seasonal climates, water stress during the dry season may cause tree growth to stop.

The mean temperature usually falls by approximately 0.6°C for every 100 m increase in altitude. Rainfall tends to increase with elevation up to a certain altitude, but then it decreases. At higher altitudes solar radiation is more intense than in lowlands, but the average annual duration of sunshine in the cloud zone is less, thereby making the total solar radiation less than in the lowlands. These factors have a profound influence on the composition, structure and productivity of forest vegetation, and give rise to altitudinal zonation, although scientists disagree about the details of how forests are influenced by this change in climate.

The existence and extent of forest in a certain area influences the climate, primarily because of the evapotranspiration. This is a complicated subject on which knowledge is improving, but is still very incomplete. See Bruijnzeel (1990) for more detailed information.

1.5.2 Soils

Edaphic conditions can also give rise to distinct forest formations. The major soil groups are (Dudal, Moorman & Riquier, 1974):

- Entisols (alluvial soils and regosols). Young sediments without prominent horizons; occurring in floodplains, valley bottoms, coastal zones, footslopes and volcanic areas throughout South-East Asia.
- Vertisols (grumusols). Dark, heavy clay soils with well-developed horizons; found in Indo-China, central Thailand, eastern Java, the Lesser Sunda Islands and Luzon.
- Inceptisols (andosols and acid brown forest soils). Young, shallow soils, weathered from volcanic ash under humid conditions and found in areas subject to continual erosion; occurring in volcanic areas and on mountains and steep hills throughout South-East Asia.
- Spodosols (podzols). Very acid, bleached, light-textured (sandy) soils with horizons rich in organic matter and iron oxides; occurring in lowlands, particularly in southern Thailand, eastern Peninsular Malaysia and Borneo.
- Alfisols (especially red-yellow podzolic soils and red-brown earths). Neutral to acid soils, especially kaolinitic clays. These are the dominant soils in South-East Asia, occurring all over the region but particularly in the western part.
- Oxisols (dark red, reddish-brown, red and yellow latosols). Acid, clayey or more sandy soils; occurring in western Thailand, Sumatra, Java, Bali, Borneo, the Philippines and the Moluccas.
- Histosols (organic soils). Acid soils with over 30% organic matter, peaty soils in poorly drained situations; occurring commonly in Peninsular Malaysia, eastern Sumatra and Borneo.

Soil erodibility is a very important soil characteristic and should be considered in relation to forestry activities. Oxisols are much less erodible than entisols, inceptisols and alfisols. Mountains and hills must have sufficient forest protection in order to prevent erosion.

Soil fertility should be maintained in forest plantations. Short rotation periods may rapidly impoverish the soil, making fertilization necessary.

1.5.3 Forest classification

Whitmore (1984) distinguished major forest formations on the basis of climatic and edaphic conditions. The forest formations are briefly described below, and some characteristic trees are mentioned. For convenience, some of Whitmores formations have been combined.

- Tropical lowland evergreen rain forest. This is the predominant forest formation in South-East Asia; it occurs in places where water stress is absent or only brief and intermittent, from sea-level up to 1200 m altitude. It has the largest number of species. In western Malesia dipterocarps are dominant (especially species of the genera *Shorea*, *Dipterocarpus*, *Dryobalanops*, *Parashorea* and *Anisoptera*). The forest trees are very tall.
- Tropical semi-evergreen rain forest. This type of forest formation is predominant in the seasonal regions of South-East Asia; it occurs in places with regular annual water stress due to rainfall regime or soil conditions (e.g. marginally to evergreen rain forest in Indo-China and Thailand, in the Lesser Sunda Islands and in rain-shadow areas in New Guinea). It includes both evergreen and deciduous trees. The number of species is high but less than in the evergreen rain forest, and it contains fewer dipterocarps.
- Heath forest (also called 'kerangas'). Heath forest develops over coarse siliceous deposits giving rise to podzols. It occurs particularly in Borneo. The storey formed by large saplings and small poles predominates and the canopy is low and uniform. Dipterocarps, mainly heavy-wooded species, are often dominant among the larger trees (e.g. *Cotylelobium*, *Hopea* (giam) and *Shorea* (balau) species); other common trees include *Cratoxylum*, *Eugenia* and *Agathis* species. Heath forest should not be exploited because of its fragility. Natural regeneration is often very slow because of the extreme poverty of the soil.
- Forest on limestone and ultrabasic rocks. Limestone hills provide a diversity of habitats and soils but the forest has no commercial value. Forest on ultrabasic rock is often derived from the surrounding forest and sometimes not clearly demarcated from it, but may in other places have a distinct species composition.
- Beach vegetation. On the beach ridge (the low ridge at the inland margin of a sandy beach) a vegetation type is found that is called the *Barringtonia* association. It forms a forest fringe that is seldom more than 50 m wide. Typical tree species include *Barringtonia asiatica*, *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Cocos nucifera*, *Terminalia catappa* and *Hibiscus tiliaceus*.
- Mangrove and brackish-water forest. These forest formations occur in estuaries, deltas and mud flats subjected to regular tides. Brackish water forest forms the inland edge of mangrove forest. Typical species are *Avicennia*, *Bruguiera*, *Rhizophora* and *Sonneratia* species, and also *Excoecaria agallocha* and the palm *Nypa fruticans*. Mangroves are (or were) valuable sources of firewood, charcoal, tannin and poles for piling and scaffolding; *Rhizophora* species produce chipwood. See Tomlinson (1986) for more detailed information.
- Peat-swamp forest. A very special type of forest is found on peat soils, which are acid and fed only by rain water. It is particularly widespread in eastern Sumatra, near the coasts of Peninsular Malaysia, Borneo and Irian Jaya.

The forest often has distinct zones from the outer part of the peat swamp to the inner part. Characteristic species are: *Copaifera palustris*, *Cratoxylum arborescens*, *Dactylocladus stenostachys*, *Dryobalanops rappa*, *Gonystylus bancanus*, *Shorea albida* (northern Borneo) and *Tetramerista glabra*. Several of these species are very interesting from a commercial point of view (for timber).

- Freshwater swamp forest. This type of forest occurs where the soil is regularly inundated with mineral-rich fresh water. The pH of the soil is higher than in peat swamp. The swamp may be permanent, or the soil surface may dry out periodically. Freshwater swamp forest occurs over large areas near big rivers, for instance in New Guinea. Some typical trees are *Alstonia*, *Campnosperma*, *Dyera*, *Melaleuca* and *Palaquium* species. Freshwater swamp forests are generally of low commercial value except for some areas with almost pure stands (e.g. *Campnosperma* stands in Malaysia and Papua New Guinea).
- Monsoon forest and tropical moist deciduous forest. These forest formations occur in a seasonal climate where water is periodically limiting to plant growth. They occur over large areas in Burma and Thailand, and only locally in Malesia (in rain-shadow areas). The trees are usually deciduous, and the undergrowth is regularly burned. The most important commercial timber species is teak (*Tectona grandis*); other characteristic species are *Dalbergia latifolia* (Thailand, Java) and *Eucalyptus* species (Papua New Guinea).
- Montane forest formations. By comparison with lowland rain forest, the montane rain forest has a lower canopy, with fewer, smaller emergent trees. Upper montane rain forest has a low, flattish canopy, with slender trees often with gnarled limbs and dense subcrowns, and has a sharp lower boundary. Lower montane rain forest merges into lowland rain forest; the lower boundary of montane forests depends on the region. Trees occurring in seasonally dry sites in the lower montane zone are *Pinus* and *Araucaria* species. *Shorea platyclados* is by far the most common lower montane dipterocarp in Peninsular Malaysia, and in New Guinea lower montane forest is often dominated by *Castanopsis* and *Nothofagus* species.

1.6 Properties

The wood properties of the timber trade groups are treated under the heading 'Properties' of each entry. The Table on wood properties of selected species (see pages 475–499) gives the physical and mechanical properties of species for which information is available. The different wood characteristics (in the order in which they are dealt with in the entries) are discussed briefly below.

- Colour. The colour is important for application of the wood as well as for identification. For this reason, it is described both in the Section 'Properties' and in the Section 'Wood anatomy'.
- Density and moisture content.

$$\text{Density} = \frac{\text{weight (kg)}}{\text{volume (m}^3\text{)}} \text{ at a certain moisture content.}$$

Often the density is given at a moisture content of 15%, but sometimes at

other moisture contents (when no information is available at 15%). The moisture content greatly influences the density.
The moisture content is determined by measuring the weight of the water in the wood, expressed as a percentage of the dry weight of the wood (approaching 0% moisture content). The moisture content before drying is

$$\frac{\text{weight before drying} - \text{dry weight}}{\text{dry weight}} \times 100\%$$

The moisture content of green (fresh) wood can be much more than 100%, especially in lightweight timbers having comparatively little wood substance and large cell cavities. It can also be measured by using an electric moisture meter.

- Grain and texture. The grain defines the arrangement or alignment of wood tissue. The texture is largely determined by the size and arrangement of the vessels, differing from very fine to coarse. Grain and texture influence the uses of wood (e.g. for veneer) and also contribute to its identification.
- Mechanical properties. Mechanical properties (strength properties) are important to determine the structural use of wood. They represent the resistance of the wood to certain external forces which cause tension and deformation. Strength properties of wood largely depend on the density and moisture content, which is why these are cited (where known) for species in the section 'Selection of species'.
  The mechanical property data have been obtained using either the American ASTM (American Society for Testing Materials) method D143-52 or the British Standard No 373. These testing systems are roughly identical. However, sometimes the test samples used differ in size and shape (e.g. for determination of the shearing strength); then the figures are not completely comparable between the systems. For most tests, wood specimens (without defects) of 50 mm × 50 mm and of various length are used. Strength values of wood in general use are also influenced by defects, duration of loading, moisture content and dimensions.
  The modulus of rupture is a measure of the load-carrying capacity in bending until breaking occurs. The modulus of elasticity measures the stiffness of beams or long columns. Compression tests on comparatively small wood specimens parallel (maximum crushing strength) and perpendicular (stress at limit proportionality) to grain give the figures for compression strengths. The shear strength measures the resistance of wood when the forces acting on it tend to make one part slide over another in the direction parallel to the grain. Cleavage (resistance to splitting) is of importance when wood is to be nailed or bolted; it may differ considerably with the plane of cleavage, with radial splitting occurring more readily than tangential. The Janka hardness is the load required to embed a steel ball to half of its diameter, causing a depression of 100 mm^2; Janka end hardness is determined on transverse sections, Janka side hardness is the average of tests on radial and tangential surfaces. Janka hardness is a measure of the resistance of the wood to indentation, and also indicates the ability to withstand abrasion.
- Shrinkage and drying. Shrinkage figures are given from green condition to 15% and/or 12% moisture content and/or oven dry. Shrinkage causes defor-

mation of wood during drying when it is high and when it differs considerably in radial and tangential direction. Information is given on the response of the wood to air drying (seasoning) and kiln drying. For kiln drying, schedules used in Indonesia (recommended temperatures and corresponding relative humidity) or Malaysia (kiln drying schedules, see Table 6) are given in the entries. The Malaysian kiln drying schedules are designed for use with timbers up to about 40 mm thick, dried in a forced draught kiln. Thicker dimensions require somewhat higher humidities to prevent severe moisture gradients from developing. When drying timber 40–75 mm thick, the relative humidity should be 5% higher at each stage of the appropriate schedule, and 10% higher with wood 75 mm or more thick.

Table 6. Kiln drying schedules in Malaysia (Malaysian Timber Industry Board, 1986).

Moisture content[1] (%)	Temperature (°C) (dry bulb)	Temperature (°C) (wet bulb)	Relative humidity (%)
Schedule A			
Green	35	30.5	70
60	35	28.5	60
40	38	29	50
30	43.5	31.5	40
20	48.5	34	35
15	60	40.5	30
Schedule B			
Green	40.5	38	85
40	40.5	37	80
30	43.5	39	75
25	46	40.5	70
20	54.5	46	60
15	60	47.5	50
Schedule C			
Green	40.5	38	85
60	40.5	37	80
40	43.5	39	75
35	43.5	38	70
30	46	39.5	65
25	51.5	43	60
20	60	47.5	50
15	65.5	49	40
Schedule D			
Green	40.5	38	85
60	40.5	37	80
40	40.5	35.5	70
35	43.5	36	60
30	46	36	50
25	51.5	38	40
20	60	40.5	30
15	65.5	44.5	30

Table 6. Continued.

Moisture content[1] (%)	Temperature (°C) (dry bulb)	Temperature (°C) (wet bulb)	Relative humidity (%)
Schedule E			
Green	48.5	46	85
60	48.5	45	80
40	51.5	46.5	75
30	54.5	47	65
25	60	49	55
20	68	53	45
15	76.5	58	40
Schedule F			
Green	48.5	44	75
60	48.5	43	70
40	51.5	43	60
30	54.5	43	50
25	60	46	45
20	68	51	40
15	76.5	58	40
Schedule G			
Green	48.5	45	85
60	48.5	45	80
40	54.5	50.5	80
30	60	55	75
25	71	63.5	70
20	76.5	64	55
15	82	62.5	40
Schedule H			
Green	57	53	80
50	57	52	75
40	60	52	65
30	65.5	54	55
20	76.5	58	40
Schedule J			
Green	57	50.5	70
50	57	48	60
40	60	47.5	50
30	65.5	49	40
20	76.5	53	30
Schedule K			
Green	71	66	80
50	76.5	68.5	70
30	82	70.5	60
20	88	67.5	40

1. The moisture content given is of the wettest timber on the air-inlet side at which changes are to be made.

Kiln schedule A is suitable for timber which must not darken in drying and for timber which has a pronounced tendency to warp but is not particularly liable to check. Schedule B is suitable for timber that is very prone to check, and schedule G for very slow drying timber that is not particularly prone to warp (Pratt, 1986).

- Working properties. Much of the information given on working properties is highly subjective as they can only be described and are not quantifiable.
- Veneer and plywood. Veneers are thin wood sheets made by peeling (most common), slicing or sawing. Some timbers can be peeled without pretreatment, but sometimes heating by steaming or boiling is needed. The quality of the veneer is also influenced by the quality of the logs, thickness of the veneer and peeling angle. The bonding strength of plywood made of veneers is often evaluated by the Japanese JAS type II standard, the German DIN 68075–IW 67 standard or the British standard.
- Durability and treatability. Durability is usually classified in 4 (tropics) or 5 (temperate regions) groups (see Table 7). The usual way to test durability is to bury test sticks of 50 mm × 50 mm in cross section of the heartwood in the ground. The actual service life of timber in common usage is often considerably longer. Sapwood is much less durable than heartwood, usually perishable. The durability classification in Indonesia differs slightly (see Martawijaya et al., 1986). In addition, durability classifications in Indonesia exist which are based on the resistance to wood-destroying fungi (in laboratory tests) and the resistance to dry-wood termites (*Cryptotermes cynocephalus*).
  The treatability of wood depends on the permeability for preservatives. Classifications are for heartwood only (sapwood is usually more permeable) and should be used with caution because evaluations are non-standard. Some classifications are based on pressure-treating systems, others on non-pressure systems, and a wide range of specimen sizes, with or without end coatings, is used.
- Chemical properties. The chemical composition of wood is important for the yield and quality of pulp. Cellulose is the basic material for pulp which is used for the manufacture of paper. For good paper, a low percentage of lignin is required. Pentosan functions as inter-fibre bond in paper manufacture. The solubility in solvents such as alcohol-benzene, cold and hot water and NaOH solution is related to pulp production, especially to the quantity of chemicals required to process the pulp.
  A high percentage of silica easily blunts sawteeth, but can make wood resistant to marine borers, together with suitable organic substances.

Table 7. Natural durability grouping (life (in years) in contact with the ground).

Classification	Wet tropics	Temperate regions
Very durable	> 10	> 25
Durable	5–10	15–25
Moderately durable	2–5	10–15
Non-durable	0–2	5–10
Perishable		< 5

- Energy value. The energy values as given in the entries are for oven-dry wood. They vary within a small range, roughly between 17000–21000 kJ/kg. A high energy value indicates suitability as fuel.

1.7 Wood processing

The global timber trade started with the export of logs from the resource-rich countries in the tropics to industrialized western countries where almost all the wood-processing industries were located. With gradual industrialization, the developing countries began to establish the relatively less capital-intensive and simple saw milling industries to convert the logs into sawn timber of different dimensions. To fetch higher prices, a system of grading was introduced. The Malaysian Grading Rules for Sawn Hardwood Timber are still widely used in the timber trade. For higher added value, an increasing quantity of sawn timber is kiln dried before shipping.

The veneer, plywood and blockboard industries were the next major primary processing industries to expand in the resource-rich countries. The manufacture of veneer and plywood requires the input of large and round logs, whereas the core of blockboard is usually made from the peeler cores. Malaysia has a well-developed and export-oriented plywood industry which produced 1.5 million m^3 of plywood and 0.7 million m^3 of veneer in 1991 in its 99 factories. The growth of the Indonesian plywood industry is impressive: the plywood/veneer production capacity increased from 4.6 million m^3 to 8.2 million m^3 from 1985–1988, and the export of plywood (produced in 108 factories) reached 8.5 million m^3 valued at over US$ 3000 million in 1990. The large outputs of processed wood from Malaysia and Indonesia have led to the decline or demise of similar industries in Korea, Singapore, Taiwan and Japan, which were traditionally dependent on log supply from Malaysia and Indonesia.

The growth of primary processing industries invariably generates a substantial amount of wood residues providing the impetus for the development of other wood-based industries which can utilize small logs and wood chips. There is a considerable increase in particle board production in the countries of South-East Asia. Research has further indicated the suitability of rubberwood for the production of medium-density fibreboard (MDF) which is in high demand for furniture manufacture. Several MDF plants have been established in Malaysia during the last 3 years and a similar development trend has been observed in Thailand and Indonesia.

With the increase in literacy, the demand for pulp and paper is growing rapidly. Thailand, Indonesia and Malaysia have increased their pulp and paper production in the last few years, based either on pulp from indigenous tree species, plantation wood and bamboo, or recycled fibre.

The current emphasis in most resource-rich countries is to further promote downstream value-added processing industries within the countries and to control, limit and even ban the export of logs and rough-sawn timber. Semi-finished products in the form of mouldings, laminated timbers and furniture components have become important export items. Several countries have even ventured into the production of finished products such as furniture, doors and utensils for export.

It is expected that in the near future very few countries will remain in the business of exporting logs, rough-sawn timber or general utility plywood. The global timber market will be offered a wide range of further processed products from the resource-rich countries. The sawn timber exported will be mostly in kiln-dry condition and the plywood will be available with various types of overlays ready for specific uses, including the phenolic film-faced concrete shuttering board and container flooring. Most countries in the tropics are now concentrating on securing a share of the lucrative wooden furniture market through increased production of high-quality and well-designed furniture.

1.8 Forest management

Forested lands are managed for a multiplicity of purposes, usually with one dominant use, most often timber production. The basic aim of forest management is to keep forest lands productive. 'Sustainable forest management is the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment' (ITTO, 1992). Important activities involved in forest management include forest valuation, forest inventory and forest management planning, and yield regulation.

There is increasing awareness of the great value of forest for local people, and that they should profit from the various forest products in the first place. Socio-economic aspects of forest management are considered very important at present.

1.8.1 Forest valuation

The procedure of determining the monetary and other value of a forest is called forest valuation. The value of forests is the sum of various products and services which fall into three major groups:

- Timber and non-timber products from trees.
- Wildlife products and products from non-woody plants.
- Intangible products and services expressed in terms of 'forest influences' and 'environmental value'.

The value of a forest is often expressed in the value of the standing timber, known as the 'stumpage value'. It is based on the expected selling price of the timber products minus the estimated costs for production, profit and risk allowance (Buttrick, 1943). The approach for stumpage value appraisal is simple in principle, but the application has many complications because forest stands vary largely in terms of the size and quality of the timber produced. The valuation of forest on a sustained yield basis is much more difficult, and the contribution of non-timber forest products and forest functions complicates the determination of the value even more.

1.8.2 Forest inventory and forest management planning

Forest inventory

Forest inventories can be conducted at various levels: per country (national forest inventory), in large forested areas (e.g. 100 000 ha) and in stands for the preparation of forest management plans. A most useful operation is a combination of partial inventories at the various levels (FAO, 1981):

- Reconnaissance of the forested area by photo-interpretation (and some field plots) to estimate the areas covered by each forest type.
- Vegetation mapping of a selection of forest reserves (with complementary field plots) to roughly estimate the growing stock of each forest type.
- Detailed inventory of the most valuable forest areas.

The following inventory methods are implemented in Indonesia, and to varying degrees in other countries:

- Terrestrial inventory. This includes 'reconnaissance surveys' which are low-intensity inventories to provide rough estimates of forest condition for an assignment plan for concession holders; 'management unit forest inventory' to provide more detailed information for long-, medium- and short-term management plans and carried out by concession holders; 'cruising' implemented by government forestry staff to check outcomes of the inventory by private concession holders; and 'forest land-use inventory' to provide information for better forest land-use.
- Remote sensing techniques. This includes interpreting satellite imagery to obtain information on ground cover and forest classification; interpreting of small-scale aerial photographs (1 : 100 000) to obtain information on existing land-use, forest vegetation stratification and forest type classification; interpreting medium- to large-scale aerial photographs (e.g. 1 : 20 000) for more detailed information on forest types based on canopy structure, accessibility and land for non-forest use; and ground check to revise the interpretation map and to construct volume tables.
- Volume tables. Volume tables are used to estimate stand volumes from aerial photographs (crown closure percentage and average stand heights). They are best applicable for pure stands and for forest of relatively homogeneous condition.
- National forest inventory. This country-wide inventory includes monitoring of forest resources (forest cover types, assessment of changes) and an assessment of forest resources (forest stratification, growth and yield studies, construction of volume functions, compilation of results).
  The national forest inventory of Indonesia started in 1988 and is scheduled to last 7 years. The first inventory in Peninsular Malaysia was carried out in 1970–1971, the second in 1981–1982, and the third was completed at the end of 1992. The first state-wide forest inventory in Sabah was conducted in in 1969–1972. The current forest resource inventory in Sarawak is being done with the aid of aerial photographs of scale 1 : 25 000; in 1985 41% of the total forested land had been inventorized. In the Philippines, forest classes or strata are mapped into forest resources condition maps (of scale 1 : 50 000) with the help of aerial photographs.

The lack of 'tree spotters' (persons who are able to recognize tree species in the forest by characteristics of buttresses, bark, cut or slash, exudates, fallen leaves, habitat, etc.) often hampers inventorying and controlling timber stands in the multi-species rain forest. The education and training of tree spotters should be an important part of forest inventory and management plans.

Forest management planning

Planning poses special problems in forestry because of the longevity of trees, the geographical extent of forest estates and the uncertainties of nature and market. The conventional planning tool in forestry is the forest management plan, which was largely developed in Germany in the 19th Century (Lanly, 1991). Forest management plans can be divided into three parts:

- General background and foundation material. This includes the purposes of management, accessibility to markets, social and economic considerations and general description of the forest. This kind of information does not change rapidly, is not a part of a specific action plan, and can best be prepared and applied to larger forest units.
- Specific information on the forest. Area, stocks, stand classification, condition, growth, cutting history and records, etc. The basic data consist of maps, cruise sheets and results of inventory, and the material is filed and kept current; it is the basic factual background.
- The plan proper. This is the action part, what is to be done. The key part is the regulatory framework determining the allowable cut by years or other periods of time, and the specific cutting budget for the period immediately ahead. The plan should also define action strategies regarding silvicultural and protection needs as directly relating to timber production, should correlate these with other uses, and provide for continuity.

There must be close links between those who prepare a forest management plan and those who are to administer it, and flexibility to meet the dynamics of a constantly changing situation.

1.8.3 Yield and yield regulation

The term 'yield' in forestry is used in two ways. Firstly, it expresses the flow of forest products harvested from a forest at a particular time or during a particular period. Secondly, it is used to express the volume or amount of forest products that may be present in a stand at a given time, or attainable over a period of time, without reference to whether it is actually harvested or not. A yield table gives the volume of forest products (timber) that can be expected per unit of area for a given age, site, stocking, and method of management (Davis, 1966).
The actual yield of a timber plantation or natural timber stand is the timber volume per ha harvested by clear-cutting or selective cutting when the rotation age has been reached. The yield can also be expressed on an annual basis (mean annual volume increment) by dividing the yield volume by the number of years of the rotation cycle. The eventual yield of thinnings can also be taken into consideration.
Clearly, the prime criterion for yield is increase in the volume of a forest. This differs considerably between natural and planted forest, different site condi-

tions and species. For a mixed-species tropical rain forest under good silvicultural management, a mean annual volume increment of bole timber of 8 m^3/ha is considered very high, but plantations of conifers and eucalypts may reach an exceptional annual increment of 50 m^3/ha. It should be realized that the actual annual volume increment (which can be estimated by girth or diameter increment and height growth) is not linear during the growth cycle. In general, the growth of trees follows a sigmoid curve with an initial slow phase followed by a phase of accelerating growth ('building phase'), finally slowing down and ultimately showing minimal growth ('mature phase').

Good yield regulation in natural forest requires the periodic removal of timber of mature trees, resulting in an equalization of the periodic yield. A balanced distribution of size or age classes is important to obtain sustainable yield, and good attuning of the yield to the forest condition is very important but difficult. In a certain area of production forest the yield can be controlled by dividing the total area by the number of years of the rotation to provide annual working areas. Differences in site quality can lead to adjustments of the size of the annual working area.

1.8.4 Socio-economic aspects of forest management

The need for agricultural land and demand for forest products is increasing with the fast-growing populations in South-East Asia. Conflicts of interest concerning forested land cannot be avoided, but eventually people are realizing that forests are indispensable for the community, economically as well as ecologically.

Foresters are increasingly acknowledging that more attention should be paid to the needs of indigenous populations in the forest and adjacent areas. This is manifested in new approaches to forest management and forest use, which can be generalized as 'social forestry' or 'community forestry', in which agroforestry practices are usually, but not always, included. 'Social forestry is the science and art of growing trees and/or other vegetation on all land available for the purpose, in and outside traditional forest areas, and managing the existing forest with intimate involvement of the people and more or less integrated with other operations, resulting in a balanced and complementary land use with a view to provide a wide range of goods and services to individuals as well as the society' (Tiwari, 1983).

Social forestry aims to meet, at least partly, the basic needs of the local population, i.e. food, medicine, fuel, timber, rattan, fodder, income and a good environment. It often concerns the use of forest products in a non-commercial manner, directly involving the beneficiaries concerned in the operations. In addition, it may also involve stimulating commercial forest utilization by local people instead of commercial logging enterprises, and stimulating the manufacture of forest products at village level. In these activities, attention is given not only to timber but also to non-timber products. The forester has to assume another role than that of forest manager and guard, since there must be cooperation with local populations (Noronha, 1982). This new role calls for changes in forestry education. 'If you want people to love the forest, first love the people' (Atmosoedaryo, 1978). Forestry agencies have abundant knowledge of timber stand management, soil and water conservation, and silviculture, but they

have limited experience working with communities to manage forest lands (Poffenberger, 1990).
At present, social forestry principles are more and more systematically applied in forestry programmes. It is a participatory approach in sustainable forest management. Case studies for Indonesia, Malaysia, the Philippines and Thailand are briefly discussed below.

Indonesia

Programmes to control shifting cultivation were started in the early 1970s in an attempt to minimize adverse effects by introduction of economically promising perennial crops for degraded lands and better soil conservation techniques, provision of wage labour employment, and intensive extension and training. The programmes are implemented by various agencies such as the Ministries of Forestry, Agriculture, Transmigration, Social Affairs and Home Affairs. The total number of shifting cultivation households involved in the different programmes is approximately 125 000.
A social forestry programme was started in 1984 in Java, organized by Perum Perhutani (Government Forest Corporation) and supported by the Ford Foundation, with the following objectives (Bratamihardja, 1987): reforesting and restoring degraded forest lands, increasing the income of farmers living in the vicinity, and improving the relations between Perum Perhutani field staff and forest farmers. Important key activities are the establishment and development of forest-farmer associations, and application of suitable agroforestry techniques.

Malaysia

An example of involving community development aspects in establishing industrial plantations is the programme of SAFODA (Sabah Forest Development Authority), concurrently promoting the establishment of forest settlements (Udarbe, 1987). The objectives of this programme are to convert wasteland and marginal agricultural land into productive forest land, to supplement the production of timber and non-wood forest products from natural forests with products coming from man-made forest, to encourage and promote active participation of the people in reforestation and afforestation, to provide mass employment, to raise the living standard of the people through forest settlement schemes, and to introduce forestry-oriented land management practices. People from villages inside the forested area are offered permanent employment and accommodation in the plantation; their income is supplemented by agroforestry projects.

The Philippines

Shifting cultivation, locally known as 'kaingin', accounts for at least 50% of total forest conversion in the Philippines. Other practices contributing to loss of forest are legal and illegal logging operations, forest fires and diseases and pests (Bayabos, 1988; Payuan, 1987). Until the early 1960s the response of the government to the problem of forest destruction was to prosecute shifting cultivators, but then there was a change of orientation towards community development, leading to the implementation of people-oriented forestry programmes. In 1982 the Integrated Social Forestry Programme (ISFP) was launched; it aims to raise the socio-economic conditions of forest occupants and communities and at the same time to help develop and conserve forest resources. Documents are issued by the Bureau of Forest Development to leaseholders, giving them the usufruct right of forest land, but committing them to conserve and protect the forest.

Thailand

Programmes which include logging permits for local wood cutters, intercropping in forest plantations (taungya system), allocation of woodlots as a source of fuelwood, integrated watershed development and voluntary tree planting programmes, were started in the early 20th Century and later consolidated in social forestry programmes in the Fifth National Economic and Social Development Plan (1982–1986). A programme for granting usufruct certificates was initiated in 1979. Under this programme the land is divided into two zones, the upper watershed area which is restricted and kept forested, and land that can be used for agriculture, which is granted to farmers under a certificate in areas not larger than 2.4 ha. The purpose of granting usufruct certificates is to give incentives to invest in the land, making it more productive, and to prevent further encroachment into forested land. In 1987 almost 100 villages were under the aegis of the forest village programme adopted by the Royal Forest Department (Pragtong, 1987).

Several socio-economic studies have examined the importance of forest utilization by rural people. An example is a study focusing on the socio-economic conditions of logging crew workers in peat-swamp areas (ramin (*Gonystylus*) forest) in Sarawak. It covers social and demographic aspects, income, consumption, health and working conditions (Ghani, 1987).

Another example is a study in planted teak forest in Java focusing on the villagers living around the forests. Besides its protective function, teak forest plays an important role in providing the basic needs of people such as food, fuel, fodder and employment. Food is mainly produced through taungya. The volume of fuelwood collected per household ranges from 10–20 kg/day, and most of the fuelwood (70–100%) is extracted from the forest (Kartasubrata, 1990).

'Who are the rightful forest keepers' is becoming a major political question and an issue behind social conflicts (Poffenberger, 1990). The controversy between tribal versus legal/state ownership of forest should also be seen in terms of sustainable management. Forest communities of South-East Asia possess a wealth of knowledge about how to sustainably manage forest lands to meet their needs. The practice of sustainable forest resources management, of which non-timber forest product collection is an element, is a hallmark of the economy of traditional forest dwellers (de Beer & McDermott, 1989).

1.9 Silviculture

Silviculture is the branch of forestry dealing with the establishment, development, care and regeneration of stands of timber trees, with the aim of sustainably producing timber and other products and services. In fact, silvicultural practices and controlled harvesting techniques are parts of forest management.

1.9.1 Silvicultural systems in natural forest

A silvicultural system is a system of procedures and methods by which trees in the forest are harvested, regenerated and tended for sustainable production, resulting in the development of distinctive types of forest.

At present, there are three broad silvicultural systems which could be applied to natural forests in South-East Asia (Tran, 1974; Soerianegara, 1976):

- The selective felling system. In this system all activities are carefully described and planned. It prescribes a diameter/girth limit, induction of natural regeneration, timber stand improvement and enrichment planting, reservation of trees for future harvest, a cutting cycle and a maximum annual allowable cut. Silvicultural systems of this type have been applied in the Philippines (Philippine selective logging system, PSLS), Indonesia (Indonesian selective felling system, TPI/TPTI), Malaysia (sustained yield selective felling system (SYSF), also referred to as selective management system (SMS) for hill dipterocarp forest, liberation thinning in Sarawak), Thailand (girth limit) and Vietnam (diameter/girth limit).
- The tropical shelterwood system. In this system several preparatory fellings are performed to improve the forest stand and promote natural regeneration, with the final felling being undertaken when natural reproduction has been established. This system was previously practised in Malaysia in lowland dipterocarp forest.
- The uniform system. This is essentially the tropical shelterwood system minus the preparatory fellings. The tree crop is harvested in a single operation if a prelogging inventory has shown that natural reproduction is satisfactory in terms of numbers and distribution. This system was applied in Malaysia for lowland dipterocarp forest (Malayan uniform system, MUS) and could be applied in Indonesia (clearfelling with natural regeneration, THPA).

1.9.2 Silvicultural procedures for natural forest management

Cutting of climbers and lianas liberates the crowns of trees. It is often necessary after serious interventions in natural forest (logging, thinning) because many species of lianas respond to improved light conditions by vigourous growth. The operation usually has to be repeated once or twice during the cutting cycle. During gradual transformation of natural forest (i.e. modifying the forest for economic reasons), undesirable trees must be removed by cutting (trees with small bole diameter) or by poisoning with arboricides (trees with large bole diameter). The arboricides used are often phytotoxic substances or synthetic growth hormones; phytohormones are considered less toxic to humans and animals.

Thinning is sometimes necessary, depending on the silvicultural system used. It may promote regeneration and improve growth of young trees by allowing more light to penetrate the canopy.

Planting is sometimes practised in logged-over natural forest. Trees are planted along cleared lines in the forest (conversion planting). Occasionally, planting in prepared openings or natural gaps is carried out to enrich natural forest (enrichment planting), usually using indigenous species.

1.9.3 Forest plantation systems

Poorly stocked natural forests and degraded land can be converted into timber tree plantations (forest plantations) by sowing or planting. This system is called clearfelling with replanting (artificial regeneration). Three types of forest plantation establishment are distinguished (FAO, 1976):

- Afforestation. The establishment of forest on land which previously (at least within 50 years) was not forested.
- Reforestation. The establishment of forest on land which was previously forested; it involves the replacement of tree species by other, more productive species.
- Artificial regeneration. The establishment of forest on previously forested land using essentially the same tree species as before.

The purposes of establishing forest plantations are manifold, not only for supplying raw materials for wood-based industries (pulpwood, sawn timber, etc.), but also for providing fuelwood and charcoal, to establish or rehabilitate protection and amenity forests, and to conserve rare and endangered tree species. Fast-growing species are usually preferred.

1.9.4 Silvicultural procedures for forest plantation systems

Species selection

Choosing the species to be planted in a plantation project is very important. The decision should depend on the purpose of the intended plantation, the species potentially available for planting, and the growing conditions of the sites.

If a plantation is planted for fuelwood or woodpulp, fast growth with early culmination of maximum growth rate is an important criterion for species selection. Large tree sizes are unimportant or even disadvantageous, and coppicing ability is desirable. For fuelwood the tree shape is unimportant, but for pulpwood straight stems facilitate rapid debarking. Wood properties are also important; the wood must dry quickly, have a low ash content, and burn steadily without smell and sparks (fuelwood), or have an appropriate fibre length, colour and extractives content (pulp wood). Examples of species chosen for large-scale industrial plantations are *Acacia auriculiformis*, *Acacia mangium* (fuelwood, pulp), *Anthocephalus chinensis* (pulp), *Eucalyptus* spp. (pulp), *Gmelina arborea* (fuelwood and pulp), *Leucaena leucocephala* (fuelwood), *Paraserianthes falcataria* (pulp) and *Pinus* spp. (pulp).

Species planted in plantations for producing sawn timber or veneer/plywood must have moderate to fast growth and be able to grow to large size. A good form is important, with good natural pruning. For sawn timber the strength, seasoning and working properties, durability and preservation are important. For veneer/plywood the peeling quality, figure and bonding strength are important. Examples include dipterocarp species, *Agathis* spp., *Swietenia macrophylla* and *Tectona grandis* (all for sawn timber as well as veneer/plywood).

Most forest plantations are monocultures, but sometimes mixed plantations are established. In the latter case, the species should have similar purposes or end uses and rotation when planted in alternating lines, but this is not necessary when planted strip- or block-wise.

Propagation and planting

Growing seedlings in a forest nursery is the major method of raising planting stock. Obtaining adequate amounts of good seed is usually an important part of a plantation programme. The aim of seed collection is to obtain large quantities of seed of the best genetic quality. Sometimes seeds are collected from production plantations, but often from seed stands or seed orchards. They can be collected from the ground (e.g. teak, *Gmelina arborea* and several dipterocarps), but sometimes cones or fruits must be collected from the trees (e.g. *Pinus*, *Araucaria* and *Swietenia* species). The ability of seeds to remain viable varies greatly. Dipterocarp seeds usually have a short viability and can be stored for only comparatively short periods, but hard-coated seeds of many legumes can be stored for several years without difficulty. Seed viability is usually prolonged by low-temperature storage, by drying to low moisture content and by treatment with fungicides.

Methods of vegetative propagation are gaining importance as a way to maintain stock with superior characteristics obtained by breeding. Cuttings, air layering, budding and grafting are used to produce planting stock. Cuttings are most often used. The success depends on the stimulation of root formation and growth. Removal of leaves, the use of misting equipment (reducing transpiration stress) and the use of growth hormones may give better results. Planting stock produced by tissue culture is sometimes available, but this method is still in an experimental stage.

Tree seedlings are raised in the nursery either in an open bed from which they are lifted and planted with bare roots, or in individual containers which are taken to the planting site and planted with a clod around the roots.

Mycorrhizal inoculation of seedlings is often essential for good growth, e.g. for pines and dipterocarps. Adding soil from healthy stands to the potting mixture or the seed-bed can give good results; another method is to grow mycorrhizal mother trees in the nursery bed. Techniques for the mass propagation of dipterocarps by shoot cuttings have been developed in the Tropenbos-Kalimantan project (Wanariset, East Kalimantan).

Often, seedlings are hardened off before planting into the field by reducing the amount of water.

The planting distance and the chosen thinning regime are among the most important silvicultural decisions. Spacing varies from 2 m × 2 m to 4.5 m × 4.5 m (5 m × 5 m or wider is usually confined to enrichment planting). Initial spacing depends on the desired product: for firewood and pulpwood the quantity of wood is of sole importance and close spacing is desirable; for sawn timber and veneer production wider spacings are desirable to obtain large log sizes, although spacing should be close enough to promote straight boles.

Direct sowing into the field has been found reliable with only a few large-seeded species such as *Gmelina arborea*, *Swietenia macrophylla* and *Tectona grandis*.

Weeding, thinning and pruning

Competition from weeds can cause seedlings to die. Selecting a weed-free nursery site reduces the need for direct weed control. Chemical weed control is largely restricted to nurseries raising conifer seedlings because the chemicals kill seedlings of broad-leaved species. Hand weeding is commonly practised. Nearly all plantations require some weeding during the first few years until the trees are approaching canopy closure. The removal of vines and creepers may be needed for many years.

Thinning usually starts 2–4 years after canopy closure. Thinning is practised to encourage crown development which results in bole diameter increment, to remove inferior trees and favour vigorous trees, and to provide an intermediate financial return from sale. The commonest form of selective thinning is removing trees in the lower canopy classes; it is largely a speeding up of natural thinning processes. The first thinning should be done before the live-crown ratio (see Paragraph 1.4.4) is reduced too much (usually below 30–40%).

Pruning is done to produce knot-free timber. It also gives easier access to timber stands and reduces the damage caused by fire. Several species show natural pruning, with dead branches falling off (e.g. pines and *Anthocephalus chinensis*). Artificial pruning is particularly important where wide spacing and heavy thinning are practised, and in plantations planted for the production of veneer/plywood and high-grade timber. Branches are sawn off flush with the trunk, often using a specially curved saw. Pruning is usually done several times, with each successive cutting round somewhat higher, until the required length of pruned stem is reached. Pruning is often carried out in association with thinning; it is considered a value-adding operation.

Fertilization

Fertilizers are used to establish plantations on infertile sites, and to promote optimal growth. Fertilizing at planting is most widely practised. Enrichment of soil nitrogen is also possible by interplanting with legumes such as *Leucaena leucocephala*. This is done in the Philippines to improve the growth of mahogany (*Swietenia macrophylla*), kadam (*Anthocephalus chinensis*) and teak (*Tectona grandis*).

Diseases and pests

Numerous organisms can harm trees. Monoculture plantations are particularly susceptible to diseases and pests.

In nurseries damping-off diseases caused by fungi (especially *Fusarium*, *Penicillium*, *Phytophthora*, *Pythium* and *Rhizoctonia*) often occur. Seedlings die when tissue near the root collar rots, causing them to topple over. Nursery hygiene, quarantine measures, soil sterilization and adequate drainage of the soil can reduce the risk of damage, and direct control of damping-off disease is possible with fungicides.

Fungi causing damage in plantations include *Armillaria*, *Corticium* and *Ganoderma* species, and sometimes the causal pathogens are bacteria (e.g. *Pseudomonas*) or viruses.

In general, a particular insect problem is localized to certain nurseries or plantations and species. Defoliators and stem- or shoot-borers most commonly cause damage. Correct identification of the pest is important for appropriate control measures, but this is not always easy. Insecticides are generally used for direct control, but often other control measures are possible, such as biological control, switching to less susceptible tree species, and avoiding practices favourable to the organism (for instance, removing the waste wood from the forest floor after thinning may prevent insect pests from developing).

Forest fire

Fire is often an important danger facing a newly established plantation. Forest fire prevention includes establishing fire-breaks along the forest boundary and between compartments, consisting of less flammable tree species or cleared ground, reducing the quantity of combustible materials on the forest floor, usually by controlled burning, and choosing less susceptible species. It is advantageous to make a forest fire prevention and suppression plan for each forest plantation unit and to use a fire danger rating system in relation to climatic conditions. It is essential to have an appropriate communication system. For successfully fighting forest fires, a sufficient quantity of water is needed and fire beaters and bulldozers are useful to make temporary breaks.

Felling and replanting

When a timber plantation has reached the rotation term (i.e. the planned number of years between planting and felling) it is clear-cut and replanted. The rotation period depends on the species, the end-use of the timber and the site quality. Good-quality teak often needs a rotation of about 80 years. The rotation of fast-growing species planted for pulpwood is usually only about 8 years. Site conditions for the second rotation are often different from those when afforestation began. Typical weeds of the first rotation have often been suppressed but there may be prodigous natural regeneration of the former crop, and stumps may produce coppice shoots. Of course, natural regeneration and coppicing can also be used to produce a second crop of the same species. However, the soil structure may have changed, making it necessary to use different silvicultural practices.

1.10 Timber harvesting and post-harvest handling

Timber harvesting can be described as the felling of trees and extraction of usable tree parts (logs) from the forest. Its aim is to supply the timber market and wood-processing industry with raw material. A number of logging techniques are typical for tropical forest exploitation. These techniques are adapted to the type of forest to be harvested: dry-land rain forest, freshwater swamp forest, peat-swamp forest, mangrove forest or plantation forest.
Nowadays the rain forests in South-East Asia are largely logged using heavy mechanical equipment. Trees are felled with power saws and transported by crawler tractors or wheeled skidders towards forest roads or navigable rivers. In steep terrain, cable yarders such as the high-lead logging system, are used

to transport logs downhill. Further transport of logs to processing areas is carried out with heavy trucks and trailers along forest roads or rivers, on barges (pontoons) or as rafts. The actual harvesting process is characterized by a high degree of logging damage and waste of harvested timber.
In Indonesia, the Philippines and Malaysia efforts have been made in recent decades to bring the rain forest under regular management in order to guarantee sustained timber production while conserving the forest. The Indonesian selective felling and replanting system (TPTI) aims at limiting and controlling felling intensity and promoting regeneration through post-harvesting treatment. The selective management system was developed in Malaysia to achieve sustained timber production through modern forest management. The Philippines introduced a system of controlled logging in 1953 for montane forest, which has to be harvested carefully to avoid erosion and land degradation. Although these logging and management systems are compulsory for concessioniares, they are difficult to implement, and control by national forest authorities is hampered by remoteness of logging areas, inadequate infrastructure, and lack of institutional staff and means of transport.
Manual transport methods are used to harvest freshwater and peat-swamp forests, or operations can be mechanized with the aid of light cable (yarding) and rail systems. A species such as ramin (*Gonystylus bancanus*) is regularly harvested in this way in Kalimantan and Sarawak.
End coating or S-hooks may prevent logs from splitting and developing end checks. The logs of timber species which are very susceptible to fungal and insect attack should be treated with fungicides and/or insecticides soon after logging, or they should be extracted immediately from logging areas and processed rapidly. Examples of such timbers are kauri (*Agathis* spp.), pulai (*Alstonia* spp.), kadam (*Anthocephalus chinensis*), sesendok (*Endospermum* spp.) and ramin (*Gonystylus* spp.).
Plantation forests are becoming increasingly important for the timber supply in South-East Asia. Not only the old established teak plantations in Java, but also other man-made forests of fast-growing tree species are beginning to play a significant role in meeting the demands for construction and industrial timber. These forests are harvested manually or with animal traction (in the Philippines buffaloes are used, in teak forests in Java cows and in Thailand elephants) but also with light skidders, agricultural tractors and cable yarders. Plantation forests offer better opportunities for sound logging and sustainable management, especially with regard to damage control and replanting.

1.11 Agroforestry and urban forestry

Trees and forests may serve other needs and functions than merely timber production. They are becoming increasingly important in integrated land-use development, which involves integrating plantation forestry and agricultural land-uses, and also planting and maintaining forest for recreational and aesthetic value.

1.11.1 Agroforestry

In 1989 ICRAF (International Commission for Research on Agroforestry) gave the following definition: 'Agroforestry refers to 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 other components of the system'.

Many distinctive agroforestry systems can be distinguished on the basis of their components and their temporal and spatial arrangements; the most important main groups are:

- Systems with tree components predominating.
- Mainly agrosilvicultural systems (trees with crops).
- Mainly or partly silvopastoral systems (trees with pastures and livestock).

Agroforestry systems can be productive (food, fodder, fuelwood and also timber) as well as protective (e.g. soil conservation, soil fertility improvement, windbreak and shelterbelt). They may also be classified using socio-economic criteria, depending on production and level of management. Some agroforestry systems are very briefly discussed below.

The taungya system is practised on forest land. Tree seedlings are planted (with wider spacing than in normal plantations) at the same time or shortly after food crops. Food crops usually continue to be grown until canopy closure of the trees. In Java the taungya system is called 'tumpangsari' and is particularly applied in the establishment of teak plantations (usually interplanted with *Leucaena leucocephala*), but also plantations of pines, *Agathis* spp., rasamala (*Altingia excelsa*) and mahogany (*Swietenia macrophylla*) in mountainous areas. The interplanted food crops include upland rice, maize, pepper, and in mountainous areas also cabbage, tomato, potato and onion. Important advantages of this system are the suppression of *Imperata* grass and the low establishment costs of forest plantations. A recent development is the intensification of cropping. Within the conventional system, farmers were allowed to intercrop for only 2 years, but in the new 'full rotation agroforestry' system, intercropping spans the entire cycle of the forest stand (Bratamihardja, 1990). In Malaysia the taungya system is also practised; banana, maize and upland rice are planted between rows of teak, yemane (*Gmelina arborea*) and pines; cocoa and rattan between rows of rubber trees (Hamsawi, 1990). Bananas, sweet potatoes and taro are grown in Papua New Guinea for up to 3 years in newly established teak plantations, passion fruit in pine (*Pinus patula*) plantations in the highlands, and papaya, pumpkins and chillies in *Araucaria* plantations (Evans, 1982). Examples of agroforestry practised successfully in the Philippines include the combination of coffee and pines (*Pinus kesiya*) and plantations of *Paraserianthes falcataria* (for pulpwood) combined with small areas planted with agricultural crops (Lasco & Lasco, 1990). In Thailand the taungya system is integrated into the reforestation scheme of the rural development programme ('modified taungya system'), and there is multistorey mixed intercropping ('home gardens'). A multistorey agroforestry garden system having a forest-like appearance is practised in western Sumatra, characterized by the integration of tree species from the forest and commercial crops.

Many other systems are applied in South-East Asia, such as the improved fallow system with fast-growing multipurpose trees, especially in shifting cultivation areas. The main objective of these systems is, however, not the production of timber, but the production of agricultural crops, non-timber products, soil protection, grazing of livestock, etc., and the systems are often practised on a small scale. For more information on agroforestry systems, see the Prosea volume on auxiliary plants in agriculture and forestry.

1.11.2 Urban forestry

Trees are planted as a contribution to the well-being of the urban population. They provide shade, give wind protection and intercept precipitation. Engineering uses of trees include erosion control and watershed protection, uses in wastewater management, noise and air pollution abatement, and glare and reflection control. The architectural and aesthetic uses are evident around buildings and parks (landscape architecture), and trees provide habitats for certain animals. Parks and forests in and near cities are important for recreation. Cities where urban forestry plays an important role include Singapore and Kuala Lumpur.
The Prosea volume on ornamental plants deals with species and aspects of ornamental and roadside trees.

1.12 Forest and timber policy

1.12.1 Global

Forests are very important worldwide. Land classified as forest covers more than 4000 million hectares, or about one-third of the earth's land surface. Of the total forested area, 58% is found in developing (mostly tropical) countries. The social and economic importance of natural and planted forests and trees for rural and urban communities and society as a whole is enormous. Forests provide industrial wood products, energy (fuelwood), food (e.g. fruits, meat), fodder, medicinal products, rubber, gums, resins, fibres etc. Forests are also extremely important ecologically, protecting land and water resources, storing and cycling nutrients, and providing habitats for wildlife. They have an important regulating function in maintaining the stability of the global biosphere in relation to carbon dioxide equilibrium. Forests constitute a rich stock of valuable genetic resources.
The concept of the word 'forest' is often a source of confusion in discussions and figures about deforestation and afforestation. The term is used both for natural undisturbed forest and for plantations of fast-growing tree species which often consist of exotics. The act of logging the natural forest and replacing it by industrial plantations of trees is called 'deforestation', for instance, by persons connected with nature conservation, but often not by foresters. Forests subject to comparatively minor human interference such as selective logging, may already differ considerably from undisturbed forests. In fact, figures on deforestation should be interpreted carefully, as they give far from complete information about disturbance to the forest.

Causes of deforestation

It is estimated that an area of 17–20 million ha of forest disappears each year. Global re- and afforestation required to counterbalance the losses is estimated

to be at least 100 million ha. However, according to FAO figures, annual planting of new forests in the tropics was only 1.1 million ha at the end of the 1980s. Global deforestation is the result of the following actions, in sequence of decreasing importance:
- Conversion into temporary farmland through shifting cultivation.
- Conversion into permanent farmland through large-scale clearance.
- Cutting by rural populations for firewood.
- Clearance for large-scale livestock farming.
- Destructive cutting for commercial exploitation of industrial timber.
- Construction of infrastructural facilities.

Conversion into farmland is by far the main cause of forest degradation; it is often estimated to be responsible for about 80% of deforestation. The direct responsibility of commercial logging for deforestation is comparatively small. The ultimate role of logging in global deforestation is often estimated as much greater since logging operations open the forest (e.g. by roads and other infrastructural facilities necessary for transporting the timber) and facilitate other human interferences. In fact, logging is of secondary importance when compared with other causes of deforestation which lie in complex socio-economic factors. Rapid human population growth, poor economic development and neglect of rural areas outside the forests are the major influencing factors. Rural development towards sustainable agriculture in rainfed areas is of the utmost importance to create sufficient food production and employment for small farmers living next to the forest. Raising incomes and living conditions on a sustainable basis will relieve the pressure on forests. An alliance of forestry and agriculture is needed (Otto, 1990).

Rain forest and climate

The role of the rain forest for the absorption of carbon dioxide and the production of oxygen, and the influence of the percentage of these substances in the atmosphere, is difficult to quantify. The ratio of carbon dioxide absorption and oxygen production is more favourable in plantations of young, growing trees than in undisturbed rain forest which is in equilibrium. However, rain forests are considered to play an important role in climatic regulation. At the same time, the exact influence of the destruction of rain forest on the climate is not known. Climatic change tends to be attributed solely to the destruction of forest over large areas, and there is a tendency to neglect other causal factors. For instance, the irregularly recurrent droughts in Borneo which cause the death of many trees and increase the incidence of forest fires, are not of recent date, as is often assumed, but have been occurring for centuries. However, the waste wood left behind after logging makes the forest more liable to fire. Moreover, climate is most probably considerably influenced by volcanic eruptions and worldwide human and industrial pollution.

Global policy to protect the rain forest

In many timber-importing countries environmental organizations lobby to restrict or even boycott the use of tropical timber and to use substitutes such as synthetic materials, metal or preserved timber of planted temperate species. It is argued that most tropical timber comes from forests which are not sustainably managed, and that restricting imports helps to slow down deforestation. Experts from international organizations such as the United Nations, the International Tropical Timber Organization (ITTO) and FAO have warned that restrictions to the import of tropical timber may be counterproductive, because they may eliminate a potentially important stimulus for conservation of forests. Moreover, an increasing amount of the timber is used domestically and does not enter international trade.

The magnitude and gravity of the problem of tropical deforestation and land degradation has been acknowledged as one of the most serious threats to mankind in recent history. Without immediate action to resolve this crisis, more plants and animals will disappear, more watersheds be degraded, more valuable forest products be destroyed, and more people will suffer from the effects. It is extremely difficult to agree upon the best world policy concerning the exploitation and protection of tropical forest, but there is a general consensus about a number of important matters.

There is a tendency towards production forests which are managed and harvested in a sustainable way. Members of large organizations such as the ITTO have expressed the hope that, by the year 2000, all tropical timber will be obtained from forests managed sustainably. It is generally agreed that completely protected forest reserves of sufficient extent should be maintained or created to protect flora and fauna. A combination of logging operations and sufficient protection of endangered species is often only possible to a limited extent. Climax species (i.e. species characteristic for mature-phase natural forest) are poorly adapted to the nomadic existence imposed on them by logging cycles and are liable to extinction. Many countries have acknowledged the importance of the development and implementation of large-scale programmes to afforest degraded land. Achieving greater land-use integration by combining agriculture and forestry is a way to slow down deforestation and should be stimulated. However, the administrative difficulties in implementing such schemes and their complexity are daunting. Ultimately, the decision about world policy should be based upon a correct balance of all interests and functions of the forest. Weighing one against another is not easy and may differ per country and area. International cooperation is indispensable. One of the initiatives to build up international cooperation is the Tropical Forestry Action Plan (TFAP), coordinated by FAO and achieved with the help of the World Bank, the World Resources Institute and the United Nations Development Programme (FAO, 1985). The International Union for the Conservation of Nature and Natural Resources (IUCN) also plays a coordinating role through its forest conservation programme. Recently, the United Nations conference on environment and development in Rio de Janeiro (1992) produced the Rio Declaration and the Forest Principles, which call for enhancing a global partnership dedicated to the sustainable development of the world's forest resources.

1.12.2 Regional

The rate of deforestation in South-East Asia (Vietnam, Thailand, Malaysia, Indonesia, the Philippines and Papua New Guinea) was approximately 1.7 million ha per year in the period 1985–1990 (Collins et al., 1991).

In general, a shift in forest and timber policy in South-East Asia is noticeable. Logging is subjected to rules of varying strictness, reforestation is accentuated, and attempts are made to manage forests sustainably. Research is focusing on reforestation and species to be used for this purpose. Enrichment planting is one research topic and is already practised locally. Much research has already been done and lack of knowledge is no longer a barrier to action. The major obstacles are the lack of political and financial incentives to apply recommendations of researchers, and insufficient control of application of the rules.

Since the 1970s, there has been greater cooperation among ASEAN countries (Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand) through regional projects, seminars, workshops, training, exchange of forestry material and field travels. The 1981 Jakarta Consensus on ASEAN tropical forestry was an important result. It covers numerous major topics in forestry, but the declared policies have hardly been pursued in the individual countries.

In South-East Asia there is a trend towards upgrading wood products within the log-producing countries in order to raise the value of exported products. The export of logs is prohibited or limited by levies, and sometimes even the export of sawn timber and other semi-manufactured wood products is restricted. Part of the money collected from levies is invested in the local wood-processing industry and used for reforestation. Basic forestry policies are all geared principally towards sustained productivity, multiple use, maintainance of a healthy environment, the establishment of permanent forest estates, alleviation of poverty, equitable distribution of wealth and providing employment opportunities (Oliva, 1989). However, the priorities vary per country.

The governments of the major exporting countries (particularly Indonesia and Malaysia) object to the import boycotts on tropical timber proposed by environmental organizations in the industrialized western countries. The revenues are a prerequisite to finance general economic development.

1.12.3 National

Brunei

Since 1986 Brunei Darussalam has had a Forestry Master Plan. It allows forests to be managed to yield forest products for domestic consumption and for the expansion of forest industries. Moreover, it allocates forest areas for functions such as ensuring a sufficient and clean water supply, maintainance of soil fertility and minimization of soil erosion, conservation of nature and wildlife, education, research and recreation. There is not much pressure on Brunei's forest resources because of the high standard of living and the comparatively low population pressure. However, part of the natural forest is being converted to plantations to increase the timber production to meet future domestic consumption.

Indonesia

The Indonesian governments national forestry plan states that the following should be the principal objectives of forestry in Indonesia:

- Proper utilization of forest resources. Logging operations and wood process-

ing should be intensified, and lesser-known timbers should be utilized. New resources are established through reforestation.
- Development of nature conservation, by protecting areas and intensifying management of nature conservation programmes.
- Accumulating knowledge about the extent, potential and condition of forest resources by conducting a national forest inventory for the preparation of national plans and policy decisions.
- Ascertaining the definite status and suitability of forest land through land-use planning.

All log exports were banned in 1985, but this was repealed in 1992; now high export taxes are applied.

The problem of long-term land utilization in Indonesia is closely related to the population size and its uneven distribution between Java and the other islands. The transmigration programme necessitates opening up and converting forest land.

The reforestation and industrial forest plantation programmes consist mostly of planting fast-growing species (pines, eucalypts, *Acacia mangium*, *Paraserianthes falcataria*) for pulp production and light timber for local use, apart from the teak plantations in Java.

Malaysia

Under the Malaysian constitution, land and forest are defined as the responsibility of the individual states and are thus within the jurisdiction of the respective states of Peninsular Malaysia, Sabah and Sarawak. Forest policy is formulated independently within each state. The National Forestry Council (NFC) was established in 1971 in order to facilitate the adoption of a coordinated and common approach to forestry. The NFC formulated a national forestry policy in 1978, of which the most important points are:
- Establishment of permanent forest estates and protection against destructive agents.
- Practice of sound forest management and encouragement of multiple use of forests.
- Promotion of integrated timber industries and efficient utilization, employment of modern scientific principles and appropriate technology, and upgrading of forestry research, education and training.
- Promotion of sound development of trade and commerce in forest products, and promotion of public awareness in the understanding of forestry.

Whereas the responsibility for timber production and forestry is mostly implemented at state level, conservation within Malaysia is both a state and a national issue.

The pressure on natural forest because of logging is still high, particularly in Sabah and Sarawak. A reduction of the export of round logs from these states and more investment in local wood-processing industry has started, and may slow down the rate of deforestation.

Specific legislation protecting tree species is very limited. In Sarawak, *Dipterocarpus oblongifolius* has been declared a protected tree; other protected trees under Sarawak's Wildlife Protection Bill 1990 are six *Shorea* species (producing edible nuts) and both *Koompassia* species. Furthermore, belian (*Euside-*

roxylon zwageri) may not be exported without special permission. In Peninsular Malaysia there is a total ban on the export of logs. However, the main way to protect individual timber species is by establishing completely protected areas.

Papua New Guinea

The total operable forest area of 15 million ha is currently being cleared very rapidly and there is urgent need for changes in the national forest policy. The new Forestry Act came into operation in June 1992. The objectives include:
- Protection of forest resources and environment.
- Maximum participation by natives in forest exploitation as a renewable resource.
- Best utilization of forests to achieve economic growth and employment creation.
- Encouragement of scientific study and research into forest resources to achieve sound ecological balance.
- Increased acquisition and dissemination of forestry-oriented skills, knowledge and information through education and training.
- The pursuit of effective strategies for managing forest resources.

The new forest policy has two main objectives: firstly, to ensure the sustainability of the forest and, secondly, to harvest the forest in a way which will bring about economic growth, job creation and increased participation of native people in the forest and timber industries by more domestic processing.

Land and forests in Papua New Guinea are owned by the indigenous people by customary rights, unlike most countries in South-East Asia where forests are state-owned. The utilization of forest resources is subject to government control, and commercial harvesting and trade in forest products require a permit. Sustained yield management is the guiding principle for granting permits. Tree planting programmes such as timber plantation and woodlot establishment and agroforestry are encouraged. Ecologically important land is allocated for conservation purposes in agreement with traditional land owners.

Most of the timber harvested is still exported as logs (except conifers, *Fagaceae*, ebony (*Diospyros* spp.), kerosene wood (*Cordia subcordata*), teak, rosewood (*Pterocarpus indicus*) and black bean (*Castanospermum australe*), for which log exports are banned).

The Philippines

In the Philippines, where the reduction in forested land has been the greatest of all South-East Asian countries in recent decades, the principal forestry legislation is the Forestry Reform Code, promulgated in 1975 by presidential decree. Its stated aims were as follows:
- The multiple use of forest lands shall be oriented to the development and progress requirement of the country, the advancement of science and technology and the public welfare.
- A land classification survey shall be systematized and hastened.
- The establishment of a wood-processing industry shall be encouraged and rationalized.

- The protection, development and rehabilitation of forest lands shall be emphasized so as to ensure their continuity in productive condition.

The most recent developments and regulations regarding national forest and timber policy are:

- Reduction of timber operating licensees to reduce pressure on existing timber resources.
- A shift in the utilization and management of forest resources from private concessioniares to local communities. There is also a shift of implementation of reafforestation from the government to the private sector (communities, non-governmental organizations, private individuals) on a contract basis.
- A total ban on commercial logging in all remaining virgin forests starting in 1992. In secondary forests, the smaller diameter timber should be utilized sustainably.
- In addition to a total ban on log export, there is a ban on cutting undersized trees (less than 60 cm diameter). Some tree species are completely protected (*Pterocarpus indicus, Agathis philippinensis, Diospyros ferrea, Diospyros digyna*).

Although regulations are very strict, there are major problems in controlling illegal cutting for timber and in limiting the destruction of forest by shifting cultivation.

Burma (Myanmar)

The forest policy in Burma was formulated already in 1894. Four main classes of forest were distinguished: protection forest, commercial forest, local supply forest and nature reserve forest. With slight modifications, this classification is still maintained today (San Maung, 1989). The present guidelines are to replace the logged areas with plantations, to increase the area of state-controlled forest and to establish new areas of completely protected forest (nature reserves).

Thailand

Over the last 25 years, Thailand has lost about 45% of its forests (Oliva, 1989). In 1985 the National Forest Policy was formulated, with the objective to manage and develop forest resources on a continuing basis. At present, forest policy is geared more towards forest conservation and development, because of problems of deforestation. In January 1989 the Ministry of Agriculture and Cooperatives ordered a halt to all logging concessions.

Vietnam

Major aspects of the timber policy adopted by the Vietnamese government for the coming years are:

- A reorganization of the national forestry organizations.
- The establishment of a sound system of granting permits for timber harvesting.
- The strengthening of afforestation programmes in order to achieve an area of planted forest of 150 000 ha by 2005.

- The diminishing of export of unprocessed timber by imposing levies or by prohibiting the export.

1.13 Biodiversity, conservation and breeding

Biodiversity can be conserved at three levels: ecosystem, species and population.

The forest formations described in Paragraph 1.5.3 can serve as a framework for the conservation of ecosystem diversity. A sufficient area of each formation should be conserved by being designated as nature reserves, taking into account that variation of individual formations may be large over the whole area, and therefore the conservation areas must be carefully chosen. In fact, very little is known about the size of area needed to conserve adequately populations of species, let alone complete ecosystems, and consequently conservation areas should, in principle, be large, since conserving adequate habitat is the underlying principle (Whitmore, 1984). Some types of forest are much more subject to logging or other human interferences than others, and are therefore disappearing more rapidly. Lowland evergreen rain forest, which is the most valuable kind of forest for logging and which is often first converted into agricultural land because of easy accessibility, is particularly vulnerable. Moreover, it needs special attention as it is the richest in species. Several national parks or nature reserves exist in name only and are not free from detrimental influences. Adequate control is sometimes difficult.

It is difficult to conserve tree species as long as logging is done at trade group level and little attention is paid to inventorying stands of individual species. In addition, species vary over their area of distribution, and therefore the complete area must be considered when taking conservation measures, in order to maintain their genetic diversity.

CITES (Convention on International Trade in Endangered Species of wild Fauna and Flora) can be invoked to protect species, although attempts to include commercially important timber species (e.g. *Gonystylus* spp. and *Intsia* spp. in South-East Asia, *Swietenia macrophylla* in South America) have failed. However, control of trade in certain species is only possible if the product (timber) is recognizable and this seems impossible to achieve within trade groups which include numerous species.

In general, conservation of the genetic diversity of species should be realized in situ, but occasionally ex situ conservation can play an important role. Endangered trees should be planted in plantations or botanical gardens. Enrichment planting is usually restricted to commercially important species, but it could be extended by using endangered species as well.

The genetic diversity of a species is very important for breeding programmes. Natural stands of species are important sources of genetic material for tree improvement programmes which aim at improving characteristics (e.g. better wood quality, pest resistance) and productivity. The use of suitable provenances, adapted to certain environmental conditions, is a first prerequisite for a successful programme. There are two main phases: the operational and the developmental. The objective of the operational phase is to produce seeds for planting, the developmental phase should provide a long-term, broad genetic base for continued breeding programmes.

Forest tree improvement encompasses the following activities:
- Investigating the variation in populations of tree species.
- Conducting provenance trials.
- Selecting and multiplying trees possessing desired characteristics.
- Storing the desired characteristics in a seed orchard.
- Crossing selected trees to obtain offspring possessing a combination of desired characteristics (breeding).
- Conducting progeny tests in plantations.

Supporting activities include studies on phenology, the biology of flowering and fruiting, breeding systems, cytogenetics, and vegetative propagation. Tissue culture has given new impetus in forest tree improvement.

1.14 Forestry research in South-East Asia

1.14.1 Main research topics

Research priorities in South-East Asia are (Salleh, 1992):
- Forestry in relation to agriculture and rural development.
- Forestry in relation to energy production and use.
- Management and conservation of the natural tropical rain forests.
- Utilization, including value-added processing, of lesser-known species and of agricultural residues.
- Multiple use and resources of non-timber forest products.
- Environmental forestry including watershed and hydrology.
- Policy and socio-economics.

1.14.2 Main institutions

The main institutes and universities conducting forest research or engaged in forest products in the respective countries of South-East Asia are:

Indonesia

- Centre for International Forestry Research (CIFOR), Bogor
- Centre for Rehabilitation of the Tropical Rainforest, Samarinda
- Forest Products Research and Development Centre, Bogor
- Forest Research and Development Centre, Bogor
- Forestry Research Institute, Kupong
- Forestry Research Institute, Manokwari
- Forestry Research Institute, Pematang Siantar
- Forestry Research Institute, Samarinda
- Forestry Research Institute, Ujung Pandang
- Institut Pertanian Bogor, Bogor
- Institute for Reforestation Technology, Banjarbaru
- Institute for Reforestation Technology, Palembang
- Pusat Penelitian dan Pengembangan Biologi, LIPI, Bogor
- SEAMEO, Regional Centre for Tropical Biology (BIOTROP), Bogor
- Tropenbos–Kalimantan, Wanariset I Samboja Research Station, East Kalimantan

- Universitas Gadjah Mada, Yogyakarta
- Universitas Hasanuddin, Ujung Pandang
- Universitas Lambung Mangkurat, Banjarmasin
- Universitas Mulawarman, Samarinda
- Universitas Pandjadjaran, Bandung
- Universitas Tanjungpura, Pontianak

Malaysia

- ASEAN Institute of Forest Management, Kuala Lumpur
- ASEAN Timber Technology Centre, Kuala Lumpur
- Forest Research Institute Malaysia (FRIM), Kepong
- Malaysian Timber Industry Board, Kuala Lumpur
- Malaysian Timber Industry Development Council, Kuala Lumpur
- MARA Institute of Technology, Shah Alam
- Sarawak Timber Industry Development Corporation, Sarawak
- State Forestry Department, Sabah
- State Forestry Department, Sarawak
- Universiti Pertanian Malaysia, Serdang
- Universiti Sains Malaysia, Penang

Papua New Guinea

- Forest Management Research Branch, Port Moresby
- Forest Products Research Centre, Port Moresby
- Forestry College, Bulolo
- Papua New Guinea Forest Research Institute, Lae
- Timber Industry Training College, Lae
- University of Technology, Lae

The Philippines

- Ecosystem Research and Development Bureau (ERDB), Los Baños
- Forest Products Research and Development Institute, Los Baños
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños
- Don Mariano Marcos Memorial State University, Batac
- Ifugao State College of Agriculture
- Isabela State University, Echague
- Mindanao State University
- Tarlac College of Agriculture
- University of the Philippines, Los Baños
- Visayas State College of Agriculture, Baybay

Burma (Myanmar)

- Forestry Research Institute, Yezin

Laos

- Forestry College, Vientiane

Thailand

- Royal Forest Department, Bangkok
- Kasetsart University, Bangkok

Vietnam

- Forestry Research Institute of Vietnam, Hanoi
- Tropical Forest Research Centre, Hanoi
- Forestry College, Xuan Mai

1.15 Prospects

The anti-tropical timber campaigns in Europe and the United States, notwithstanding the scientifically weak position of several arguments (such as global warming), influence political and economic decisions in those countries, and will affect the international market potential of the South-East Asian hardwood timbers. Sustainable management of natural production forests and production of timber in plantations will eliminate the objections to using tropical hardwood. The International Tropical Timber Organization (ITTO, 1990) has expressed the hope that all tropical timber entering the international market will originate from sustainably managed forests or timber plantations by the year 2000. This will require an adequate system of labelling the timber obtained from sustainably managed forest. More efforts should be made to bring the forests of South-East Asia under a system of scientific forest management and controlled timber harvesting. As well as improving harvesting regulations, the forestry institutions should also be strengthened to perform their tasks of guarding and protecting the forest, and of guiding the loggers.

Undoubtedly, natural forests can be managed in a sustainable manner to produce a variety of high-quality hardwoods, but the felling systems, cutting cycles, and silvicultural practices such as enrichment planting need to be very carefully attuned to the type and conditions of the forest concerned. Much is known about harvesting and silvicultural practices, but they need further improvement through research. Dissemination of knowledge should be improved by education, training and extension, and aimed at forestry personnel as well as small farmers. To achieve sustainable management, timber extraction will have to be reduced in many forests. The prices of timber and wood products can be expected to increase considerably, which may make metal and synthetic materials more important as substitutes (e.g. for window frames) and wood more a luxury article on the international market.

The significance of forests goes far beyond their yield of timber. The functions of forests include such essential ones as climatic regulation, protection of environment and conservation of biodiversity. These functions are essential for life on earth and cannot be expressed in economic values. There is increasing recognition of the value of non-timber products of the forest such as rattans, bamboos, medicines, edible fruits and game. To maintain the full genetic diversity of plant and animal species, sufficient and representative samples of tropical rain forest must be permanently conserved. However, it is unreasonable to expect countries to conserve more than a small proportion of their forested land area as protected national parks, despite the increasing benefits from tourism. Comprehensive financial support from industrialized countries is indispensable.

The establishment of timber plantations can greatly contribute to timber production, but should be integrated in land-use programmes including agriculture. Timber production will be increasingly important in agroforestry systems. Modern breeding and propagation techniques can contribute to develop strains of plantation trees that are superior in productivity, wood quality and resistance to diseases and pests.

National forestry research organizations should be strengthened through financial support, training opportunities and links to institutions within and outside the region. The linkage can best be realized through networking mechanisms (Salleh, 1992).

In conclusion, it seems realistic to expect that in the future a reasonable level of timber production can be combined with decent forest protection, provided there is good collaboration between countries and disciplines, and all parties are prepared to make concessions. The integration of forestry in agricultural programmes and the execution of large-scale afforestation programmes will be important. Far-reaching decisions on timber policy and their implementation must not be postponed any longer, because time is running out.

I. Soerianegara & R.H.M.J. Lemmens

with contributions from P. Baas (wood anatomy), J. Hendrison (timber harvesting and post-harvesting handling), J. Kartasubrata (forest management, agroforestry and urban forestry), S.I. Wiselius (properties) & W.C. Wong (wood processing)

2 Alphabetical treatment of genera

Afzelia J.E. Smith

Trans. Linn. Soc., London 4: 221 (1798).
LEGUMINOSAE
x = unknown; n = 12 reported for several non-Malesian species

Trade groups Afzelia: heavy hardwood, *Afzelia javanica* (Miq.) J. Léonard, *A. rhomboidea* (Blanco) S. Vidal, *A. xylocarpa* (Kurz) Craib.

Vernacular names Afzelia (En). Philippines: tindalo (Tagalog), balayong (central), apalit (Luzon). Cambodia: beng. Laos: kha. Thailand: makha-mong (general), makha-luang (northern), makha-yai (central). Vietnam: g[ox].

Origin and geographic distribution *Afzelia* consists of some 15 species, most (about 10) of which are African. Three species occur in the Malesian region and are confined to eastern Sumatra, western Java, western and northern Borneo and the Philippines. *A. rhomboidea* is the most widespread Malesian species. One species is native to mainland South-East Asia (Burma, Indo-China, Thailand).

Uses *Afzelia* wood is highly valued; it is nicely figured and durable. It is regarded as one of the finest woods for high grade furniture, cabinet work, parquet flooring and interior finish. It is also used for house construction, mainly as door and window frames but also for beams, panelling, doors and stairs. Other general uses are wood handicrafts, musical instruments, agricultural tools, boats, waterwheels, carts and sleepers. A decorative veneer can be made from the wood, but the wood is often regarded as too hard and dense for making utility plywood.
The bark of *A. xylocarpa* is used for tanning cattle hides and goat and sheep skins. The fatty cotyledons of young seeds are edible.

Production and international trade The production of wood from *A. xylocarpa* in Thailand was 25 000 m³ in 1985, 28 000 m³ in 1986, 40 000 m³ in 1987, and 34 000 m³ in 1988. The wood is mostly used domestically to produce furniture and parquetry. The average price of sawn *Afzelia* timber in Thailand was US$ 430/m³ in 1985 and 1986, increasing to US$ 715/m³ in 1988. Production and trade figures are not available from other countries. *Afzelia* timber is not important in the trade in South-East Asia except for Thailand, although *A. rhomboidea* wood is highly valued in the Philippines for furniture and interior finishing. There is probably still some trade in the Philippines.

Properties *Afzelia* wood is heavy and hard. The heartwood is reddish-yellow, red to dirty red-brown, often with some streaks, and distinctly demarcated from the grey-white sapwood. The density is 850–900 kg/m³ at 15% moisture content. The grain is interlocked or sometimes straight (e.g. *A. javanica*), texture moderately fine to moderately coarse. Planed surfaces are often glossy.
For *A. xylocarpa* at 15% moisture content, the modulus of rupture is 95–125 N/mm², compression parallel to grain 53–65 N/mm² and shear about 17 N/mm². For *A. rhomboidea* at green condition (about 50% moisture content), the modulus of rupture is 84 N/mm², modulus of elasticity 11 000 N/mm², compression parallel to grain 33 N/mm², compression perpendicular to grain 12 N/mm², shear 12 N/mm², Janka side hardness 7635 N and Janka end hardness 7135 N.
The wood seasons well with little shrinkage and warping. It is moderately difficult to work, but easy in comparison with other high-density woods. The wood takes a high finish. It is very durable; the durability under exposure is about 10 years in tropical conditions.
The bark of *A. xylocarpa* contains catechol and pyrogallol; these chemical substances have tanning properties.

Description Medium-sized trees of up to 42 m tall; bole straight or twisted, branchless for up to 15(–20) m, up to 120(–180) cm in diameter, buttressed or not, or fluted; bark thin, smooth, grey, sometimes with brown or black spots, inner bark white to brown or red; crown often broad and sprawling. Leaves alternate, paripinnate with 3–9 leaflets; stipules very small and early caducous; leaflets opposite, leathery and usually glabrous. Inflorescence paniculate, terminal or lateral with puberulous peduncles. Flowers bisexual, rather large, with bracteoles shorter than the flower buds; receptacle elongate; sepals 4, imbricate, puberulous on the outer side; petal 1, orbicular or kidney-shaped with a long claw; fertile stamens usually 7, free or fused in the basal half, staminodes 2–4, rarely absent; ovary stipitate, with the stipe adnate to the tubular receptacle, with many uniseriate ovules, style elongate with a small dark stigma. Pod compressed, woody, glabrous, dark brown or black at maturity. Seed elliptical to orbicular, rather thick, with a prominent yellow to red aril. Seedling with epigeal germination; cotyledons succulent, hardly spreading; first two leaves opposite, subsequent leaves arranged spirally, first leaves often with somewhat larger leaflets.

Wood anatomy

– Macroscopic characters:

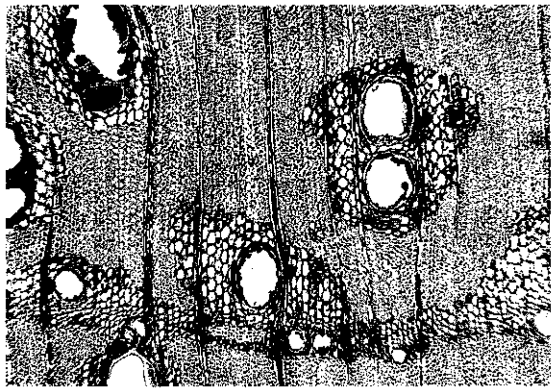
Heartwood dirty red-brown, distinctly demarcated from the grey-white sapwood. Grain straight. Texture moderately coarse. Growth rings usually distinct because vessels are absent in the inner part of a growth ring; in the remaining part, vessel diameter decreasing from inner to outer side; vessels just visible to the naked eye, in heartwood locally filled with a homogeneous red-brown mass; vasicentric parenchyma distinct, rays only visible with a lens; ripple marks absent.

– Microscopic characters:

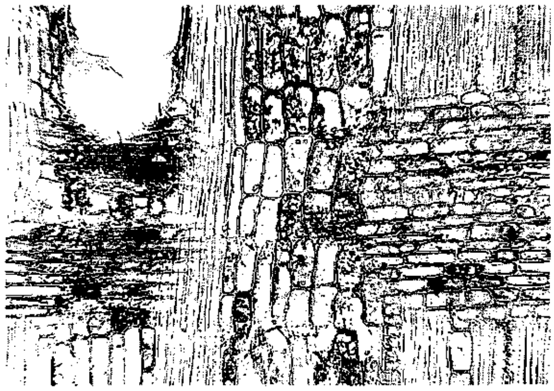
Growth rings boundaries marked by initial parenchyma and/or by a difference in vessel frequency. Vessels diffuse, usually absent in the inner part of a growth ring, 3–8/mm^2, solitary and in radial multiples of 2–4, solitary vessels often arranged in zones separated from zones with predominantly radial pore multiples, completely surrounded by parenchyma, round to oval, average tangential diameter 110–190 μm; perforations simple; intervessel pits alternate, distinctly vestured, hexagonal, 6 μm, often with coalescent apertures; vessel-ray pits numerous, vessel-axial parenchyma pits scarce to very numerous, both similar to intervessel pits but half-bordered. Fibres 450–675 μm long, non-septate, thick-walled, with simple pits confined to the radial walls; gelatinous layers often present, almost entirely filling up the fibre lumina. Axial parenchyma abundant, mainly paratracheal but also banded and apotracheal; paratracheal parenchyma vasicentric to winged-aliform, often developing into banded parenchyma; banded parenchyma present except in the inner part of a growth ring where vessels are often absent, 1–4 cells wide, some bands long in tangential direction, also initial; apotracheal diffuse parenchyma scarce, usually near paratracheal and banded parenchyma; parenchyma strands (2–)4-celled. Rays 6–10/mm, (1–)2–3(–4)-seriate, up to 5–25 cells high, homocellular, entirely composed of procumbent cells. Crystals prismatic, in chambered axial parenchyma cells. Deposits present in heartwood; vessels locally with red-brown gummy contents, also libriform fibres, axial and ray parenchyma often entirely or partly filled up with red-brown solid deposits or with colourless to red-brown grains. All elements non-storied.

Species studied: *A. javanica*.

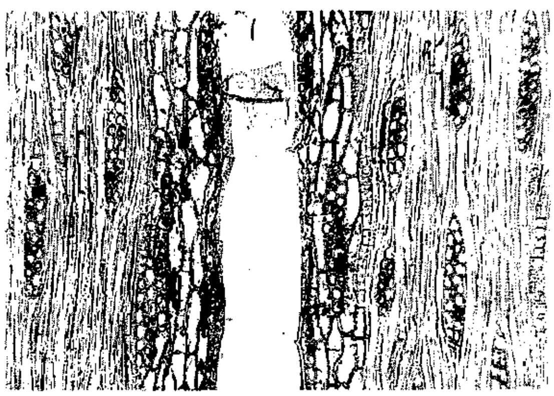
Growth and development Four-month-old seedlings of *A. xylocarpa* are 30–35 cm high; after 3 years they are 135 cm tall on average. As expected from the dense wood, *Afzelia* trees are slow



transverse section (×25)



radial section (×75)



tangential section (×75)

Afzelia javanica

growers. Mean annual girth increment is unknown.
A. javanica flowers in Java from October to November, *A. rhomboidea* in the Philippines from August to September. Fruits of *A. xylocarpa* in Thailand are fully mature in June to August.

Other botanical information The genus *Afzelia* is closely related to *Intsia*, differing only in the number of fertile stamens, the thicker and more woody pod and the arillate seed. The wood of *Afzelia* and *Intsia* is fairly similar. The Asian species were formerly placed within a separate genus, *Pahudia*, because they differ from the African species in having partly fused filaments. This feature has, however, been proved to be variable and consequently *Pahudia* has been united with *Afzelia*. *Afzelia* J.E. Smith is conserved against the older homonym *Afzelia* J.F. Gmelin, a genus of the *Scrophulariaceae*.

Ecology *Afzelia* occurs scattered in mixed deciduous and dry evergreen forests, usually on well-drained clayey or laterite soils but sometimes in periodically inundated places. It is found at low altitudes, up to 400 m within Malesia, but up to 900 m on the South-East Asian mainland. In Java, *A. javanica* is locally planted up to 800 m altitude. In the Philippines, tindalo (*A. rhomboidea*) is found on low ridges and hills near the coast and along the edges of dipterocarp forests.

Propagation and planting In Thailand, pods of *A. xylocarpa* are collected when they become brown or dark brown and before they split open. After air drying for one week, the pods are opened to retrieve the seeds, which are then cleaned. The seed weight of *A. xylocarpa* is 6.5–8 g on average. Before sowing, the aril is removed and the seeds are soaked in water for 24–72 hours. Soaking for one hour in a 20% solution of sulphuric acid promotes germination. The seeds are then sown in nursery beds or in pots filled with compost. The beds must be shaded (with a light reduction of 50%) and watered occasionally. Usually the seeds germinate in 1–2 weeks. Seedlings are often transplanted into containers filled with a mixture of black ash (25%), coarse sand (12.5%), green manure (12.5%) and garden soil (50%). They are planted into the field when about 35 cm tall, generally at 4 m × 4 m.

Silviculture and management *Afzelia* wood is usually obtained from natural forests which are managed under selective cutting systems. In Thailand, trees were formerly cut selectively in a 15–30-year-rotation. At present the minimum girth of the bole permitted for cutting is 200 cm at breast height (about 64 cm in diameter). Only a few plantations of *Afzelia* exist. In Thailand, *A. xylocarpa* is planted in mixed plantations, together with rosewood (*Dalbergia* spp.) and teak (*Tectona grandis* L.f.). In Java, *A. javanica* is planted very locally.

Diseases and pests Seedlings of *A. xylocarpa* in nurseries often suffer from damping-off, a disease caused by fungi such as *Phytophthora, Pythium, Fusarium* and *Rhizoctonia* spp. Seedlings are also attacked by larvae of insects such as longhorn beetles of the genera *Aristobia* and *Batocera*, but these pests are less serious in mixed plantations.

Harvesting As the branchless bole of *Afzelia* trees is usually not long and the wood is heavy, the logs prepared for transportation are usually short. The logs sink in water and must be transported over land. To prevent insect attack, the logs are debarked soon after cutting, and to prevent splitting they are coated at both ends with tar or lime.

Genetic resources Usually *Afzelia* trees occur scattered in the forest. As the timber is regarded locally as very valuable (e.g. in Thailand and the Philippines) the desire to cut the trees is great, and in the past exploitation has been considerable, at least locally. This makes the species liable to genetic erosion.

Prospects *Afzelia* yields a timber that can be used for many purposes. The supply is, however, limited. Planting is carried out on a very small scale. The establishment of mixed plantations seems promising, but more information on growth, propagation and silviculture is needed, in particular for the species occurring outside Thailand, about which almost nothing is known.

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Larsen, K. (Editors): Flora of Thailand. Vol. 4. TISTR Press, Bangkok. pp. 126–128. |**7**| Reyes, L.J., 1938. Philippine woods. Technical Bulletin No 7. Commonwealth of the Philippines, Department of Agriculture and Commerce, Manila. pp. 137–139. |**8**| Royal Forest Department, 1985. The Thai hardwoods. Technical Bulletin No R.188. 127 pp. |**9**| Santisuk, T. & Niyomdham, C., 1983. Leguminosae. In: Phengklai, C. (Editor): Thai economic trees. Part 3. ACFT Press, Bangkok. pp. 199–201. |**10**| Switachart, S., 1972. A study on seed germination of makha mong (Afzelia xylocarpa) by soaking in different concentrations of sulphuric acid. Technical Bulletin No R.138. Royal Forest Department, Thailand. pp. 5–10.

Selection of species

Afzelia borneensis Harms

Feddes Repert. 14: 256 (1916).

Synonyms *Pahudia borneensis* (Harms) Merr. (1917).

Vernacular names Malaysia: ipil darat (Sabah).

Distribution Sabah and Sarawak.

Uses The timber is used locally.

Observations A small to medium-sized tree of up to 25 m tall, bole up to 80 cm in diameter, buttresses thin and steep; leaves with 3 pairs of leaflets, leaflets 6–12(–17) cm × 3.5–6(–7) cm, sharply acuminate at apex, glabrous; fertile stamens about 4 cm long, style about 1 cm long; mature pod 6–9 cm × 3.5–5 cm. *A. borneensis* occurs scattered and locally in lowland and lower montane forest up to 1400 m altitude.

Selected sources 146, 184, 421, 477.

Afzelia javanica (Miq.) J. Léonard

Reinwardtia 1: 63 (1950).

Synonyms *Pahudia javanica* Miq. (1855), *Intsia puberula* Miq. (1860), *Pahudia puberula* (Miq.) Meijer Drees (1938).

Vernacular names Indonesia: (ki)julang, katarum (Java), merbau (Sumatra).

Distribution North-eastern Sumatra and western Java.

Uses The timber is used locally, sometimes as a substitute for merbau (*Intsia* spp.).

Observations A medium-sized to fairly large tree of up to 42 m tall, buttresses large, over 5 m high; leaves with 4–8 pairs of leaflets, leaflets 3.5–12.5 cm × 2.0–5.5 cm, rounded to acute or shortly acuminate at apex, pubescent on the lower surface when young; fertile stamens 2.5–6.5 cm long, style 4–5.5 cm long; mature pod 7.5–15 cm × 4–7.5 cm, the ventral suture straight, the dorsal one strongly curved. *A. javanica* occurs on clayey non-inundated soils and is locally common in both primary and secondary forest up to 500 m altitude. It is planted for local use up to 800 m altitude. The species is divided into two subspecies occurring on Java and Sumatra respectively. The one from Sumatra (subsp. *longiflora* de Wit) differs from subsp. *javanica* by having more leaflets per leaf and longer stamens.

Selected sources 35, 183, 184, 318, 421, 477.

Afzelia rhomboidea (Blanco) S. Vidal

Cat. Pl. Prov. Manila: 28 (1880).

Synonyms *Intsia rhomboidea* (Blanco) O. Kuntze (1891), *Pahudia rhomboidea* (Blanco) Prain (1901).

Vernacular names Indonesia: kupang, tanduk tarum (Sumatra). Philippines: tindalo (Tagalog), balayong (central).

Distribution Eastern Sumatra, northern half of Borneo and the Philippines.

Uses The timber is used for various purposes and is especially in demand for high grade furniture and cabinet work.

Observations A small to medium-sized tree of up to 30 m tall, bole branchless for up to 15 m and up to 80(–180) cm in diameter, buttresses absent; leaves with 4–5 pairs of leaflets (sometimes 3 on flowering branches), leaflets 7–8 cm × 4–4.5 cm, acute to acuminate at apex, usually glabrous except for the hirsute midrib on the lower surface; fertile stamens 4 cm long, style 3.5–5.0 cm long; mature pod somewhat rhomboid, 9–20 cm × 7–10 cm. *A. rhomboidea* occurs scattered on low hills and ridges, or on sites at low and medium altitudes temporarily inundated with fresh water. See also the table on wood properties.

Selected sources 100, 159, 175, 184, 421, 477, 485, 579.

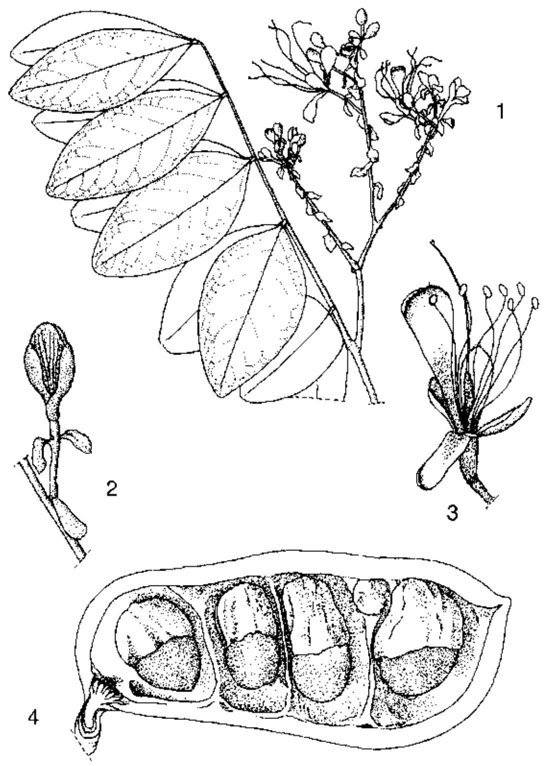
Afzelia xylocarpa (Kurz) Craib

Kew Bull.: 267 (1912).

Synonyms *Pahudia xylocarpa* Kurz (1876), *Pahudia cochinchinensis* Pierre (1899), *Afzelia siamica* Craib (1911).

Vernacular names Cambodia: beng (general). Laos: tê[2] kha[1], kha[1] (general). Thailand: makhamong, makha-luang (general), makha-hua-kham (northern). Vietnam: c[af] te, g[ox] d[or], g[ox] t[of] te (southern).

Distribution Burma, Cambodia, Laos, south-



Afzelia xylocarpa (Kurz) Craib – 1, flowering twig; 2, flower bud; 3, flower; 4, opened fruit with seeds.

ern Vietnam and Thailand.

Uses The timber is used for various purposes and is very valuable in the region. The bark is used for tanning hides and skins. The fatty cotyledons of young seeds are edible.

Observations A small to medium-sized tree of up to 30 m tall, bole branchless for 6–9 m, with a diameter of over 100 cm; leaves with 3–5 pairs of leaflets, leaflets 5–9 cm × 4–5 cm, rounded to emarginate at apex, glabrous; fertile stamens 7–8, 3 cm long, style 2.0–2.5 cm long; mature pod elliptical-oblong, 15–20 cm × 7–9 cm. *A. xylocarpa* occurs in mixed deciduous or dry evergreen forest on clayey or laterite soil at 100–600 m altitude.

Selected sources 121, 159, 235, 421, 589, 590, 598, 626, 675.

C. Phengklai (general part),
T. Smitinand (general part),
R.P. van der Zwan (properties),
R.W. den Outer (wood anatomy),
M.S.M. Sosef (selection of species)

Agathis Salisb.

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

Trade groups Kauri: lightweight softwood, e.g. *Agathis borneensis* Warb., *A. dammara* (Lambert) Rich., *A. labillardieri* Warb.

Vernacular names Kauri: kauri pine, Amboyna pitch tree (En). Agathis indien, 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).

Origin and geographic distribution *Agathis* is the most tropical genus of the *Coniferae*. Opinions differ on the number of species. Some authorities recognize 21 species, 11 of which occur in the Malesian area. Others, applying a broader species concept, distinguish 13 species, with only 4 occurring in the Malesian area. The natural distribution of the genus is from Peninsular Malaysia, Sumatra, Borneo, Sulawesi, the Philippines, the Moluccas, New Guinea and New Britain towards western Australia, the Solomon Islands, New Caledonia, Vanuatu, Fiji and northern New Zealand. There are centres of diversity in western North Queensland and New Caledonia. If a narrow species concept is adopted, a third centre can be recognized in Borneo. 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 subsequently occurred. 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 the natural range, especially in Irian Jaya. Outside the natural range, it has been planted in Java, India, Mauritius, tropical Africa, South Africa and Central America.

Uses The wood of kauri is used as a general-purpose softwood, and has many uses. It is excellent for joinery, boat building (especially masts), construction under cover, household utensils, panelling, turnery, mouldings, packaging and foundry pattern making. More specific purposes are drawing boards and rulers, matches, matchboxes, pencils, furniture, battery separators, piano parts and artificial limbs. As the timber is odourless it was formerly used for food containers such as tea chests and butter boxes. It makes a good peeled veneer with an attractive colour and figure for decorative plywood panelling. Wood-wool boards are manufactured from kauri wood. Kauri is very suitable for the manufacture of wrapping, writing and printing paper and rayon-grade pulp. The wood is also suitable for the manufacture of charcoal and activated carbon.

The inner bark of kauri exudes a translucent or clear white resin which is called 'copal' or 'Manila copal'. This resin used to be an important component of varnish and was used in the manufacture of linoleum. There is still a steady demand in the export market for specialized uses such as in varnishes for labels of food tins and photographic colour prints, reflector paint, as a component of paint for lines on roads and for fluxes. Local demand is still high and applications of the resin for varnish, incense, torches, illumination, for making patent leather, sealing wax, as a liniment and as an unguent to prevent the attacks of leeches have been reported. Kauri is also used in reforestation projects.

Production and international trade The export of round logs from Indonesia was 425 000 m^3 in 1970 and increased steadily to 760 000 m^3 in 1973. In the early 1980s, *Agathis* wood accounted for 2.3% of the export of forest products from Indonesia. In 1987 the export of sawn *Agathis* timber was 67 000 m^3 (with a value of US$ 20.1 million) and in 1988 83 000 m^3 (with a value of US$ 22.2 million).

Malaysia, especially East Malaysia, is also an important exporter of kauri timber. In 1987 Sarawak exported 22 000 m^3 in log form (and only 108 m^3 as sawn timber), and Sabah in the same year 130 000 m^3 in log form (with a value of US$ 17.3 million, and an average price of US$ 133/m^3). In 1992 the export of sawn kauri timber from Sabah was 37 000 m^3 and of logs only 9000 m^3 with a total value of US$ 18 million. In Peninsular Malaysia the largest export volume was reached in 1967 with 8300 m^3 (round logs), and export decreased steadily to 3250 m^3 in 1973. In the 1980s the export of sawn kauri from Peninsular Malaysia increased from 800 m^3 (worth US$ 230 000) in 1981, to 3300 m^3 (worth US$ 740 000) in 1986, to 6000 m^3 (worth US$ 2.5 million) in 1989 and amounted to 5500 m^3 (worth US$ 3.0 million) in 1990 and 3500 m^3 (worth US$ 1.9 million) in 1992.

In the Philippines the log production of kauri was recorded as 7000 m^3 in 1988, but no export was reported. There is now a total ban on cutting *Agathis* trees in the Philippines. The export of kauri logs is banned in Papua New Guinea.

In 1926 the world production of copal was 18 000 t, 88% of which came from Indonesia, 7% from the Philippines and 5% from Sabah. In 1977 the Philippines exported a total of 778 t of Manila copal worth US$ 325 000. In 1987 the export of copal from Indonesia was still 2650 t (with a value of US$ 1.7 million), but it decreased to 1230 t (with a value of US$ 650 000) in 1989. The area planted with kauri in Java is estimated to be about 8500 ha. Elsewhere, kauri is planted on a small scale.

Properties Kauri is a lightweight softwood. The heartwood is pale yellow to straw-coloured, often with a pinkish tinge and not clearly differentiated from the sapwood; it may weather to pale golden-brown or pale pinkish-brown. The density is 360–660 kg/m^3 at 15% moisture content. The grain is generally straight, texture very fine and even; the planed surface is lustrous. The wood has no distinct odour and is not resinous.

At 15% moisture content the modulus of rupture is 49–65 N/mm^2, modulus of elasticity 9400–12 000 N/mm^2, compression parallel to grain 29–34 N/mm^2, shear 6–7 N/mm^2, cleavage 26–30 N/mm radial and 31–43 N/mm tangential, Janka side hardness 1450–2430 N and Janka end hardness 2200–3060 N.

The rates of shrinkage are small to moderate, from green to 15% moisture content about 1.2% radial and 2.5% tangential, and from green to oven dry about 3.8% radial and 6.2% tangential. The timber air dries satisfactorily without significant defects; slight end checks and splitting are recorded. The air drying of 12 mm thick boards takes about 2 months, of 25 mm thick boards 2.5 months, and of 40 mm thick boards 5 months. The kiln drying of 2.5 cm thick boards to 10% moisture content takes 5 days; the preferred drying temperature is 53–83°C with corresponding relative humidity of 76% to 30%. Care should be taken to prevent blue stain.

The wood is easy to saw and plane. Boring and sawing sometimes give slightly rough surfaces. In general, turning, sanding and mortising give good results. The wood takes varnish well and can be lacquered after filling with putty. The resistance to splitting when nailed is rated as good. Kauri wood can be peeled at a 90° peeling angle without pretreatment to produce veneer of good quality. Sometimes the presence of spiralled grain causes a rough surface. Fine veneer can easily be glued with urea-formaldehyde to plywood, and it is also suitable for face veneer. The wood can be pulped by the sulphate process at a temperature of 150°C, a consumption of chemicals of 16%, and a boiling time of 14 hours. The yield of kraft cellulose is 52%. The pulp is suitable for making kraft paper. The wood can also be pulped by the sulphite process.

Kauri wood is rated as non-durable. Graveyard tests in Malaysia and Indonesia show an average service life in contact with the ground of 6 months to 1.5 year. The wood is very susceptible to subterranean and dry-wood termites and wood-rotting and wood-staining fungi; it is, however, reported to be resistant to powder-post beetle attack. The treatability with preservatives is rated as very easy to moderately difficult. Tests in Malaysia, using the standard open tank treatment and creosote, showed an absorption of 350–630 kg/m^3, but tests in Indonesia, using the vacuum-pressure method, showed considerably less absorption. In Malaysia, treated test sticks proved very durable in contact with the ground.

Wood of *A. borneensis* contains 52% cellulose, 25% lignin, 13% pentosan, 1.1% ash and 0.1% silica. The solubility is 2.0% in alcohol-benzene, 0.6% in cold water, 1.3% in hot water and 7.3% in a 1% NaOH solution. The energy value of the wood is about 19 950 kJ/kg.

Tests on *A. borneensis* indicate that wood from plantations has a tendency to have thinner fibre walls, smaller fibre diameter and fibre lumen diameter, shorter fibres, less resistance to wood-rotting fungi, but better treatability than wood from natural forest.

Kauri copal is a translucent or clear white resin, slowly hardening on exposure to a white or yellow to dark brown, hard, ultimately brittle mass. It is soluble in alcohol; the melting point is between 115–135°C. It is a complex mixture of monoterpenes, diterpenes and sesquiterpenes, and contains dammaric acid, dammaran and a resin.

Description Medium-sized to very large monoecious but strongly dichogamous trees of up to 60(–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, globular or umbrella-shaped in older ones, large branches often irregularly upturned. Leaves entire, very shortly petioled, subopposite to opposite, 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. Foliage buds globular, tightly covered with several pairs of overlapping scales. 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. Seed cones terminal, massive, oval 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.

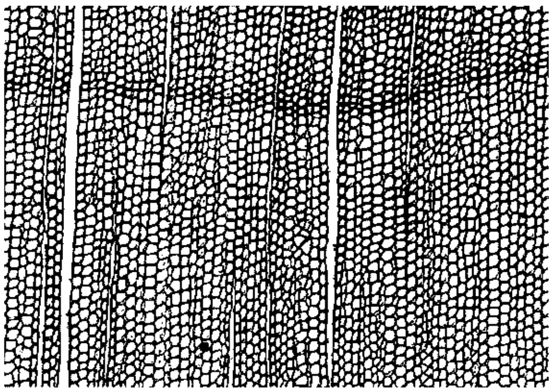
Wood anatomy

– Macroscopic characters:

Sapwood not distinct from the heartwood, whitish, heartwood pale yellow-brown, straw-coloured or buff, sometimes with a pinkish tinge, ageing to a golden brown colour; wood somewhat lustrous, caramel-like odour present. Grain straight. Texture very fine and even. Growth rings barely distinguishable, but backsawn faces generally with some figure; rays very fine, not visible to the naked eye and generally not prominent on the radial surface.

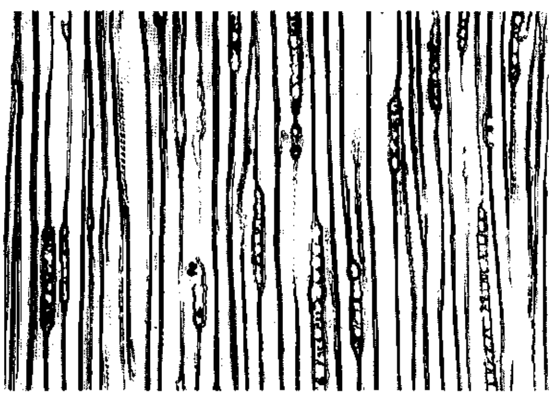
– Microscopic characters:

Tracheids irregularly polygonal, rounded to square in cross-section, radial diameter approximately 50 μm (up to 70 μm in the earlywood), 3–6(–8) mm long, resin plugs abundant; intertracheid pits alternate in 1–2(–3) rows, large and hexagonal to flattened; pits on tangential walls rare and smaller. Rays 6–8/mm, uniseriate, 2–7 cells high, large and open, end walls oblique or rounded, side walls usually not parallel; ray-tracheid pits bordered, small, 2–7 (mostly 4–6) per crossfield.



transverse section (×25)

radial section (×150)



tangential section (×75)

Agathis dammara

Species studied: *A. borneensis*, *A. dammara*.
Anatomically it is very difficult to distinguish wood of *Agathis* spp. from wood of *Araucaria cunninghamii* Aiton ex D. Don. Generally, *Agathis* wood is slightly denser and free of compression wood; the heartwood is slightly darker. *Agathis* is devoid of the very small pin knots usually seen in *Araucaria*. Ray height in *Agathis* is often less than in *Araucaria*.

Growth and development Seedlings need shade and show slow growth during the first years. Afterwards, when released from competition with herbs, growth is rapid, as in most typical primary rain forest trees. 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. Annual volume increment may be 20–30 m^3/ha. 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. The root system is sensitive to lack of oxygen and the trees do not tolerate waterlogging.

Kauri is reputed to be a self-pruning tree, but open-grown trees of some species and provenances retain their low branches for some time. In general, the stem form is good.

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.

Other botanical information The genus *Agathis* is one of the two genera in the family of *Araucariaceae*. All recent authors agree that the most useful characters to distinguish species are the shape and size of the microsporophyll and to some extent the male cone, which must both be studied in their mature stage. *Agathis* is subdivided into three sections, section *Prismobracteata* Meijer Drees with sharply angled microsporophylls, section *Rostrata* de Laubenf. with a distinct beak on the seed scale and section *Agathis* with no such beak. The differences between two recent revisions of *Agathis* (Whitmore, 1980 and de Laubenfels, 1988) are considerable and it is not possible to make a good synthesis of the two. Here, for the sake of uniformity the Flora Malesiana treatment (de Laubenfels) has been followed, except that the name *Agathis dammara* has been used again, because the proposed rejection of this name was not accepted by the Committee for Spermatophyte Nomenclature. Whitmore (1980) and de Laubenfels (1988) have distinctly different opinions on the number of species that can be recognized in *Agathis*. According to Whitmore, *A. dammara* and *A. celebica* represent one single species. He concluded that the best taxonomical solution would be to consider *A. dammara, A. borneensis, A. australis* (Lambert) Steud. and their New Caledonian relatives as infraspecific taxa of one species, but this has not been done because of the radical consequences for established nomenclature.

A. australis from New Zealand is probably the best known *Agathis* species and has a long history as a timber. *A. macrophylla* (Lindley) Masters from the Solomon Islands, Vanuatu and Fiji is planted locally in Peninsular Malaysia and Indonesia.

Ecology *Agathis* is the conifer genus par excellence of lowland tropical rain forest. Within the Malesian area kauri 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(–2400) m altitude. In Malesia, kauri is confined to regions 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. Kauri occurs on a diversity of soils and in a wide variety of habitats. It has been found in places as divergent as heath forest, on ultrabasics, limestone and in peat-swamp forest. Kauri 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. Natural stands on sand ridges in swamp forest in Kalimantan contain 1-2.6 m^3/ha of standing timber; *A. borneensis* is there associated with ramin (*Gonystylus bancanus* (Miq.) Kurz). Kauri is generally least successful in species-rich forest and as a rule does not tolerate stagnant water.

Propagation and planting Natural regeneration may occur under shade near mother trees, but seedlings are often rare. They seem able to establish in secondary vegetation. Naturally established seedlings in plantations can be used as planting stock. The shade tolerance of several species allows them to be managed under a selective felling system, always maintaining a good forest cover, which is important on erosion-prone soils on steep hills.

Artificial regeneration is mainly by sowing. Seed supply is limited by the very rapid decline in viability and the high costs of collecting seed from species whose cones disintegrate. In Indonesia and Papua New Guinea cones are collected when they have ripened and become blackish-green. It is not easy to collect female cones, as they are produced mainly in the upper parts of the crown at the ends of branches. It is not recommended to collect fallen seeds. The weight of 1000 dry seeds is about 200 g. Seeds must be sown as soon as possible, because the viability drops rapidly, from 90–100% initially to zero after some weeks. Germination starts 6 days after sowing, 80% of the seedlings emerging within 10 days. Storage time can be extended by quick drying without heating, and storage at temperatures below 0°C. Air-dried seeds have a germination rate of 40–50% after 14 days, but this drops to zero after about 9 weeks. After soaking for 24 hours, seeds are directly sown on seed-beds, and covered thinly with soil. Seedlings prefer shade and will survive open planting only if the roots are minimally damaged and soil is moist. Plants are more resistant to exposure when more than a year old.

Potting stock at least 15 cm high, but preferably larger as small stock shows high mortality, is used for planting. The best nursery seedlings for transplanting are those of 1–1.5 years old and 25–60 cm tall. If the taproot is bent sharply when transplanting, the plant dies. Mycorrhizal association is easily formed with ubiquitous soil fungi. When planted in open terrain, e.g. under taungya systems, with food crops between the rows of kauri for 1–2 years, a shade plant, e.g. *Leucaena leucocephala* (Lamk) 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 side-shoots.

Trees for tapping are planted at a wide spacing of about 10 m × 5 m. Close planting, in Java 3 m × 3 m, encourages the formation of long branchless boles. In Papua New Guinea a spacing of 6 m × 6 m is often practised to make unmerchantable thinnings redundant; the self-pruning ability of the trees makes wide spacing possible.

Vegetative propagation, to overcome lack of seed, has proved 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. Root suckers can be produced several times from potted seedlings and are considered to be the most successful material for vegetative propagation. *A. robusta* has been propagated successfully by in vitro culture in Australia, using stem segments with 3–5 leaf axils, excised from the upper portion of the main stem of 2-year-old seedlings. The success rate of rooting was, however, only 5–20% on a medium of half-strength Murashige and Skoog inorganic salts plus growth regulators.

Silviculture and management Commercial plantations should be on gentle slopes on well-drained soils with good aeration. Extensive clearing, often accompanied by burning, is required to prepare the sites. Initially it is preferable to retain some overhead shade from shade trees, but in the sapling period, openings in the canopy are needed for further successful growth. In plantations of *A. dammara* in Java (with initial spacing of 3 m × 3 m), the first thinning is often at the age of 6 years, and then every 3 years until the age of 20 years, and every 5 years afterwards. In Papua New Guinea, an extremely heavy thinning and tending of the upper canopy, leaving only trees of commercial value, is implemented around the age of 10 years. Selective felling, with a diameter limit, often benefits the natural regeneration of kauri.

Young trees seem to be sensitive to competition from grass and also to overgrowing by vines, so young plantations must be weeded. The usual rotation for pulpwood production is 20 years in Java, but a longer rotation is needed for timber production.

Diseases and pests The rust *Aecidium* may infest seedlings in nurseries and young trees in the field. The symptoms are reddish-brown raised lesions on the leaf surface. The disease may slow down growth. Fungi of *Gloeosporium* are reported to infest young seedlings in seed-beds. Pink disease caused by *Corticium salmonicolor* may damage twigs, branches and finally whole trees. Several fungal diseases are associated with waterlogging. Diseases reported for kauri in the Philippines are seedling dieback caused by *Colletotrichum gloeosporoides,* seedling leaf blight caused by *Phoma* sp., seedling dry rot caused by *Fusarium solani*, and butt and heart rot caused by *Fomes* and *Ganoderma* spp.

In Papua New Guinea a seed-eating moth (*Agathiphaga*) is widespread and may severely damage seeds. The termite *Coptotermes eliseae* sometimes attacks trees in Papua New Guinea. Parrots and cockatoos feed on the cones of *Agathis* trees in New Guinea, and wild pigs and squirrels may destroy young plantations.

Harvesting In natural stands, trees with a diameter of more than 50 cm or 60 cm are usually harvested for timber. The logs float in water and can be transported by river. Kauri wood must be dried immediately, as it is susceptible to blue stain.

Overtapping and incorrect tapping techniques have caused many kauri trees to die and stands to be depleted in several areas, e.g. in the Philippines and Sabah. To prevent trees from dying the following recommendations have been made in the Philippines: only trees over 40 cm diameter should be tapped, and tapping should not be done less than 30 cm from the ground; the width of vertical tappings should be 1–2 cm, that of horizontal tappings 30 cm; the distance between the cuts should be twice the width of the cut (for vertical tapping 4 cm, for horizontal 60 cm); the cambium should not be cut; hardened resin should be collected 2 weeks after tapping; after collection, a fresh cut should be made immediately above the first one, and the first cut closed; not more than 37.5 kg resin should be collected per tree.

Bigger diameter trees give more resin, and spraying 40% sulphuric acid on the freshly cut streaks of tapped trees increases the resin flow by dissolving the hardened copal on the surface. Resin is more abundant during dry months. Copal production can be increased by making a V-shaped cut and covering it with black plastic sheet.

Yield The annual wood production of kauri planted in Java in a pulpwood rotation of 30 years is reported as 23–32 m^3/ha, and in a plantation for veneer production in a 50-year-rotation 22–28 m^3/ha. The total yield of pulpwood after 20 years is about 300 m^3/ha, and the total yield of timber after 40 years 570 m^3/ha.

In Palawan (the Philippines) kauri trees give an average annual yield of copal of 3.6 kg, but in other places in the Philippines annual yields of 1.8 kg and 0.6 kg have been reported. However, the annual yield of large trees can be as high as 10–20 kg.

Genetic resources and breeding Kauri trees are easy to recognize and are sought for their resin and for timber. Natural populations have been seriously depleted. The once huge stands of *A. borneensis* in South Kalimantan for instance, with a standing volume of 100–400 m^3/ha, have been exploited heavily for timber, and populations of *A. dammara* have been depleted in the Moluccas. *A. philippinensis* is declining in the Philippines because of unscrupulous tapping for resin, illegal cutting and deforestation.

Some protected areas contain very important gene pools of *Agathis* species, 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*. In Australia, New Zealand and on the Pacific Islands conservation measures have been introduced to protect several endangered *Agathis* species.

Ex situ conservation can play an important role for some species, e.g. for *A. dammara* which is planted on a fairly large scale in Java. In 1979 a worldwide provenance trial was coordinated by the Oxford Forestry Institute (Great Britain); seed from the entire range of distribution of *Agathis* was sent to 19 countries.

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 improved resistance to diseases and pests.

Prospects Much information is available on propagation and silviculture. It shows that certain species of *Agathis* have good prospects for large-scale planting for timber and copal production. Vegetative propagation is an important field of research because of problems with seed harvesting and storage, and because it will allow mass production of superior provenances. More breeding programmes should be set up.

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Selection of species

Agathis borneensis Warb.

Monsunia 1: 184, t. 80 (1900).

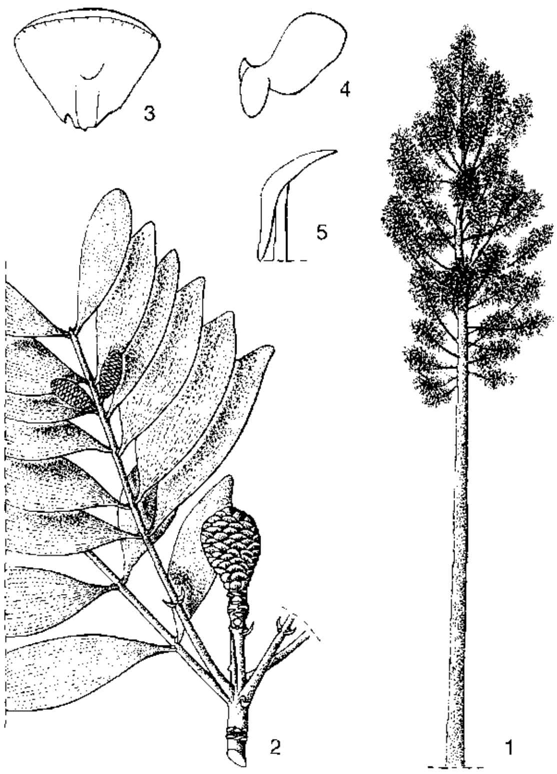
Synonyms *Agathis beccarii* Warb. (1900), *Agathis alba* Foxw. (1909), *Agathis latifolia* Meijer Drees (1940).

Vernacular names Brunei: bindang. Indonesia: bembueng (south-eastern Kalimantan), damar pilau (Dayak, Kalimantan), hedje (Sumatra). Malaysia: damar minyak (general), bindang (Sarawak), tambunan (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *A. borneensis* is an important source of kauri timber. A good-quality resin can be tapped from the trees. It is planted as a plantation tree and in enrichment planting.

Observations 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 oblong, 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 oval, 6–8.5 cm × 5.5–6.5 cm, seed bracts roughly obtriangular with



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

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. *A. borneensis* occurs scattered in upland rain forest up to 1200 m altitude in Peninsular Malaysia and Sumatra, but is often found in pure stands on sandy peat soil at low elevation in Borneo. The density of the wood is 380–550 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 92, 100, 102, 146, 163, 181, 369, 406, 415, 453, 461, 478, 495, 542, 551, 554, 647, 748, 749, 762, 774, 775, 776, 778, 779, 780, 791.

Agathis dammara (Lambert) Rich.

Comm. bot. Conif. Cycad.: 83, t. 19 (1826).

Synonyms *Agathis loranthifolia* Salisb. (1807), *Agathis celebica* (Koord.) Warb. (1900), *Agathis hamii* Meijer Drees (1940).

Vernacular names Indonesia: dammar raja (general), kisi (Buru), salo (Ternate). Philippines: dayungon (Samar).

Distribution The Philippines (Palawan and Samar), Sulawesi and the Moluccas; planted on a fairly large scale in Java.

Uses The wood is used as kauri. *A. dammara* is an important source of copal resin.

Observations 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 4–6 cm × 1.2–1.4 cm, subtended by a peduncle c. 3 mm long, microsporophylls with a spoon-shaped apical part of c. 2 mm × 2.5 mm, slightly angled at the apex; mature seed cones oval, 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. dammara* is scattered but locally common in lowland rain forest up to 1200 m altitude. It is sometimes regarded as conspecific with *A. philippinensis*. The density of the wood is 380–660 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 92, 146, 163, 180, 359, 453, 463, 478, 565, 584, 629, 663, 666, 748, 749, 762, 773, 774, 775, 776, 780.

Agathis endertii Meijer Drees

Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 470 (1940).

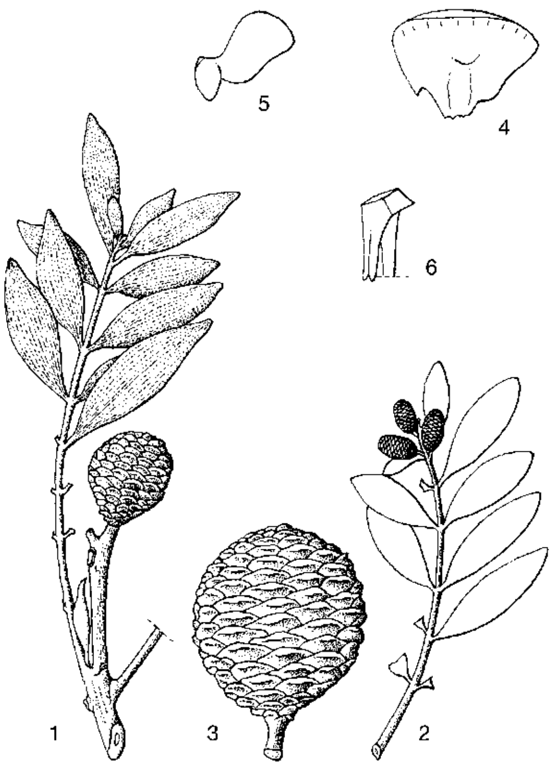
Vernacular names Malaysia: bulok (Iban, Sarawak).

Distribution In more or less isolated populations on Borneo.

Uses The wood is used as kauri.

Observations A very large tree of up to 65 m tall; adult leaves ovate, 5–8 cm × 1.7–3.6 cm, broadly acute to semicircular and blunt at the apex, glaucous beneath, resin canals solitary; mature pollen cones 2.6–3.8 cm × 0.7 cm, sessile, the apical part of the microsporophylls spoon-shaped and slightly angled at the apex, 2.5 mm × 2 mm; mature seed cones oval, 4.5 cm × 7 cm, seed bracts with a bluntly triangular projection at the apical margin and a small projection near the base on one side; seed with a short acute projection on one upper corner and a broad wing on the other. *A. endertii* is often found in heath forest on sandstone at 220–1600 m altitude and is sometimes believed to be conspecific with *A. borneensis*.

Selected sources 146, 163, 181, 453, 478, 748, 773, 775.



Agathis labillardieri Warb. – 1, twig with female cone; 2, twig with male cones; 3, mature female cone; 4, seed scale; 5, seed; 6, microsporophyll.

Agathis labillardieri Warb.

Monsunia 1: 183 (1900).

Vernacular names Indonesia: kayu damar putih (general), kessi, fuko (Irian Jaya). Papua New Guinea: New Guinea kauri.

Distribution Western and central New Guinea; also cultivated in the same region.

Uses The wood is used as kauri, especially for plywood and veneer as well as for pulp. Trees are tapped to obtain copal ('papeda').

Observations 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 5–7 mm long petiole; mature pollen cones 2.5–3.5 cm × 1–1.5 cm, subtended by a 2–6 mm long peduncle, apical part of the microsporophylls prismatic with a series of lateral facies surrounding a flat hexagonal upper face 1–1.5 mm wide and long, the dorsal part sharply angled; seed cones not shattering on maturity, oval, 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. labillardieri* is locally common and seems to prefer slightly oligotrophic soils which are often podzolized, but it occurs on a wide variety of other soil types from sea-level up to 1700(–2500) m altitude. The density of the wood is 420–520 kg/m³ at 15% moisture content.

Selected sources 79, 116, 163, 259, 263, 331, 453, 461, 478, 748, 773, 774, 775, 776, 780.

Agathis lenticula de Laubenf.

Blumea 25: 537, f. 4 (1979).

Vernacular names Malaysia: tanggilan, tengilan, tungilan (Dusun, Sabah).

Distribution Endemic to Sabah.

Uses The wood is used as kauri.

Observations A large tree of up to 45 m tall; adult leaves elliptical to narrowly elliptical, 5–7 cm × 1.8–2.4 cm, more or less acute, tapering to a 3–7 mm long petiole; mature pollen cones 3–4 cm × 0.9–1 cm, microsporophylls with a spoon-shaped, blunt apex of 2–2.5 mm × 1.5–2 mm; mature seed cones nearly spherical, about 7 cm × 6 cm, seed bracts very broadly obtriangular-ovate, with a hooked projection above the base on one side; seed without or with a small, blunt projection on one upper corner and a wing on the other. *A. lenticula* is an emergent tree in montane rain forest at 1150–1700 m altitude. It is sometimes regarded as conspecific with *A. dammara*.

Selected sources 181, 748, 774.

Agathis orbicula de Laubenf.

Blumea 25: 540, f. 5 (1979).

Vernacular names Malaysia: tumuh (Murut, Sarawak), tubu (Kenyah, Sarawak), bulok (Iban, Sabah).

Distribution Sarawak and southern Sabah.

Uses The wood is used as kauri.

Observations A fairly large tree of up to 40 m tall; adult leaves ovate to orbicular, 2.4–4.0 cm × 1.2–2.4 cm, broadly rounded to slightly angled at the apex, narrowed into a 3–7 mm long petiole; mature pollen cones 8–14 mm × 4–6 mm, microsporophylls with a helmet-shaped apex of 1.2–1.5 mm × 1–1.2 mm; mature seed cones oval, about 7 cm × 4.5 cm, seed bracts transversely broadly elliptical, with a projection near the base on each side. *A. orbicula* occurs scattered in montane forest and heath forest at 450–1050 m altitude.

Selected sources 181, 748.

Agathis philippinensis Warb.

Monsunia 1: 185, t. 8E (1900).

Synonyms *Agathis regia* Warb. (1900), *Agathis dammara* auct. non (Lambert) Rich.

Vernacular names Indonesia: goga, solo (Sulawesi). Philippines: almaciga (general).

Distribution The Philippines, Sulawesi and the northern Moluccas.

Uses *A. philippinensis* is an important source of kauri timber and the trees are tapped for Manila copal.

Observations A very large tree of up to 60 m tall; adult leaves ovate, 4.5–6 cm × 1.5–2 cm, slightly to distinctly acute at the apex, tapering at base into a 5–8 mm long petiole; 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 oval, 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. *A. philippinensis* occurs scattered and often as an emergent tree in upland rain forest at (250–)1200–2200 m altitude. It is sometimes regarded as conspecific with *A. dammara*. The density of the wood is 470–660 kg/m^3 at 15% moisture content.

Selected sources 146, 163, 180, 244, 279, 280, 453, 478, 565, 566, 748, 774.

Agathis robusta (Moore) Bailey

Syn. Queensl. fl.: 498 (1883).

Synonyms *Agathis palmerstonii* (F. v. Mueller) Bailey (1891).

Vernacular names Smooth-barked kauri (En).

Distribution New Britain, south-eastern Papua New Guinea and eastern Australia.

Uses The wood is used as kauri. Trees are tapped for resin which is also dug up at the base of the tree.

Observations A large tree of up to 48 m tall; adult leaves ovate, 5–9.5 cm × 1–2.6 cm, acute to rounded at the apex, tapering into a 3–10 mm long petiole; mature pollen cones 4–8.5 cm × 0.7–0.9 cm, microsporophylls with a sharply angled apex with 3 lateral faces of c. 1 mm wide; mature seed cones oval to elongated, 9–15 cm × 8–10 cm, seed bracts rounded obtriangular-ovate, with a large projection on one side and a smaller one near the base on the other; seed with a prominent, acute projection on one upper corner and a wing on the other. *A. robusta* is locally common in recently disturbed places and occurs on a variety of soils up to 900 m altitude. The density of the wood is about 475 kg/m^3 at 15% moisture content.

Selected sources 105, 163, 359, 748, 773, 774, 776, 780.

Agathis spathulata de Laubenf.

Fl. Malesiana, ser. I, vol. 10: 435 (1988).

Synonyms *Agathis robusta* (Moore) Bailey subsp. *nesophila* Whitmore (1980).

Vernacular names Papua New Guinea: New Guinea kauri.

Distribution Papua New Guinea.

Uses The wood is used as kauri.

Observations A very large tree of up to 60 m tall; adult leaves 7–10 cm × 1.8–3 cm, bluntly acute to broadly rounded at the top, tapering into a 5–10 mm long petiole; mature pollen cones oblong, 4–7 cm × 0.9–1.3 cm, microsporophylls with a spoon-shaped apex of 1.5–2 mm × 1.3–1.5 mm; mature seed cones oval, 8.5–10 cm × 6.5–7.5 cm, seed bracts broadly obtriangular-ovate, with a small projection at the base on one side and a larger one higher up on the other; seed with a sharp projection on one upper corner and a wing on the other. *A. spathulata* occurs scattered as an emergent tree of rain forest or in groves on exposed sites at 900–2000 m altitude.

Selected sources 331, 748, 774, 778, 780.

I. Soerianegara (general part),
N.R. de Graaf (general part),
J.M. Fundter (general part),
J.W. Hildebrand (general part),
A. Martawijaya (properties),
J. Ilic (wood anatomy),
C.C.H. Jongkind (selection of species)

Alstonia R.Br.

On Asclepiad.: 64 (1810).

APOCYNACEAE

$x = 11$; *A. macrophylla*: $2n = 22$, *A. scholaris*: $n = 20, 22$, $2n = 22, 44$

Trade groups

- Pulai: (very) lightweight hardwood, e.g. *Alstonia pneumatophora* Backer ex den Berger, *A. scholaris* (L.) R.Br., *A. spatulata* Blume.
- Hard alstonia: medium-heavy hardwood, e.g. *A. macrophylla* Wallich ex G. Don, *A. spectabilis* R.Br.

Vernacular names

- Pulai: white cheesewood, white pine, milkwood, milky pine (En). Shaitan (Fr). Brunei: pelai

(Malay). Indonesia: kayu susu (general), rita (Sulawesi). Malaysia: basong (Peninsular), mergalang (Sarawak). Papua New Guinea: white cheesewood, milky pine. Philippines: dita (general). Burma: lettok, sega, shaitan. Thailand: sattaban (central), thia. Vietnam: c[aaly m[of] cua, c[aa]y s[uwx]a.

- Hard alstonia: hard milkwood (En). Malaysia: pulai bukit. Philippines: batino (Pilipino). Thailand: thungfa (peninsular).

Origin and geographic distribution *Alstonia* consists of about 40 species and occurs in a continuous belt in the paleotropics. It ranges from tropical West Africa to the Marquesas in the far eastern Pacific and from the Himalayas in the north to New South Wales in the south. Two species are native in tropical Africa, 4 in Australia, about 15 in the Pacific region, 12 in the Malesian region and the rest occur in continental Asia. *A. scholaris* is the most widespread species and occurs from India and Sri Lanka through Indo-China (including southern China) towards Malesia, south to Queensland and east to the Solomon Islands. Several species have been planted outside their natural area of distribution.

Uses Due to its weakness, pulai is not recommended for structural purposes. It is suitable for boxes, crates, coffins, drawing boards, picture frames, matches, shuttering, interior trim, furniture components, prahus, foundry patterns and handicrafts such as wooden shoes, toys, puppets and masks. The occurrence of large latex traces makes it unsuitable for face veneers but it can be applied as core wood in plywood production. The pulp obtained from the wood has satisfactory paper-making qualities. The wood produces a poor-quality charcoal and as a match timber it is inferior to terentang (*Campnosperma* spp.). The root wood of several species of pulai is amongst the lightest woods of the world. It is called 'basong' and has been used for making pith helmets and floaters for nets; it is an inferior alternative to cork.

Hard alstonia, being stronger than pulai, can be applied for medium and sometimes even for heavy constructional work, railway sleepers and boarding. When properly protected against the weather and fungal and insect attacks, it can be used for house building; it has been used for beams, rafters and joists. Because of its wavy and attractive grain it is also used for making furniture and cabinets.

A latex which contains alkaloids can be tapped from the bark (though not from the bark of hard alstonia). The latex is important and is often used in traditional medicine. In Fiji it has been applied to people with eye troubles. Mixed with oil, it has been used to treat earache. The bark is used against malaria and is the source of a popular drug in the Philippines. It is also popular in India and Java to treat diarrhoea and dysentery. The leaves are used medicinally against all diseases of the skin. An extract of the roots, leaves and latex of *A. scholaris* is used as a febrifuge. The latex of that species is used for chewing gum. Outside Malesia other species are used for this purpose too. Some species of pulai are planted as ornamental trees because of their pagoda-like crown.

Production and international trade The export of sawn pulai timber in Indonesia increased from 50 000 m^3 (with a value of US$ 8.7 million) in 1987 to 70 000 m^3 (with a value of US$ 12.3 million) in 1988 and 90 000 m^3 (with a value of US$ 18.5 million) in 1989. Pulai ranks among the six most important export timbers of Indonesia. Because of its lightness and limited uses, sawn pulai timber does not fetch a high price compared with other export timbers: US$ 206/m^3 in 1989.

The production and trade of pulai in Malaysia is less than in Indonesia; Sarawak and Sabah export small amounts of this timber (e.g. in 1992 the export of round logs of pulai from Sabah was 20 000 m^3 and of sawn timber 9500 m^3, worth US$ 3.1 million). In Papua New Guinea pulai is not ranked among the most important export timbers; it is in MEP (Minimum Export Price) group 5 and fetched a minimum export price of US$ 40/m^3 for saw logs in 1992. Papua New Guinea exports small amounts of hard alstonia timber, mainly to Japan. In the Philippines pulai seldom reaches the market.

Properties Pulai is a lightweight hardwood. The heartwood is cream-white, sometimes weathering to yellow-brown, and not clearly differentiated from the sapwood. The density of the wood is 210–500 kg/m^3 at 15% moisture content. However, the root wood may be much lighter, 48–80 kg/m^3 at 15% moisture content. The grain is straight or interlocked, texture moderately fine to moderately coarse. Planed surfaces are moderately lustrous, the tangential surface occasionally with zigzag markings.

At 15% moisture content, the modulus of rupture is 33–52 N/mm^2, modulus of elasticity 6300–9000 N/mm^2, compression parallel to grain 22–32 N/mm^2, compression perpendicular to grain 2–4 N/mm^2, shear 5–7 N/mm^2, cleavage 26–45 N/mm radial and 30–51 N/mm tangential, Janka side hardness 725–2000 N and Janka end hardness 1315–3225 N.

The rates of shrinkage are moderately low, from green to 15% moisture content about 2.3% radial and 2.8% tangential, and from green to oven dry 3.1–3.4% radial and 4.9–6.1% tangential. Pulai air dries fast and easily, and without defects except for slight cupping, bowing, twisting and end checking. Boards of 15 mm thick take 1–1.5 months to air dry, boards of 40 mm thick approximately 2.5 months. In Malaysia, kiln schedule J is recommended; boards of 25 mm thick can be kiln dried from 50% to 10% moisture content in about 5 days. Pulai is very susceptible to fungal and insect attack during drying; it should be treated chemically or dried quickly.

Pulai is easy to saw, plane and bore in green as well as in air-dried condition; dry wood is easy to turn. The surfaces produced are generally smooth. The wood has an excellent resistance to splitting when nailed. Tests in Indonesia on the machining properties of wood of *A. pneumatophora* showed good results for sanding, planing, turning and shaping, and moderate results for boring and mortising. Tests on *A. angustiloba* wood showed good results for turning, but moderate for planing and poor for shaping, boring, mortising and sanding. In Indonesia, veneer with a smooth surface has been made at a 90° peeling angle from *A. scholaris* without pretreatment; glued with urea-formaldehyde, the veneer makes good plywood. On the other hand, tests in Malaysia showed that pulai is easy to peel but produces veneer with fuzzy grain; clean veneer is difficult to obtain due to the presence of traces of latex. In Malaysia, pulai is considered unsuitable for producing veneer. The wood gives a sulphate pulp with satisfactory paper-making qualities.

Pulai is non-durable; it is very perishable in exposed conditions and in contact with the ground. Graveyard tests in Indonesia and Malaysia showed an average service life in contact with the ground of 6–16 months. The wood is very susceptible to blue stain and dry-wood borer attack. It is poorly to moderately resistant to dry-wood termites. Pulai is easy to treat with preservatives. Using the open tank method, the wood absorbs 300–560 kg/m^3 of an equal mixture of creosote and diesel fuel. The wood is also easy to treat by the vacuum-pressure process with CCA preservative.

Wood of *A. scholaris* contains 54% cellulose, 25% lignin, 15% pentosan, and 0.9% ash. Pulai contains no silica. The solubility is 1.4% in alcohol-benzene, 0.3% in cold water, 3.6% in hot water and 11.1% in a 1% NaOH solution. The energy value is 19 900 kJ/kg.

Hard alstonia is a moderately heavy hardwood. The heartwood is yellowish-white to pale yellowish-brown and not distinctly demarcated from the sapwood. The density of the wood is 560–850 kg/m^3 at 15% moisture content. The grain is moderately interlocked, texture moderately fine. This timber is much stronger and much harder than pulai. The shrinkage rates are low to moderately low, from green to 15% moisture content 1.4% radial and 2.7% tangential, and from green to oven dry 3.2% radial and 4.7% tangential. Hard alstonia seasons well, although warping and checking occur. It is easy to work and takes a good finish. It is fairly durable, even when exposed to the weather or in contact with the ground.

The latex contains triterpenes, particularly α-amyrin, β-amyrin and lupeol. Leaves and bark contain alkaloids which have medicinal and poisonous properties.

Description Shrubs or small to large, evergreen or (rarely) deciduous, laticiferous trees of up to 50 m tall; bole straight, generally coarsely fluted at the base and up to 125 cm in diameter; bark surface generally tessellated with small scales or shallowly fissured, appearing smooth at a distance, variable in colour, generally pale or purplish-black, outer bark granular, inner bark cream, soft, frequently conspicuously exuding sticky white latex; branches verticillate, mostly 4–5 together, distant. Leaves verticillate (or sometimes opposite) in verticils of 2–8, simple, entire, with very variable shape (even in the same tree), from lanceolate to obovate and obtuse to acute or acuminate, glabrous or sometimes hairy, generally fleshy but drying papery; venation pinnate, with many parallel secondary veins often linked near the margin by a hardly looped intramarginal vein; petiole generally short and unswollen, with or without intrapetiolar stipules. Inflorescence cymose, terminal, usually 1–5 together, thyrsoid or compound-subumbellate. Flowers actinomorphic, bisexual, protandrous, generally small and fragrant; calyx 5-lobed, united at base into a short tube; corolla white, yellow or red, with 5 rotate, contorted, imbricate and spreading lobes, tube long, cylindrical, widening around the anthers, thickened at the throat, rather densely pubescent inside just below the stamens and on the lobes; stamens included, inserted on the corolla tube, with short but distinct filaments, anthers basifixed, introrse, triangular to narrowly triangular, apices touching each other above the stigma in bud; disk annular, entire or lobed, free or adnate to the ovary, often indistinct; ovary superior, with 2 carpels, apocarpous or syncarpous, with 2 placentas per locule, ovules numerous, in 2–many rows, style 1, long and filiform to very short, glabrous, with 2 short stigmas. Fruit composed of 2 follicles, free or connate at the base (sometimes united into a single capsule), woody, long and slender, dehiscent along an adaxial suture, inconspicuously striate outside, containing many seeds. Seed with endosperm, thin, flattened, minutely foveolate, glabrous or (often dorsally) pubescent, ciliate at both ends, sometimes winged. Seedling with epigeal, erect hypocotyl; cotyledons leaf-like, thin, oblong or ovate-oblong with an obtuse top and rounded base; leaves decussate, exstipulate.

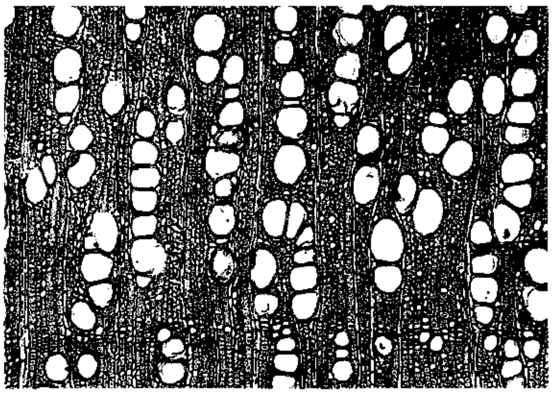
Wood anatomy

– Macroscopic characters:

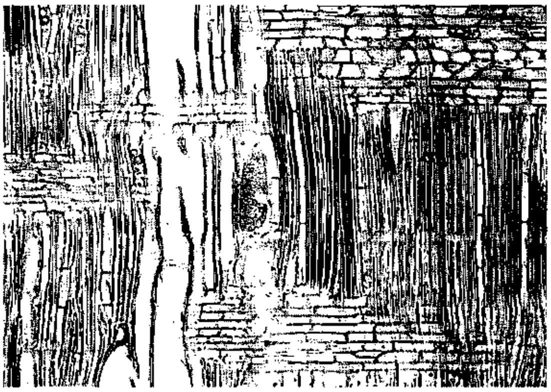
Sapwood very wide, not well defined from the yellowish, cream-white or straw-coloured to pale yellow-brown heartwood; in the pulai group, true heartwood is often not present. Grain straight to interlocked. Texture moderately fine to moderately coarse, variable; wood with an attractive figure in species with higher density. Growth rings generally not evident, sometimes with a tendency to indistinct rings, particularly in species with denser wood; vessels intermediate to small in size, distinct or indistinct to the naked eye; parenchyma bands sometimes evident; rays not evident without lens. Characteristic latex traces appear as open slit-like radial passages.

– Microscopic characters:

Growth rings not evident, sometimes vaguely indicated, particularly in species with denser wood, due to zones of thicker-walled fibres. Vessels diffuse, few (2–3/mm^2) to numerous (more than 20/mm^2), evenly distributed, typically in radial multiples of 2–3(–6) and sometimes in clusters, solitary vessels few, rather angular in transverse section, small to large, tangential diameter ranging from 70–220 μm, generally with maximum tangential diameter of 150–220 μm in the pulai group and less than 120 μm in the hard alstonia group; perforation plates simple, markedly oblique; intervessel pits alternate, vestured, small (c. 3 μm); vessel-ray pits half-bordered, otherwise similar to intervessel pits, occasionally unilaterally compound. Fibres 1200–1760 μm long, non-septate, thin- to moderately thick-walled, pits small but distinctly bordered; tension wood fibres often present. Parenchyma abundant apotracheal, diffuse or in fine, numerous, wavy or discontinuous lines of 1 cell wide in species with small pores, or



transverse section (×25)



radial section (×75)

tangential section (×75)

Alstonia spectabilis

in 1–2 cell wide moderately closely spaced bands, irregular to loosely regular in other species; paratracheal parenchyma sparse to absent, strand length 5–10 cells. Rays 6–7/mm, (1–)2–3(–4)-seriate, uniseriate rays few, generally 20–30 cells high, occasionally up to 40 cells high, uniseriate rays heterocellular with 3–4 rows of marginal upright cells and 2–3 rows of marginal procumbent cells of larger vertical dimensions than the central procumbent cells; with small latex tubes only in the pulai group. Chambered prismatic crystals moderately abundant in parenchyma strands, central ray cells and sometimes in the marginal rays cells of the hard alstonia group. Silica absent. Species studied: *A. angustiloba, A. macrophylla, A. scholaris, A. spatulata, A. spectabilis.*

The wood of *Dyera costulata* (Miq.) Hook.f. (jelutong) is very similar to pulai wood, but it can usually be distinguished by its very fine, regularly spaced uniseriate bands forming a reticulate pattern with the rays.

Growth and development Seedlings are vigorous and hardy, and young trees demand full light in order to grow vigorously. Under favourable conditions they are undoubtedly fast growers, although no data are available on growth rates. Young trees of most species have a pagoda-like crown with a monopodial appearance (according to Prévost's architectural tree model). The growth of branches is intermittent. However, crowns of *A. angustifolia* and *A. macrophylla* are of normal sympodial structure, even when young (Koriba's architectural tree model).

The trees are often deciduous at irregular intervals. They do not flower at every leaf-change, but only after marked periods of dry weather. The large branches of big pulai trees provide favourable nesting sites for wild bees.

Pollination is by insects; when flowering, trees are often surrounded by butterflies and bees. The fruits open on the tree and the seeds, which have a tuft of silky hairs at each end, are dispersed by wind.

Other botanical information The genus *Alstonia* is divided into 5 sections, mainly on the basis of seed morphological characteristics. The sections *Alstonia* and *Monuraspermum* Monach. occur in Malesia. They mainly differ from each other by the number of secondary veins, direction of the contortion of the corolla lobes, shape of the seed and architecture. Pulai trees often resemble jelutong (*Dyera costulata*) trees, but they can be distinguished by their usually tall buttresses and typically fluted stems. Within South-East Asia *Alstonia* can also be confused with the genera *Rauvolfia*, *Tabernaemontana* and *Ochrosia*, which all have verticillate leaves, but *Alstonia* can be distinguished by its slender fruits and ciliate seeds. The name *Alstonia* R.Br. is conserved as a later homonym of *Alstonia* Scop. which is a synonym of *Pacouria* Aublet (*Apocynaceae*). Giant stomata have been observed in *A. macrophylla*.

Ecology Species of *Alstonia* grow in both primary and secondary lowland evergreen to deciduous rain forest. They occur on humus-rich clayey soils but also on sandy or even limestone soils and in places which are periodically inundated and carry swamp or peat-swamp forest, to comparatively dry areas with savanna woodlands. In Sarawak several distinct subtypes of mixed peat-swamp forest can be distinguished, in one of which pulai (*A. pneumatophora*) occurs in association with terentang (*Campnosperma* spp.) and in another in association with meranti (*Shorea* spp.). The species occur from sea-level to up to 1000 m altitude, and in the area of distribution the annual number of dry months ranges from 0 to 3.

Propagation and planting Seeds are difficult to collect, as the fruits open while still on the trees. The weight of 1000 seeds is about 1.5–2 g. The germination rate of fresh seeds is high, nearly 100%. Seeds can be stored in closed tins for 2 months, maintaining a germination rate of 90%. Seeds of *A. angustiloba* germinate in 2–8 weeks after sowing. In Indonesia, seedlings are planted into the field when they are 15–25 cm tall, with spacing of 1 m × 2 m and interplanted with *Leucaena leucocephala* (Lamk) de Wit.

A. scholaris has been grafted. Cleft grafting and inverted T-grafting have been found to be most appropriate.

Silviculture and management Natural regeneration of pulai is often scarce, and seedlings are found scattered or in groups, particularly in open places at forest edges and in secondary forest. Regeneration can be enhanced by enrichment planting using the strip system, but sufficient opening of the canopy is essential for optimal growth of the seedlings. There is hardly any experience with silviculture of pulai. Young pulai trees coppice well.

Harvesting In most countries of South-East Asia pulai is harvested selectively from natural forest, with a diameter limit of 40 cm, 50 cm or 60 cm. Pulai logs float easily in water when freshly cut, but they tend to become waterlogged and to sink after some weeks. The logs are very susceptible to insect and fungal attack and should be dried quickly or treated with preservatives after felling. The latex is harvested by making incisions in the bark.

Genetic resources Most *Alstonia* species are common and widely distributed, although they occur scattered, and do not seem immediately liable to genetic erosion, largely because they often easily invade severely disturbed places. However, stands are heavily depleted locally as a result of deforestation caused by logging and shifting cultivation (e.g. in the Philippines) and the remaining stands need protection.

Prospects As a fast-growing tree, pulai seems to have good prospects for timber production, notwithstanding the limited uses of the timber. Research on all silvicultural aspects is highly desirable, and experimental plantations should be established and studied.

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Selection of species

Alstonia angustifolia Wallich ex A.DC.

Prodr. 8: 409 (1844).

Synonyms *Alstonia latifolia* Ridley (1923), *Alstonia beccarii* (Benth.) Pichon (1947).

Vernacular names Malaysia: pulai penipu paya, pulai penipu bukit (Peninsular), pulai pipit (Sarawak).

Distribution Peninsular Malaysia, Sumatra, Bangka, West Java, Borneo and Sulawesi.

Uses The wood is used as hard alstonia, but because the trees are small, it is often used only locally. The bark contains alkaloids and presumably has medicinal properties.

Observations A small to medium-sized tree of up to 20 m tall, inner bark yellowish, without latex; leaves on slender petioles of c. 15 mm long, usually in whorls of 3, oblanceolate, 6–14 cm long, acuminate, with 18–25 pairs of secondary veins; calyx and corolla densely tomentose outside; follicles glabrous. *A. angustifolia* occurs in seasonal peat swamps, often at low altitude but sometimes up to 1500 m. The density of the wood is about 800 kg/m^3 at 15% moisture content.

Selected sources 35, 89, 146, 269, 370, 455, 496, 619, 779.

Alstonia angustiloba Miq.

Fl. Ind. Bat. 2: 438 (1856).

Synonyms *Alstonia calophylla* Miq. (1856), *Alstonia iwahigensis* Elmer (1912), *Paladelpha angustiloba* (Miq.) Pichon (1947).

Vernacular names Brunei: pelai beruang. Indonesia: pulai hitam. Malaysia: pulai (Peninsular), pulai bukit (Sabah). Philippines: silhigan (Tagbanua).

Distribution Peninsular Malaysia, Sumatra, Java, Borneo (Sarawak, Sabah and Brunei) and the Philippines.

Uses The wood is used as pulai. It is suitable for pencil manufacture, matches, tea chests, crates, plywood and carpentry. The latex is used with copper sulphate to treat yaws, a skin disease.

Observations A medium-sized to large tree of up to 45 m tall, bole tall, straight, fluted, up to 100 cm in diameter, buttresses straight, c. 4.5 m tall and spreading out at the base for c. 1.5 m, outer bark brown or grey to whitish, smooth to finely tessellated, inner bark mottled, yellow-brown, with copious latex; leaves on a stout petiole, in whorls of 5–8, 8–16 cm long, elliptical, subacuminate or obtuse, with numerous secondary veins; calyx hirtellous, corolla glabrous outside; follicles pilose. *A. angustiloba* occurs on a wide variety of soils and is common in mixed dipterocarp forest on low hills and undulating land, and in freshwater swamp forest, up to 700 m altitude. It becomes abundant in secondary forest and is apparently a fast-growing light demander. The density of the wood is 240–490 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 33, 35, 100, 146, 307, 370, 373, 452, 455, 461, 475, 496, 560, 619, 704, 762, 779.

Alstonia macrophylla Wallich ex G. Don

Gen. syst. 4: 87 (1837).

Synonyms *Alstonia batino* Blanco (1845), *Alstonia pangkorensis* King & Gamble (1907), *Alstonia oblongifolia* Merr. (1915).

Vernacular names Malaysia: pulai penipu bukit (Peninsular), pulai daun besar, sayongan (Sabah). Philippines: batino (general), cayacayao. Thailand: thungfa (peninsular), kra thungfa hai (Chumphon), teen thian (Songkhla). Vietnam: s[uwx]a l[as] l[ows]n, m[ows]p l[as] to.

Distribution From Sri Lanka and mainland South-East Asia to Peninsular Malaysia, Sumatra, Borneo (Sabah), the Philippines, Sulawesi and the Moluccas. Cultivated in Africa.

Uses The wood is used as hard alstonia. Because of its wavy and attractive nature, it is especially suitable for furniture and flooring. The bark is used as febrifuge and to treat dysentery.

Observations A small to medium-sized tree of up to 30 m tall, bole straight, up to 65 cm in diameter, sometimes fluted at the base or with small buttresses, outer bark blackish-brown to grey, smooth, tessellated, with small, square, adherent scales, inner bark cream, with broken, orange-yellow laminations, without latex; leaves on a slender petiole, in whorls of (3–)4, 8–30 cm long, oblong-lanceolate, acuminate, with less than 20 secondary veins; calyx laxely puberulous to glabrous, corolla glabrous outside; follicles glabrous. *A. macrophylla* grows in secondary or disturbed forest, sometimes near the coast.

Selected sources 100, 146, 175, 307, 315, 370, 455, 484, 496, 568, 575, 579, 608, 617, 619, 625, 704, 779.

Alstonia pneumatophora Backer ex den Berger

Meded. Proefst. Thee 97: 153 (1926).

Vernacular names Brunei: pulai puteh. Malaysia: pulai basong (Peninsular). Indonesia: basung (Sumatra).

Distribution Peninsular Malaysia, Sumatra, Borneo and Sulawesi.

Uses The wood is used as pulai; it is suitable for carving. The wood of the aerial roots is used as a substitute for cork. The latex from the bark can be used for healing wounds and, when mixed with oil, to make glue sticks.

Observations A medium-sized to large tree of up to 45 m tall, bole fluted, up to 100 cm in diameter, with large, narrow buttresses of up to 10 m tall, sometimes spreading as stout tortuous ground roots with knees (pneumatophores), sometimes with flying buttresses, outer bark grey to white, tinged yellow or purplish, smooth, sometimes with scaly patches, inner bark thick, soft, orange-brown, granular, with copious latex; leaves in whorls of 4–6, 8–10 cm long, spatulate, with a rounded or retuse apex and numerous secondary veins; inflorescence with 2 nodes of many crowded flowers on 0–3 mm long pedicels; calyx hirtellous, corolla glabrous outside; follicles pilose. *A. pneumatophora* occurs in mixed peat-swamp forest on shallow peat, especially overlying sand near the coastal fringe, becoming abundant near the mouth of large rivers. The density of the wood is about 400 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 33, 100, 274, 318, 455, 496, 559, 619, 779.

Alstonia scholaris (L.) R.Br.

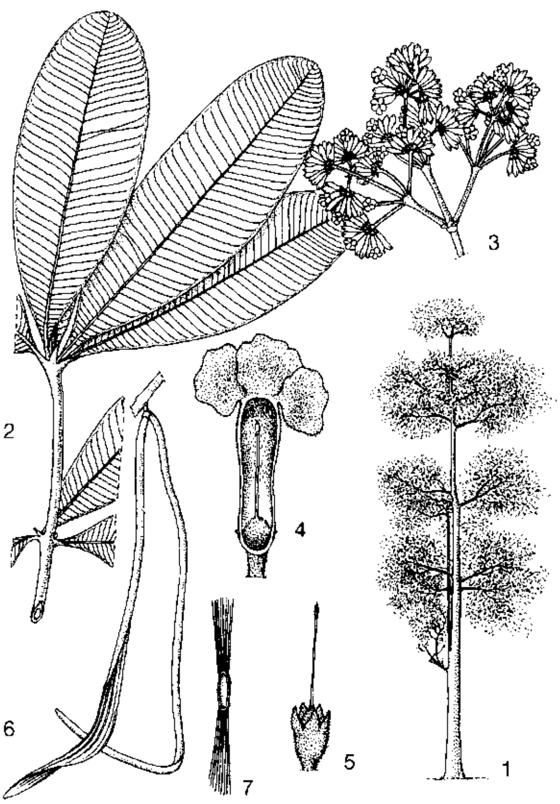
Mem. Wern. Nat. Hist. Soc. 1: 76 (1811).

Synonyms *Echites scholaris* L. (1767), *Tabernaemontana alternifolia* Burm. (1768), *Echites pala* Ham. (1822).

Vernacular names White cheesewood, milkwood pine, blackboard tree (En). Brunei: pulai lilin. Indonesia: pulai (general), pule (Java), rite (Ambon). Malaysia: pulai (Peninsular). Papua New Guinea: white cheesewood, milky pine. Philippines: dita (general), dalipaoen. Burma: lettok. Laos: tinpet. Thailand: sattaban, teenpet (central), hassaban (Kanchanaburi). Vietnam: c[aa]y m[of] cua, c[aa]y s[uwx]a.

Distribution *A. scholaris* is the most widely distributed species in the genus, found from Sri Lanka and India through mainland South-East Asia and southern China, throughout Malesia, to northern Australia, the Bismarck Archipelago and the Solomon Islands. Planted elsewhere.

Uses *A. scholaris* is the most important source of pulai timber. The wood yields a good-quality pulp. In Java the wood was formerly used for school blackboards (hence 'scholaris'). The thin roots and the bark have a bitter taste; the bark contains many alkaloids and is used medicinally for many purposes (e.g. as anthelmintic, astringent tonic, alterative, antidiarrhoeaticum and an-



Alstonia scholaris (L.) R.Br. - 1, habit of young tree; 2, sterile twig; 3, inflorescence; 4, sectioned flower; 5, calyx; 6, fruits; 7, seed.

tiperiodicum as well as for treating fever and other debilitating diseases). The latex can be used to clean wounds, or when mixed with oil, to treat earache and is often used in traditional medicine. It also provides a good-quality chewing gum. A poultice made from the leaves has been reported as a good remedy against skin diseases. The tree is sometimes planted as an ornamental.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole cylindrical, in older trees massively fluted, up to 125 cm in diameter, with stout buttresses of c. 6 m tall which spread out at the base for up to 2 m, outer bark brown or yellowish-white, smooth but coming off evenly in small papery flakes, with horizontally enlarged lenticels and hoops, inner bark yellow to brown, usually tinged yellowish, with copious white latex; leaves on a 1.5–3 cm long petiole, in whorls of 5–8, 7–17 cm long, elliptical, usually with a rounded apex and numerous secondary veins; calyx pubescent, corolla pubescent outside; follicles glabrous. Two varieties can be recognized: var. *scholaris*, having glabrous leaves, and var. *velutina* Monach., having strigillose-pilose leaves beneath. The latter variety occurs in Peninsular Malaysia, Borneo and New Guinea. *A. scholaris* is most abundant in monsoon areas, and it tolerates a variety of soils and habitats, including secondary vegetation. It occurs up to 500(–1000) m altitude. As an ornamental it has proved adaptable to the climates of southern Florida and California (United States). The density of the wood is 270–490 kg/m^3 at 15% moisture content. See also the table on wood properties.

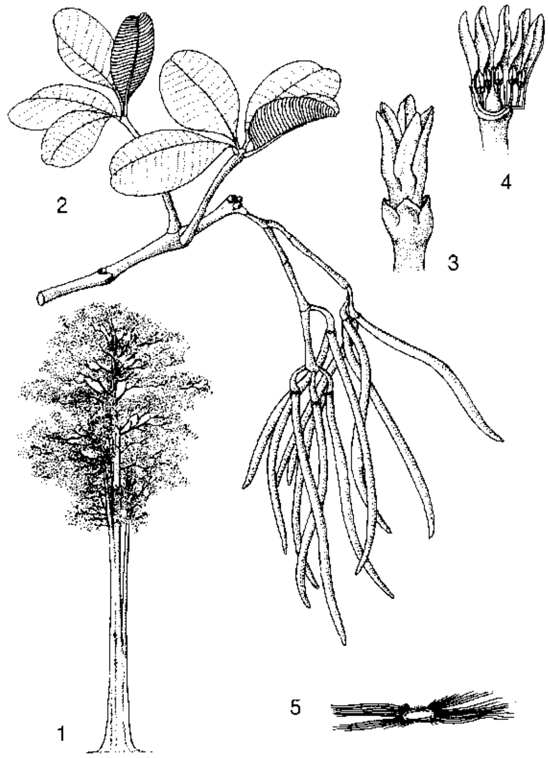
Selected sources 33, 35, 67, 100, 175, 177, 307, 315, 318, 359, 370, 440, 455, 461, 481, 484, 496, 560, 579, 608, 619, 625, 671, 704, 753, 779.

Alstonia spatulata Blume

Bijdr. fl. Ned. Ind. 1037 (1826).

Synonyms *Alstonia cuneata* Wallich ex G. Don (1837), *Alstonia cochinchinensis* Pierre ex Pitard (1933).

Vernacular names Hard milkwood, siamese balsa (En). Indonesia: lame bodas (general), pulai



Alstonia spatulata Blume - 1, tree habit; 2, fruiting twig; 3, flower; 4, sectioned flower; 5, seed.

gabus (Sumatra). Malaysia: pulai paya (general), pulai basong (Peninsular), pulai lilin (Sabah). Thailand: thia, sia, teenpet phru (peninsular).

Distribution Laos, Cambodia, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Bangka, West Java, Borneo and New Guinea.

Uses The wood is used as pulai and is suitable for tea chests, crates, carving, plywood and carpentry. The wood of the roots is used for pith helmets, rafts, rafters for fishery and as a replacement for cork. The latex is applied to sores and skin diseases; the bark contains alkaloids and probably has medicinal properties.

Observations A small to medium-sized tree up to 20(–30) m tall, bole at first cylindrical, becoming fluted and shortly buttressed at the base, up to 75 cm in diameter, outer bark grey, smooth, coming off in small papery flakes, inner bark pale yellow, with copious latex; leaves on a narrowly winged petiole, in whorls of 4–6, 7–10 cm long, spatulate, rounded at the top, with numerous secondary veins; inflorescence loose, flowers on 2–10 mm long pedicels; calyx glabrous, corolla glabrous outside; follicles glabrous. *A. spatulata* occurs scattered on poorly drained, frequently flooded, clay-rich alluvium and on gley soils on undulating land, particularly near streams, usually below 300 m altitude; it is often abundant in secondary or shrub vegetation.

Selected sources 33, 35, 89, 100, 146, 174, 307, 315, 318, 359, 373, 455, 496, 625, 671, 779.

Alstonia spectabilis R.Br.

Mem. Wern. Nat. Hist. Soc. 1: 76 (1811).

Synonyms *Alstonia villosa* Blume (1826), *Alstonia subsessilis* Miq. (1868), *Alstonia longissima* F. v. Mueller (1877).

Vernacular names Hard milkwood (En). Indonesia: legarang (Java), pole (Timor), oli (Irian Jaya). Papua New Guinea: hard alstonia.

Distribution Java, Borneo, the Philippines, Sulawesi, the Moluccas, New Guinea and northern Australia.

Uses The wood is used as hard alstonia and is suitable for building houses and bridges; it is also used for household implements.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole up to 60 cm in diameter; leaves on a 0–2 cm long petiole, usually in whorls of 3, 10–30 cm long, oblong-lanceolate, shortly acuminate to obtuse and with about 15 pairs of secondary veins; calyx and corolla white tomentose outside; follicles glabrous. *A. spectabilis* is often common in rain forest up to 450 m altitude. The density of the wood is 600–800 kg/m^3 at 15% moisture content.

Selected sources 35, 359, 373, 455, 496, 671.

Rudjiman (general part, selection of species),
N. Gintings (general part),
A. Martawijaya (properties),
J. Ilic (wood anatomy)

Altingia Noroña

Verh. Batav. Genootsch. Kunsten 5, art. 2: 1 (1790).

HAMAMELIDACEAE

x = probably 8; $2n$ = 32

Trade groups Rasamala: medium-weight hardwood, a single species, *Altingia excelsa* Noroña, Verh. Batav. Genootsch. Kunsten 5, art. 2: 1 (1790).

Vernacular names Rasamala. Indonesia: mala (Java), tulasan (Sumatra), mandung (Minangkabau). Burma: nantayok. Laos: sop. Thailand: sop, hom (northern), satu (eastern). Vietnam: t[oo] h[aj]p l[as] h[if]nh tim.

Origin and geographic distribution *Altingia* consists of 8 species and is distributed from southern Tibet, Assam (India) and mainland South-East Asia including southern China towards the Malesian area. Only a single species is represented in Malesia: *A. excelsa*. This species is distributed from the Himalayas through the moister parts of Burma towards Peninsular Malaysia (where it is extremely rare), Sumatra and West Java. It is planted for reforestation (mainly West and Central Java).

Uses Rasamala is regarded as the most valuable timber in West Java. Because of its ability to form very long branchless boles, it was favoured for frames of bridges and columns and beams for buildings. The wood is very durable and can be used in direct contact with the ground, for example for power transmission poles, telephone line poles and railway sleepers. However, poles and sleepers are often made of wood from young trees (especially from thinnings); they are not durable then and should be treated with preservatives. Furthermore, the timber is used for heavy construction, vehicle bodies, ship and boat building, heavy flooring and rafters. The wood yields a veneer and plywood of suitable quality and gives good results in the manufacture of wood-wool boards. Pulp for the manufacture of paper can also be obtained from rasamala wood.

The bole yields an aromatic resin, called 'getah malai', which is collected and used as an incense. Small bees (*Apona* spp.) which inhabit hollows in the trunk collect the resin and use it to build their combs. Resin collected from these combs is called 'getah kandai'. Young leaves (flushes) emit a pleasant aromatic odour when crushed and in Indonesia they are mixed in a salad ('lalab') or cooked and eaten as a vegetable. When masticated, the leaves have also been used to cure coughs and in traditional medicine on Java. The dried bark has been used as tinder.

Production and international trade No production and trade statistics are available for rasamala. The wood is not exported, and is used only locally.

Properties Rasamala is a medium-weight hardwood. The heartwood is dark pinkish, red or reddish-brown, gradually merging into the yellowish or reddish-brown sapwood. The density is 610–900 kg/m^3 at 15% moisture content. The grain is straight to slightly interlocked, texture fine and even.

At 15% moisture content, the modulus of rupture is about 102 N/mm^2, the modulus of elasticity 9000 N/mm^2, compression parallel to grain 59 N/mm^2, shear 5–6 N/mm^2, cleavage 65 N/mm radial and 90 N/mm tangential, Janka side hardness 6200 N and Janka end hardness 6200 N. See also the table on wood properties.

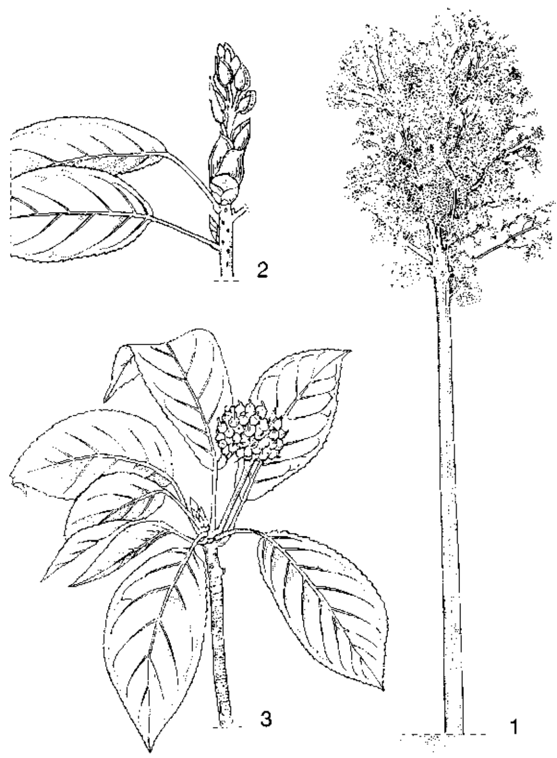
The rates of shrinkage are high, from green to oven dry 5.6% radial and 11.6% tangential. Rasamala dries slowly and with considerable defects; it is prone to cupping, twisting, and checking at the knots, especially in pieces with interlocked grain. The wood must be dried carefully and stacked properly, especially during kiln drying. The air drying of 2 cm thick boards to 15% moisture content takes over 5 months, and boards of 3 cm thick require almost 7 months to dry. The recommended temperature for kiln drying is 38–60°C with a corresponding relative humidity of 86% to 38%.

Rasamala is easy to work and to saw. Tests on the machining properties show very good results for planing, boring, mortising and sanding, whereas turning is rated as good. Veneer of 1.5 mm thick can be made at a peeling angle of 91° after boiling for 24 hours; gluing with formaldehyde produces good-quality plywood.

Rasamala is classified as moderately durable to very durable. Graveyard tests under tropical conditions showed an average service life in contact with the ground of 12.7 years. However, graveyards tests of rasamala wood from plantation forest indicate a lesser durability, possibly because of the faster growth and younger age of the trees. Laboratory tests show that the wood is moderately resistant to resistant to dry-wood termites. The wood is moderately resistant to impregnation by the full cell process.

The wood contains 46% cellulose, 30% lignin, 17% pentosan, 1.4% ash and up to 0.7% silica. The solubility is 1.5% in alcohol-benzene, 2.4% in cold water, 2.8% in hot water and 14.4% in a 1% NaOH solution. The energy value of the wood is 20 220 kJ/kg.

Description A monoecious, evergreen, large and lofty tree of up to 50(–60) m tall; bole branchless for 20–35 m, 80–150(–185) cm in diameter, often slightly twisted or fluted at base; bark surface almost smooth, with narrow, longitudinal fissures and finally irregularly flaky with long, thin, light grey to yellowish or brownish-grey flakes; crown irregularly globular, that of juvenile specimens conical and acute; branches generally steeply ascending. Leaves arranged spirally, simple, elliptical to oblong or ovate to ovate-lanceolate,



Altingia excelsa Noroña – 1, tree habit; 2, young male inflorescence; 3, fruiting twig.

6–12(–16) cm × 2.5–5.5(–6.5) cm, rounded to slightly cordate at base, acute to acuminate or sometimes caudate at the apex, pinnately veined; margin glandular crenate-serrate; upper surface glabrous, lower surface glabrous to puberulous; petiole usually with sessile or shortly stalked glandular appendages at the apex; stipules very small, caducous. Inflorescence consisting of peduncled male or female heads, initially enveloped by 4 bracts; male heads 6–14 per inflorescence, in 1–2 cm long racemes, consisting of masses of short stamens, perianth, disk and ovary absent, anthers with 4 pollen sacs, dehiscing with longitudinal slits; female head solitary, globose to subglobose, 6–9 mm × 5–8 mm, puberulous, 4–18-flowered, stamens rudimentary or absent, flowers without perianth but with disk consisting of a variable number of minute lobes, ovary 3/4-inferior, 2-celled, with numerous ovules in each cell, styles 2, divergent and often strongly recurved, with decurrent, papillose stigmas. Fruit head 1.2–2.5 cm × 1.2–2 cm, woody, on a 2–3.5 cm long peduncle; fruit 4-valved, surrounded by a ring of enlarged, hardened disk lobes, light brown puberulous at the apex. Fertile seeds 0–1(–2) in each cell, dorsoventrally flattened, obovate, surrouded by a narrow wing, sweet scented; sterile seeds up to 35 in each cell. Seedling with epigeal germination; cotyledons foliaceous, on a hairy petiole; leaves arranged spirally.

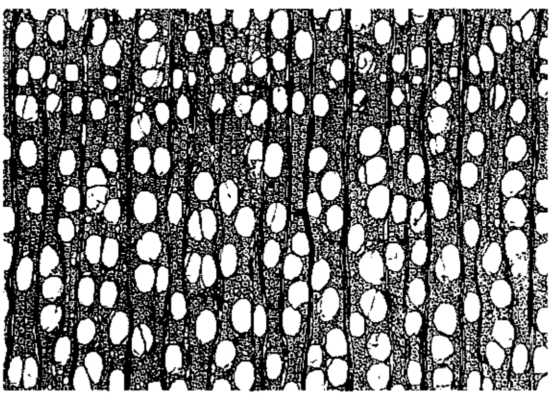
Wood anatomy

– Macroscopic characters:

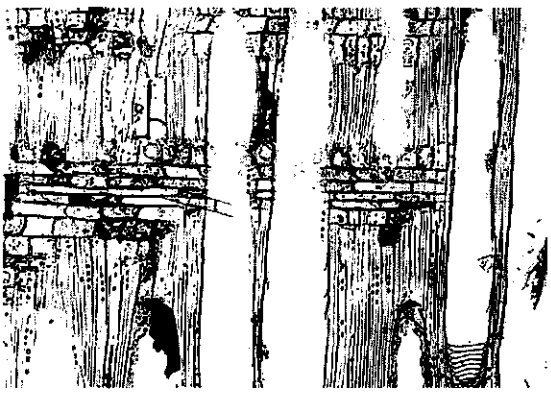
Heartwood pink to dull reddish-brown, indistinctly demarcated from the somewhat lighter sapwood. Grain straight, irregular to somewhat interlocked. Texture fine and even. Wood usually dull but with some lustre on radial surfaces. Growth rings wide and prominent macroscopically (1–2/cm); vessels, parenchyma and rays not visible without a hand lens.

– Microscopic characters:

Growth rings tending to be distinct, marked by a narrow band of thicker-walled fibres with fewer vessels. Vessels diffuse, 26–48/mm^2, predominantly solitary but long overlapping vessel segment tips produce pairs in transverse section, evenly distributed throughout the growth ring but reduced in the latewood, tending to be larger in the middle of the ring but generally exhibiting little variation throughout the growth ring, rounded or angular, 60–110 μm in diameter; perforation plates scalariform, with 15–30 thin bars; intervessel pits scalariform, up to 50 μm in horizontal diameter, with prominent borders; vessel-ray pits



transverse section (×25)



radial section (×75)

tangential section (×75)

Altingia excelsa

half-bordered with reduced borders to almost simple, mostly confined to upright cells, oblique to horizontally scalariform, up to 35 μm. Fibres 1100–2700 μm long, non-septate, moderately thick- to thick-walled; fibre pits in radial and tangential walls distinctly bordered with maximum diameter up to 10 μm; gummy deposits occasionally present. Parenchyma apotracheal, scarce to fairly abundant, diffuse and tending to diffuse-in-aggregates with 2 to several cells spanning the rays, cells tending to be flattened tangentially, strand length 2–6 cells, gummy deposits relatively plentiful. Rays 8–11/mm, conspicuous on radial surfaces because of gummy deposits, up to 1(–2.2) mm high, heterocellular with up to 3 upright marginal cells, 1–4(–5) cells wide and up to 40 cells high, sometimes linking axially; few low rays mainly uniseriate, 2–15 cells high and consisting of upright cells. Enlarged prismatic crystals often present in upright ray cells. Silica usually absent. Traumatic gum ducts occasionally present in narrow tangential bands.

Growth and development The growth of seedlings is slow for the first few years, but is rapid later. Seedlings tolerate shade. Trees attain an average height of 14 m and an average diameter of 12.5 cm in 10 years, 22 m height and 23 cm diameter in 20 years, 34.5 m height and 39.5 cm diameter in 40 years, and 47 m height and 61.5 cm diameter in 80 years. The growth rates strongly depend on elevation; growth is fastest at 600–700 m altitude.

Rasamala occurs in more or less pure stands. There are indications that inbreeding is common because of the presence of 'family clumps' in the forest.

Flowers appear together with new flushes. Although rasamala flowers every year, in certain years the tree blossoms more abundantly. In Java, rasamala flowers particularly in April – May. The best seeds are obtained from fruits produced in August – October. The seeds have a sweetish scent, and are dispersed by ants. Monkeys and birds may contribute to the dispersal as well, by eating the seeds.

Other botanical information *Altingia* belongs to the more primitive genera of the *Hamamelidaceae*. Together with the Asiatic genus *Semiliquidambar* and the more or less pantropical genus *Liquidambar* it is grouped in the subfamily *Altingioideae*. This subfamily has a rather isolated position, deviating from the rest in various ways, including features of wood anatomy, the unisexual flowers, pollen type and cytology. It has been suggested that this subfamily be promoted to a family level (*Altingiaceae*). The genus *Altingia* is divided into 2 sections: section *Altingia* and section *Oligocarpa* H.-T. Chang on the basis of their fruiting heads. The records for Thailand of *A. excelsa* probably all refer to the closely related *A. siamensis* Craib.

Ecology Rasamala is a characteristic element of humid mixed hill and montane forest. It often occurs gregariously and forms the backbone of the forest at altitudes between 550 and 1700 m where precipitation is at least 100 mm during the driest month. When planted outside its natural distribution area, it will tolerate less rainfall. Rasamala occurs on rich, well-drained volcanic soils or sometimes on the better soils overlying sedimentary rock. In primary forest 10–35 specimens may be encountered per ha containing (50–)75–85% of the total timber volume. Its principal associates are *Podocarpus* and *Quercus* species and further a number of elements of this type of montane forest such as *Schima, Castanopsis, Eugenia, Sloanea, Dysoxylum, Engelhardtia, Magnolia, Michelia,* and *Elaeocarpus* species.

Propagation and planting Rasamala was first planted in the mid-19th Century. Originally, seedlings from natural regeneration in the forest were used (natural regeneration is usually plentiful, even in plantations), but later the seeds were sown on seed-beds. Fruits contain up to 35 seeds, but usually only one of these is fully developed and viable. The best way to obtain viable seeds is to pick nearly ripe fruits and dry them in the sun. The weight of 1000 seeds is about 6 g.

Seeds are viable for a short period and should be sown rapidly. They start to germinate after about 10 days; the germination rate of fresh seed is reported to be 40%. It is not recommended to use stumps for plantation establishment as this often results in multiple leaders. The usual planting distance is 1 m × 3 m, but on steep slopes 1 m × 2.5 m is used.

Silviculture and management *Leucaena leucocephala* (Lamk) de Wit is often interplanted in young plantations to suppress weeds. Interplanting with other timber trees is not recommended. Young rasamala trees tend to form double leaders when much light is available, and therefore close planting in pure stands is preferable. Thinning is needed about every 5 years. The rotation is at least 60 years, but preferably 80 years.

Diseases and pests The fungus *Rhizoctonia* sp. may cause damping-off of seedlings in nurseries. Root and bark borers such as *Endoclita sericeus* may cause damage in young plantations, as well as caterpillars like *Eutelia inextricata* and *Cricula trifenestrata* which feed on the leaves. *Exopholis hypoleuca* and *Leucopholis rorida* are pests of young plantations but can be controlled by using insecticides.

Harvesting Selective cutting of rasamala trees started several centuries ago. Rasamala timber was in great demand for building purposes. Nowadays it is still selectively harvested in Indonesia under the selective felling system, with a diameter limit of 60 cm and leaving 25 healthy trees/ha as core trees for future harvest. Harvesting is often not easy in the hills and mountains where rasamala occurs naturally. Yarding can be done by cable. It is difficult to transport the logs in mountainous terrain, especially because of their large size and the high density of the wood.

Yield The average annual production of timber in plantations is 9–13 m^3/ha. On sites of reasonable quality, a pure rasamala plantation of 60 years old may have a timber volume of 450 m^3/ha. Natural stands may yield 100–150 m^3/ha.

Genetic resources Rasamala forests, natural and planted, are threatened in many areas by harvesting of firewood, conversion into rice fields and tea plantations, and cattle grazing. However, at present comparatively large stands of rasamala still thrive in many different areas and therefore genetic resources seem still to be sufficient. In Java, mountain people distinguish 3 types of trees based on the colour of the wood: 'mala beureum' for light red or flesh-coloured wood, 'mala gadok' for dark red wood and 'mala taribih' for very dark red wood. When looking for genetic variability in *A. excelsa*, the variation in wood colour could be taken into consideration.

Prospects The prospects for rasamala as a producer of construction timber in areas at higher altitude (500–1000 m) are promising. The wood has good properties and it is available in large sizes. The quality of plantation-grown wood should, however, be further investigated.

To avoid the depletion of resources, regeneration should be promoted by enrichment planting. Large-scale planting in pure stands is profitable. Seed-orchards of rasamala must be designated and managed appropriately, as good-quality seed for establishing plantations is often not available. Research should be done on the optimal methods of vegetative propagation.

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Other selected sources 102, 192, 277, 318, 350, 458, 460, 551, 668, 684, 762.

I. Soerianegara (general part),
M.A. Rifai (general part),
A. Martawijaya (properties),
J. Ilic (wood anatomy)

Anisoptera Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 65 (1841).

DIPTEROCARPACEAE

x = probably 11; *A. costata*: $2n = 20$, *A. laevis*: $2n = 22$, *A. scaphula*: $2n = 20, 22$

Trade groups Mersawa: lightweight hardwood, e.g. *Anisoptera laevis* Ridley, *A. marginata* Korth., *A. thurifera* (Blanco) Blume.

Vernacular names Mersawa. Brunei: benchaloi. Malaysia: kayu pengiran (Sabah), kelapok (Iban). Philippines: palosapis. Burma: kaunghmu, kaban, boilam. Cambodia: phdiek, trabak, ven ven. Laos: bak. Thailand: krabak, tabak (Lampang). Vietnam: v[ee]n v[ee]n.

Origin and geographic distribution *Anisoptera* consists of 11 species and is distributed from Bangladesh eastwards towards Thailand and Vietnam and throughout Malesia to New Guinea. The majority of the species are confined to western Malesia. The genus is absent from the Lesser Sunda Islands. Holocene fossils have been discovered in north-western India.

Uses The timber is extensively used for general light construction such as door and window frames, weatherboards, decorative panelling, ceilings, beams and scantlings, girders, rafters, packing cases, crates and boxes, vehicle bodies and furniture. Other uses are for butcher's blocks, drop siding, spools, baseball bats, venetian blinds and clothes hangers. Due to the moderate durability of the wood, it should not be used in contact with the ground. It is suitable for light to medium traffic flooring. Since the wood is resistant to marine borer attack, it is suitable for ship building, barrels and vats. It is in great demand for plywood manufacturing and can be used both as core and face veneer.

Comparatively small amounts of resin can be obtained from the trees; this is sometimes mixed with other kinds of resin and used locally for torches and caulking boats. It is not collected on a commercial scale. In some areas of Papua New Guinea the nuts of *A. thurifera*, which are rich in edible oils, are eaten after being cooked. The gum is used traditionally as a chewing gum.

Production and international trade The export of sawn mersawa timber from Peninsular Malaysia in 1981 was 14 000 m^3 with a value of US$ 1.6 million. The annual quantity exported was more or less stable until 1987, when it increased suddenly to 53 000 m^3 with a value of US$ 7.4 million. In 1990 the largest annual export quantity of 63 000 m^3, worth US$ 15.8 million, was reached; in 1992 the export was 42 000 m^3, worth US$ 15.0 million. Fairly large amounts of mersawa are also exported from Borneo. For instance, the export of round logs from Sabah in 1987 was 43 000 m^3 with a value of US$ 3.1 million, and in 1992 17 000 m^3 of round logs and 6500 m^3 of sawn timber with a total value of US$ 3.5 million. Recently small amounts of mersawa ('palosapis') have been exported from the Philippines; in 1980 the export value was US$ 196 000 but it fell to US$ 19 000 in 1988 and was only US$ 2500 in 1989. Production and export figures are not available from Papua New Guinea and Sarawak, or from Indonesia. Undoubtedly, mersawa is important for plywood production in Indonesia. Japan imports fairly large amounts of mersawa, particularly from Papua New Guinea, Sabah and Sarawak.

Mersawa has some importance in Burma, Indo-China and Thailand. The annual production at the beginning of the 1980s was about 1000 m^3 in Burma, 25 000 m^3 in Cambodia, and 10 000 m^3 in Thailand.

Mersawa is sometimes traded in mixed consignments with white and yellow meranti (*Shorea* spp.).

Properties Mersawa is a light to moderately heavy hardwood. The sapwood is very pale yellow when fresh, becoming darker on exposure and often not clearly demarcated from the light to dark yellow heartwood which sometimes has a rose tinge and which also darkens to a straw brown on exposure. The density is (460–)510–740(–895) kg/m^3 at 15% moisture content. The grain of the wood is straight to interlocked or sometimes slightly spiral, texture moderately coarse but even.

Tests of mersawa wood in green condition in Indonesia, Malaysia, the Philippines and Papua New Guinea showed the following mechanical properties: modulus of rupture 49–76 N/mm^2, modulus of elasticity 9200–12 800 N/mm^2, compression parallel to grain 25–33 N/mm^2, compression perpendicular to grain 4.5–6 N/mm^2, shear 5.5–7.5 N/mm^2, cleavage 50–65 N/mm radial and 54–69 N/mm tangential, Janka side hardness 2185–4180 N and Janka end hardness 2740–3600 N.

Tests in Indonesia at 15% moisture content showed the following figures: modulus of rupture 67–81 N/mm^2, modulus of elasticity 9600–12 150 N/mm^2, compression parallel to grain 36–45 N/mm^2, shear 6–8 N/mm^2, cleavage 56–66 N/mm radial and 61–73 N/mm tangential, Janka side hardness 2215–3520 N and Janka end hardness 2450–3310 N.

The rates of shrinkage are moderate, from green to 15% moisture content 1.4% radial and 3.2–3.8% tangential, from green to oven dry the shrinkage may be as much as 3.8% radial and 11% tangential. Mersawa air dries very slowly with slight seasoning defects such as cupping and bowing. Boards of 25 mm and 40 mm thick take respectively 7.5 months and 9 months to air dry. In Malaysia kiln schedule E is recommended. Kiln drying is also slow but without degrade, although the core of logs of old trees tends to retain a high moisture content. After satisfactory drying, the wood is fairly stable in service.

Mersawa is difficult to rip, to cross cut and to plane because of the presence of silica. Stellite-tipped saws are necessary. The planed surface is smooth when sharp tools are used, and boring and turning is easy, giving smooth surfaces (although sometimes rough after boring). Mersawa is easy to nail and screw, and holds nails and screws well.

It is suitable to be peeled for veneer of good quality, although the veneer dries slowly and with slight buckling. The gluing properties are good and good-quality plywood can be made. Experimental particle boards made in Malaysia with 8% resin and 1% wax and with a density of 634 kg/m^3 had properties exceeding those stipulated in the British standards. Hardboards made from wood of *A. scaphula* in Thailand had good properties, both by wet- and dry-processes (satisfying the specifications stipulated in the Japanese standard).

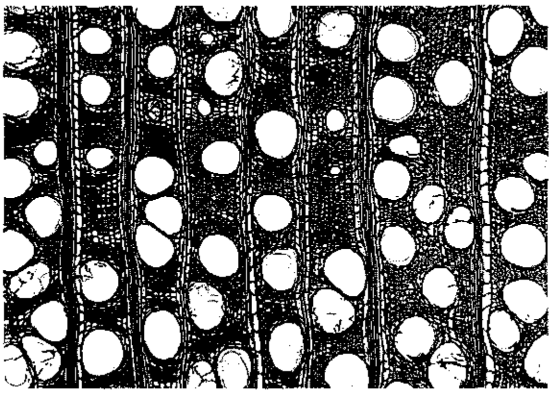
Mersawa is classified as moderately durable under exposed conditions. Untreated stakes of *A. marginata* (600 mm × 50 mm × 50 mm) lasted 5 years in graveyard tests in Malaysia. Mersawa is very susceptible to fungal attack; blue stain infection of the sapwood occurs easily. It is moderately susceptible to attack by *Lyctus* beetles and termites. However, because of the fairly high silica content, it is rather resistant to marine borers. Mersawa is difficult to treat with preservatives. Absorption of creosote is less than 32 kg/m^3 using the open tank process.

Description Medium-sized to very large trees up to 65 m tall; bole straight, branchless for up to 30 m, and up to 150(–200) cm in diameter, often with prominent, thick, rounded, tall and straight buttresses; outer bark highly variable between immature and mature trees, up to 2 cm thick, containing resin, greyish or yellowish, dotted with warty lenticels, shallowly and irregularly fissured, ridges flat and flaking, inner bark laminated with alternate layers of light and dark yellow; crown comparatively small, with a few large and twisted branches; twigs ribbed; young parts at first densely lepidote with emarginate peltate (scale-like) hairs. Leaves alternate, simple, entire, oblong to ovate, base usually obtuse, apex shortly acuminate, lower surface persistently covered with peltate hairs; secondary veins curved and anastomosing at the apex; petiole distinctly geniculate; stipules relatively large, narrow and fugaceous. Inflorescence a long, lax, pendant, densely tomentose panicle; bracteoles small, linear, caducous. Flowers bisexual, regular, 5-merous, distinctly pedicellate in bud; calyx imbricate or rarely valvate, 2 outer lobes obtuse and slightly more thickened than the 3 inner acute ones, united at base in an indistinct tube; corolla with oblong-linear petals, which are shed separately; stamens 15–65, in 3 verticils or irregularly placed, the outer somewhat shorter than the inner, glabrous, filaments rather short, slender, filiform, connate at base, anthers latrorse, the inner 2 pollen sacs shorter than the outer 2, with a long or short appendage; ovary 3-locular, semi-inferior, with enlarged stylebase forming a distinct stylopodium, style long or short, obscurely trifid, stigma minute. Fruit a globose or subglobose nut, the fruit calyx with an ellipsoid tube almost entirely enclosing the nut and adnate to it, with 2 long, narrowly spatulate, obtuse, untwisted, 3-veined lobes and 3 acuminate short lobes. Seed lacking endosperm. Seedling with epigeal germination; cotyledons unequal, chlorophyllous; the first leaves paired, with interpetiolar stipules, or in a whorl of 4 without stipules, subsequent leaves arranged spirally.

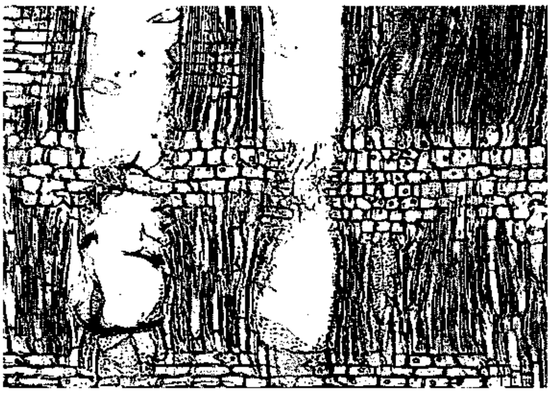
Wood anatomy

– Macroscopic characters:

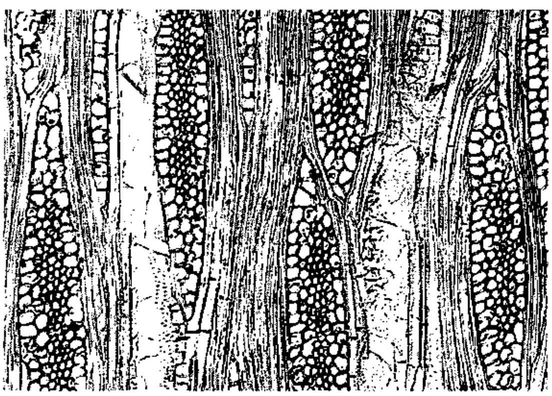
Heartwood light to dark yellow, usually with a characteristic rose tinge or with streaks when fresh, darkening on exposure, often not clearly demarcated from the sapwood (very pale yellow when fresh, becoming darker on exposure). Grain straight, interlocked or sometimes spiral. Texture moderately coarse but even; prominent ribbon figure sometimes present. Freshly sawn wood from Papua New Guinea sometimes with mild resinous odour. Growth rings indistinct; vessels moderately large, visible to the naked eye, vessel lines conspicuous on longitudinal surfaces, tyloses sparse to abundant; parenchyma diffuse; rays of two sizes, finer rays not visible without lens, larger rays not conspicuous on longitudinal surfaces; ripple marks absent. Axial intercellular canals as large as vessels (*A. laevis*) to less than half the vessel diameter (*A. scaphula*), mostly scattered, but sometimes in long tangential series (especially in *A. costata*), very scarce in *A. laevis* and *A. scaphula*, and numerous in *A. costata* and *A. marginata*.



transverse section (×25)



radial section (×75)



tangential section (×75)

Anisoptera thurifera subsp. *polyandra*

– Microscopic characters:
Growth rings indistinct or absent. Vessels diffuse, 5–8(–12)/mm^2, predominantly solitary (over 95%) with a few pairs, uniformly distributed, generally oval, average tangential diameter 145–250 μm; perforation plates simple; intervessel pits alternate, vestured, with a pit border diameter of 6–8 μm; vessel-ray pits with reduced borders to almost simple, rounded, c. 20 μm; tyloses present. Vasicentric tracheids present as well as cells grading from vasicentric tracheids to fibres in the immediate proximity of the vessels. Fibres 1.0–1.2 mm long, non-septate, thick-walled, with conspicuously bordered pits mainly confined to the radial walls. Parenchyma paratracheal, occasionally aliform; apotracheal parenchyma diffuse or short aggregates between the rays, strand length 4–6 cells. Rays of 2 sizes, (3–)4–7(–9)/mm, mostly multiseriate 4–10(–11) cells wide, up to 2 mm high, heterocellular with 1–3 rows of square to upright marginal cells (Kribs type heterogeneous III and II), uniseriates few, short, sheath cells prominent. Horizontal intercellular canals absent; axial gum canals diffusely scattered, sometimes in more or less tangential series, commonly occluded with chalky white deposits, diameter of canals large in *A. laevis* (c. 160 μm), smaller in other species (60–120 μm). Silica bodies present, abundant in some species, mainly in the marginal ray cells, also in parenchyma cells in some species.
Species studied: *A. aurea, A. costata, A. curtisii, A. grossivenia, A. laevis, A. marginata, A. scaphula, A. thurifera*.
The axial gum canals enable mersawa to be distinguished from non-dipterocarps. The larger pores, the lower density and distinctive colour of the wood separate mersawa from keruing (*Dipterocarpus* spp.), resak (*Vatica* spp.) and upun (*Upuna borneensis* Sym.); the distribution of axial canals helps to distinguish it from *Hopea* spp.

Growth and development Germination of *A. thurifera* seeds has been studied in Papua New Guinea. Seeds often germinate while the fruit is still on the tree (viviparous), the radicle breaking through the upper section of the globose nut. Usually seedlings will not survive in the shade of a dense subcanopy; they require high light intensity and occur naturally along forest margins and in logged forest, actively colonizing old logging tracks. Under these conditions, initial growth rates are high. However, seedlings of *A. thurifera* are also reported to survive in the forest under heavy shade.
Growth is fairly rapid; trees of *A. thurifera* may

already reach a bole diameter of 30–45 cm after 12 years. At this age the larger individuals are sexually mature and the smaller trees are suppressed and start to die. Trees of *A. scaphula* may reach a bole diameter of 65 cm in 40 years. For *A. laevis* the growth rate is less rapid: a maximum diameter of 45 cm can be reached in 40 years.
The trees need mycorrhizal infection for optimal growth. *A. thurifera* in Papua New Guinea may be infected by a variety of ectomycorrhizae which are also found on *Castanopsis* spp. and *Lithocarpus* spp.
In stands studied in Papua New Guinea, *A. thurifera* usually flowered and fruited annually. If conditions are unfavourable, flowering may not occur. Although the fruit is winged, the dispersal of nuts is restricted; over 90% of the seedlings occur under the parent tree.
The resin of *A. thurifera* is collected by bees to build their nests.

Other botanical information The genus *Anisoptera* is divided into 2 sections: section *Anisoptera* (8 species in Malesia) and section *Glabrae* Heim (2 species in Malesia), based on the form of the flower buds, number of stamens, form of the stylopodium, length of the style and form of the stigma. The genus *Anisoptera* is included in the tribe *Dipterocarpeae*, together with *Dipterocarpus*, *Upuna*, *Cotylelobium* and *Vatica*. It differs mainly from the latter 3 genera by the calyx which is united into a tube at base and encloses at least half of the nut. *Anisoptera* differs mainly from *Dipterocarpus* by the nut being adnate to the calyx tube (in *Dipterocarpus* the nut is free), the peltate hairs on innovations and leaf beneath (absent in *Dipterocarpus*) and the prominent looped intramarginal vein (absent in *Dipterocarpus*).

Ecology Species of mersawa are canopy trees or rarely emergents generally occurring in primary but sometimes secondary evergreen or semi-evergreen rain forest. They usually occur scattered but several species (e.g. *A. thurifera*) grow markedly gregariously. Mersawa usually occurs on well-drained soils but also in peat swamps and in kerangas (heath forest) on podzols. Preferred sites are low hills and ridges at altitudes of up to 1200 m.

Propagation and planting Seeds rapidly lose their viability; after 2–3 weeks the germination rate is often already almost zero. Tests on fresh seeds of *A. costata*, collected from trees and the ground soon after falling, showed a germination rate of 80–90%. Seeds can be stored for very short periods only. The best temperature for storage of *A. thurifera* seeds is 18°C. The moisture content should be reduced to 20–25% by air drying, and the seeds should be packed in polyethylene bags. Viability is significantly reduced when the moisture content of the seeds falls below 14%.
Vegetative propagation can be practised successfully. Trials on air layering branches of *A. thurifera* in the Philippines showed some success: 25% of the branches developed roots. Grafting had 10% success. In Malaysia, *A. scaphula* is propagated by cuttings. Short cuttings, consisting of one node with its leaf and axillary bud and part of the internode below, can be used, or 12–15 cm long cuttings prepared from leader shoots and branches of vigorously growing young plants (about 2 years old) raised from seeds in the greenhouse. When the cuttings are treated with indole butyric acid, they produce green buds in a period of 16–25 days and have a rooting rate of 80%. The shoots are 20–25 cm tall after one year. The cuttings are placed in beds of washed coarse sand, and should be kept moist, e.g. by a mist-spraying mechanism. The beds should be shaded, for instance with green plastic net, so that the relative light intensity is maintained below 10%.
Both in vegetative and seed propagation a mycorrhiza has to be provided to realize optimal growth.

Silviculture and management *A. thurifera* is known to invade disturbed areas and can be an agressive invader following logging in the Philippines and Papua New Guinea. It readily reinvades cultivated land. The trees are used in Papua New Guinea to fill up gaps in selectively logged tropical rain forest. Natural regeneration of other species of mersawa is recorded as sparse, and strip planting is practised in Indonesia to maintain a fair share of mersawa in the forest after logging.

Harvesting Trees are harvested according to the selective felling systems as practised in various countries. In Indonesia the diameter limit is 50 cm. Logs should be removed quickly from logging areas since they are susceptible to blue stain (particularly the sapwood) and sometimes also to pinhole borers (ambrosia beetles). Mersawa logs usually sink in water; this is due to the high water content of green logs. Transport must be over land. The core of old trees is sometimes hollow.
To tap the resin, the bark is scraped off and V-shaped incisions are made in the sapwood after which sulphuric acid is sprayed into the streaks. Resin can be collected weekly, and after each collection the trees are rechipped and sulphuric acid

reapplied. Trees with a bole diameter of at least 60 cm yield more resin than smaller trees.

Yield In Indonesia the average standing stock of mersawa timber is 2.1 m^3/ha for trees over 50 cm in diameter. Locally this figure may be higher, e.g. in the Moluccas where a value of 10 m^3/ha was obtained.

Genetic resources Some species are gregarious and widespread (e.g. *A. costata, A. thurifera*) and seem not to be at risk of genetic erosion. Other species are scattered and not common (e.g. *A. marginata, A. megistocarpa*) and are more vulnerable to genetic erosion.

Prospects Mersawa seems to be promising for enrichment planting in selectively logged forest and for reforestation of logged-over areas. The timber can be used for various purposes, and the trees are often rapid growers. *A. thurifera* in particular should receive more attention in research.

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Selection of species

Anisoptera aurea Foxw.

Philipp. Journ. Sc. 67: 271 (1938).

Synonyms *Anisoptera curtisii* Foxw. (1911) non Dyer ex King.

Vernacular names Philippines: dagang (general), palosapis (Tagalog, Pangasinan), dagum (Bikol).

Distribution The Philippines.

Uses The wood is suitable for general construction, interior finish, ship planking, wooden tanks, tight cooperage and for veneer and plywood.

Observations A fairly large tree of up to 40 m tall, bole up to 160 cm in diameter, bark cream-brown, shaggily flaky; leaves 7–11 cm × 2.5–5.5 cm, oblong or oblanceolate, densely golden lepidote beneath, with 18–20 pairs of secondary veins prominent on both surfaces; flower bud lanceolate, stamens 35–38, stylopodium broadly ellipsoid-cylindrical, densely golden stellate-puberulent. *A. aurea* grows in mixed dipterocarp forest, especially on ridges up to 600 m altitude, in areas with rainfall throughout the year. The density of the wood is 550–790 kg/m^3 at 15% moisture content.

Selected sources 18, 175, 258, 748.

Anisoptera costata Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 67 (1841).

Synonyms *Anisoptera cochinchinensis* Pierre (1886), *Anisoptera marginatoides* Heim (1902), *Anisoptera mindanensis* Foxw. (1918).

Vernacular names Brunei: mersawa kesat. Indonesia: masegar (Sumatra), mersawa daun lebar (Java), ketimpun (Kalimantan). Malaysia: mersawa kesat, mersawa terbak (Peninsular), pengiran kesat (Sabah). Philippines: Mindanao palosapis (general), balingan (Sulu). Burma: kabanthangyin. Cambodia: phdiek, phdiek krâham, phdiek sâ. Laos: bak, maiz bak. Thailand: krabak (central), krabak khok (north-eastern), krabak daeng (peninsular). Vietnam: v[ee]n v[ee]n, v[ee]n v[ee]n tr[aws]ng, v[ee]n v[ee]n xanh.

Distribution Burma, Thailand, Cambodia, Laos, southern Vietnam, Peninsular Malaysia, Sumatra, western Java, Borneo and the Philippines.

Uses The wood is used as mersawa. It is suitable for interior finish, ship planking, general construction, wooden tanks, tight cooperage, and veneer and plywood.

Observations A large to very large tree up to 50(–65) m tall, bole cylindrical, branchless for up to 35 m and up to 150 cm in diameter, with few buttresses of up to 4 m high and spreading out up to 2.5 m, continuing up the bole as ribs up to 10 m high, bark greyish-brown; leaves 6–18 cm × 7–11 cm , oblong to obovate, dull yellowish or greenish lepidote beneath, with 8–22 pairs of secondary veins hardly or not depressed above; flower bud ovoid, acute, stamens about 25, stylopodium cylindrical, densely pubescent. *A. costata* is a very variable species (forms vary from apilose to densely pilose) which possibly hybridizes with *A. curtisii*. *A costata* grows commonly, often gregariously, in semi-evergreen dipterocarp forest and evergreen forest in seasonal areas and is rare but widespread in lowland forest of humid areas; up to 700 m altitude. The density of the wood is 460–850 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 100, 175, 235, 258, 318, 359, 442, 461, 465, 561, 625, 628, 677, 748, 753, 804, 807.

Anisoptera curtisii Dyer ex King

Journ. As. Soc. Beng. 62(2): 100 (1893).

Vernacular names Indonesia: keruing kucing (Singkep). Malaysia: mersawa kuning, rengkong (Peninsular). Thailand: krabak thong (Nakhon si Thammarat, Trang).

Distribution Peninsular Thailand, Peninsular Malaysia and Sumatra; possibly also in peninsular Burma.

Uses The timber is used as mersawa.

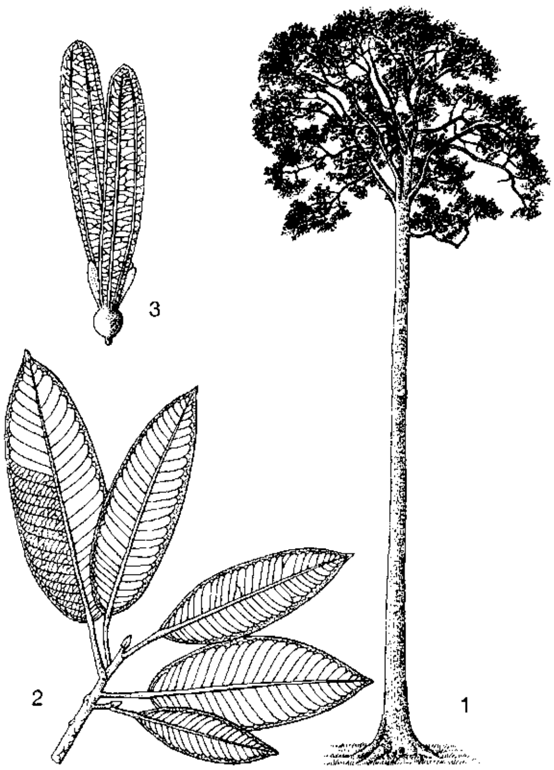
Observations A large tree, with a prominently buttressed bole up to 75 cm in diameter; leaves (4–)7–14 cm × (1.5–)2.5–6 cm, narrowly elliptical to oblanceolate, brilliant golden lepidote beneath, with 15–25 pairs of secondary veins prominent beneath and narrowly depressed above; flower bud lanceolate, stamens about 25, stylopodium broadly ellipsoid-cylindrical, densely golden puberulent. *A. curtisii* possibly hybridizes with *A. costata* and grows in mixed dipterocarp forest on well-drained, at least periodically dry soils, especially on coastal hills and inland ridges up to 700 m altitude. The density of the wood is 610–815 kg/m^3 at 15% moisture content.

Selected sources 258, 442, 625, 628, 677, 736, 748, 807.

Anisoptera grossivenia v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 431 (1940).

Vernacular names Brunei: benchaloi, merbakau. Indonesia: cangal padi, kantooi (Dajak, Kalimantan), damar kelasi (Malay, Kalimantan). Malaysia: mersawa kunyit (general), pengiran kasar (Sabah), merkunyit (Sarawak).



Anisoptera grossivenia v. Slooten – 1, tree habit; 2, sterile twig; 3, fruit.

Distribution Borneo.

Uses The wood is used as mersawa, especially for plywood production.

Observations A large tree up to 60 m tall, bole tall and straight, branchless for 14–30 m, up to 145 cm in diameter, buttresses of moderate size, spreading out as large surface roots, outer bark grey to purplish-brown, rough and rather finely longitudinally fissured; leaves 9–12 cm × 3–5 cm, oblong to narrowly obovate, densely golden-yellow lepidote beneath, with 18–28 pairs of secondary veins, depressed above; flower bud lanceolate, acute, stamens about 36, stylopodium subcylindrical, densely shortly golden-brown tomentose. *A. grossivenia* grows in lowland dipterocarp forest on sandy clay soils at low altitude. The density of the wood is 555–895 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 461, 561, 748, 804.

Anisoptera laevis Ridley

Fl. Mal. Pen. 1: 219 (1922).

Vernacular names Brunei: mersawa durian. Malaysia: mersawa durian, medang sawa (Peninsular), pengiran durian (Sabah).

Distribution Peninsular Malaysia and Borneo (Sarawak, Brunei, Sabah).

Uses The wood is used as mersawa.

Observations A very large tree up to 65 m tall, bole tall and straight, up to 200 cm in diameter, buttresses up to 15 m high, spreading out up to 4 m; leaves 7–11 cm × 3–4 cm, oblong to obovate, rusty to golden lepidote beneath, with 10–14 pairs of secondary veins; flower bud subglobose, stamens 15, stylopodium disk-like, glabrous. *A. laevis* is widespread and is often common in inland lowland and hill forest up to 900 m altitude. The density of the wood is 510–815 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 235, 258, 297, 417, 442, 677, 748.

Anisoptera marginata Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 66 (1841).

Synonyms *Anisoptera grandiflora* Brandis (1895).

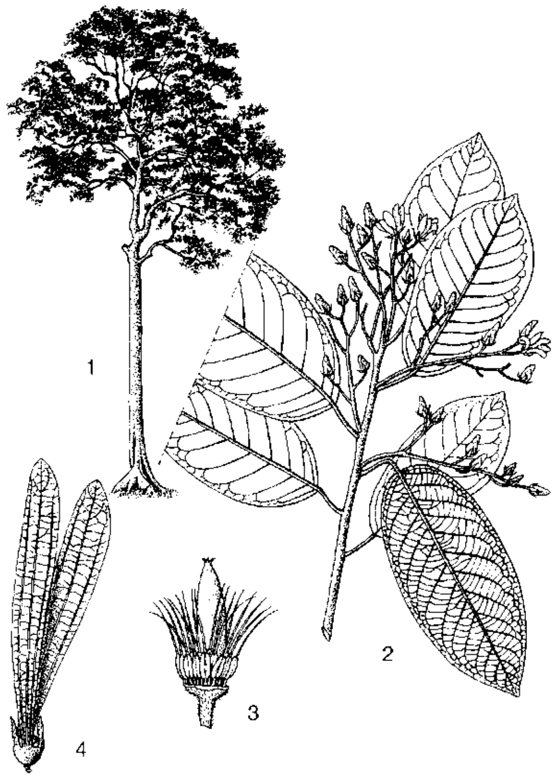
Vernacular names Brunei: mersawa paya. Indonesia: mersawa tenam (Sumatra, Kalimantan), resak pantai (Sumatra), ketimpun (South Kalimantan). Malaysia: mersawa paya (Peninsular), pangiran kerangas (Sabah).

Distribution Peninsular Malaysia, Bangka, eastern Sumatra and Borneo.

Uses The wood is used as mersawa, especially for house building.

Observations A medium-sized to large tree up to 45 m tall, bole branchless for 15–25 m and up to 135 cm in diameter, with buttresses up to 3 m high and spreading out up to 1.5 m; leaves 7–10 cm × 3.5–4.5 cm, oblong to obovate, densely golden-brown lepidote beneath, with 10–14 pairs of secondary veins; flower bud lanceolate, acute, stamens about 25, stylopodium cylindrical, shortly densely tomentose. *A. marginata* is widespread but rarely common and grows in mixed peat-swamp forest and locally in heath forest on podzols, up to 1200 m altitude. The density of the wood is 520–800 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 100, 258, 297, 417, 442, 461, 561, 677, 736, 748, 804.



Anisoptera marginata Korth. – 1, tree habit; 2, flowering twig; 3, ovary and stamens; 4, fruit.

Anisoptera megistocarpa v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 12, f. 2 (1926).

Vernacular names Indonesia: beurmen (Aceh, Sumatra). Malaysia: mersawa merah, mersawa api, sepah petri (Peninsular).

Distribution Southern Thailand, Peninsular Malaysia and Sumatra.

Uses The timber is used as mersawa.

Observations A large tree with bole up to 120 cm in diameter and prominently buttressed; leaves (5.5–)9–20 cm × (2.5–)3.5–8 cm, narrowly oblong-elliptical to oblanceolate, dark golden-brown lepidote beneath, with 23–33 pairs of secondary veins prominent beneath and depressed above; flower bud lanceolate, stamens about 60, stylopodium ovoid, pubescent. *A. megistocarpa* grows scattered in mixed dipterocarp forest on well-drained undulating land and low hills. The density of the wood is 575–840 kg/m^3 at 15% moisture content.

Selected sources 258, 442, 677, 736, 748.

Anisoptera scaphula (Roxb.) Kurz

Fl. Burma 1: 547 (1877).

Synonyms *Anisoptera glabra* Kurz (1873), *Vatica scaphula* (Roxb.) Dyer (1874), *Hopeoides scaphula* (Roxb.) Cretz. (1941).

Vernacular names Malaysia: mersawa gajah, sanai, terbak (Peninsular). Burma: kaunghmu (general), taungsagaing (Ataran), kaunghmu-yweth-the (Toungoo). Thailand: krabak khao, champa bai lek, cha muang (peninsular).

Distribution Bangladesh, Burma, Thailand and Peninsular Malaysia.

Uses The timber is used as mersawa.

Observations A large or very large tree, bole up to 285 cm in diameter and prominently buttressed; leaves 8–16 cm × 3.5–8 cm, oblong-lanceolate to oblanceolate, greyish-green lepidote beneath, with 13–18 pairs of secondary veins prominent on both surfaces; flower bud broadly ovoid, stamens 15, stylopodium absent, style columnar, glabrous. *A. scaphula* grows in semi-evergreen and evergreen dipterocarp forest on undulating land and valleys. The density of the wood is 510–815 kg/m^3 at 15% moisture content.

Selected sources 258, 442, 495, 628, 644, 677, 748.

Anisoptera thurifera (Blanco) Blume

Mus. Bot. Lugd.-Bat. 2: 42 (1852).

Vernacular names Indonesia: baoti (Sulawesi), bolam (Morotai, Moluccas), aren marei (Irian Jaya). Papua New Guinea: garawa, barida, karalaka. Philippines: palosapis (general), mayapis (Sambali, Tagalog), dagang (Tagalog, Bikol, Panay Bisaya).

Distribution The Philippines, New Guinea, and possibly Sulawesi and the Moluccas.

Uses The wood is suitable for interior finish, floors, furniture, ship planking, general construction, wooden tanks, tight cooperage, and veneer and plywood. Wood extractives are reported to have a tumour-inhibiting capacity. In the Philippines the resin is collected locally but not on a commercial scale. The gum is used as a chewing gum in some areas of Papua New Guinea. The nuts are eaten (after cooking), and have a high content of edible oils.

Observations A medium-sized to very large tree up to 60 m tall, bole branchless for up to 25 m, up to 200 cm in diameter and prominently buttressed; leaves 6–18 cm × 2.5–8.5 cm, elliptical to lanceolate or oblanceolate or obovate, greyish to brown lepidote beneath, with (10–)12–18(–20) pairs of secondary veins; flower bud lanceolate, stamens 35–57, stylopodium narrowly ellipsoid-cylindrical, the apex puberulent. *A. thurifera* is extremely variable and is divided into 2 subspecies: subsp. *thurifera* (synonym: *A. brunnea* Foxw.) from the Philippines and subsp. *polyandra* (Blume) P. Ashton (synonyms: *A. polyandra* Blume, *A. kostermansiana* Dilmy) from Papua New Guinea and possibly also Sulawesi and the Moluccas. *A. thurifera* grows in evergreen and semi-evergreen dipterocarp forest especially on ridges, below 750 m altitude (subsp. *thurifera*) or scattered or in small groups in lowland forest on flat and undulating land or ridges up to 600(–1000) m altitude, especially on sedimentary rocks (subsp. *polyandra*). It is the only dipterocarp which readily reinvades cultivated land. The density of the wood is 580–710 kg/m^3 (subsp. *thurifera*) and 500–850 kg/m^3 (subsp. *polyandra*) at 15% moisture content. See also the table on wood properties.

Selected sources 67, 175, 203, 248, 258, 347, 348, 359, 579, 674, 713, 735, 736, 815.

R.J. Johns (general part),
W.C. Wong (properties),
J. Ilic (wood anatomy),
M.H.A. Hoffman (selection of species)

Anthocephalus A. Rich.

Mém. Rubiac.: 157 (1830).

RUBIACEAE

x = unknown; *A. chinensis*: $n = 22$

Trade groups Kadam: lightweight hardwood, *Anthocephalus chinensis* (Lamk) A. Rich. ex Walp. and *A. macrophyllus* (Roxb.) Havil.

Vernacular names Kadam: cadamba, common bur-flower tree (En). Brunei: bangkal, kaatoan bangkal. Indonesia: jabon (Java), laran (Kalimantan), emajang (Sumatra). Malaysia: kelempayan (Peninsular), laran (Peninsular, Sabah), selimpoh (Sarawak). Papua New Guinea: labula. Philippines: kaatoan bangkal (Pilipino, general). Burma: mau-lettan-she, maukadon, yemau. Cambodia: thkoow. Laos: koo-somz, sako. Thailand: krathum (central, northern), krathum-bok (Bangkok), taku (Sukhothai, Chanthaburi, Nakhon Si Thamarrat). Vietnam: c[aa]y g[as]o, c[af] tom, g[as]o tr[aws]ng.

Origin and geographic distribution *Anthocephalus* consists of 2 species and occurs naturally from Sri Lanka, India, Nepal and Bangladesh eastward through Malesia to New Guinea. *A. chi-*

nensis covers the complete area of distribution of the genus. It has been planted as an ornamental and plantation tree and has been successfully introduced in South Africa, Puerto Rico, Surinam, Taiwan and other tropical and subtropical countries.

Uses The wood, being highly perishable in contact with the ground, cannot be used in outdoor conditions and is moderately durable under cover. It can be used for light construction work, beams and rafters, boxes, tea-chests, packing cases, shuttering, ceiling boards, toys, wooden shoes, bobbins, yokes, carvings, matches, chopsticks and pencils. It is also suitable for dug-outs or canoes and less expensive furniture if properly seasoned. The wood is applied as both face and core veneer in plywood and is suitable for the manufacture of particle board, cement-bonded board and hardboard. Its most important usage is for the manufacture of low- and medium-quality paper. The pulp is sometimes mixed with other, generally long-fibred, material. The tree is also suitable as an ornamental and shade tree for other crops and is used for reforestation and in agroforestry.

An extract of the leaves serves as a gargle and the fresh leaves are used as fodder for cattle or sometimes as plates and serviettes. The inflorescences and the fruits are said to be edible. The dried bark is used to relieve fever and as a tonic. A yellow dye can be obtained from the bark of the roots.

Production and international trade Although kadam is planted in many places in the tropics, production data are scarce. Most of the wood is used locally. Export data on the wood are mixed with data from other, not well-defined lightweight woods. In 1987 the export of kadam round logs from Sabah was 67 000 m^3 with a value of US$ 4.1 million, and in 1992 32 000 m^3 of logs and 9000 m^3 of sawn timber with a total value of US$ 3.9 million. In 1988 the average price of one cubic metre of wood was about US$ 60. In Papua New Guinea kadam wood is ranked in MEP (Minimum Export Price) group 3, which fetches moderate prices (minimum export price of logs about US$ 50/m^3). In Thailand only very small amounts are traded in the domestic market (about 300 m^3 in 1988).

Kadam is becoming one of the most frequently planted trees in the tropics. In South-East Asia alone, several hundred thousand ha are estimated to be planted. In the future, kadam might compete with the African obeche/samba/wawa (*Triplochiton scleroxylon* K. Schumann) wood.

Properties Kadam is a lightweight hardwood. The heartwood is white with a yellow tinge darkening to creamy yellow on exposure, and not clearly differentiated from the sapwood. The density is 290–465(–560) kg/m^3 at 15% moisture content. The grain of the wood is generally straight, texture fine and even.

At 15% moisture content, the wood of *A. chinensis* has the following mechanical properties: modulus of rupture 50–73 N/mm^2, modulus of elasticity (5000–)6700–9300 N/mm^2, compression parallel to grain (23–)28–44 N/mm^2, shear 5–8 N/mm^2, cleavage c. 35 N/mm radial and 54 N/mm tangential, Janka side hardness 1950–2625 N and Janka end hardness 3000–4000 N.

The rates of shrinkage are low to moderate, from green to 15% moisture content about 0.8% radial and 2.1% tangential, from green to 12% moisture content 0.8% radial and 3.1% tangential, and from green to oven dry 2.5% radial and 5.9% tangential. The timber air dries fairly rapidly with little or no degrade, but care is needed to prevent blue stain. Boards 2.5 cm thick take about 1.5 month to air dry from green to 15% moisture content. For kiln drying from green to 20% moisture content a temperature of 57–76.5°C and corresponding relative humidity of 80% to 40% is recommended.

Kadam is easy to work with hand and machine tools, it cuts cleanly and gives a very good surface, although tearing out may give slight problems. Test results of the machining properties indicate that the wood can be shaped, mortised and sanded with good results, and planed, bored and turned with moderate results. The nailing properties are excellent, and the wood glues well. It peels readily at a cutting angle of 92°, producing good veneer 1.5 mm thick. It produces sulphate pulp with sufficient paper-making quality. Kraft pulping gives a yield of 48.5% and pulp of satisfactory brightness and performance as a handsheet.

The wood is regarded as non-durable. Graveyard tests in Indonesia show an average life in contact with the ground of less than 1.5 years. The wood is susceptible to wood rotting fungi and blue stain. It is also susceptible to termite, *Anobium* and marine borer attack. It is, however, very easy to treat using either the open tank system or the vacuum-pressure system. It can easily be impregnated with synthetic resins to increase density and compressive strength.

The wood of *A. macrophyllus* is much like that of *A. chinensis*, but it is believed to be somewhat stronger. It is rose-coloured.

The wood of *A. chinensis* contains 47–52% cellulose, 25.5% lignin, 16–24% pentosan, 0.8–1.9%

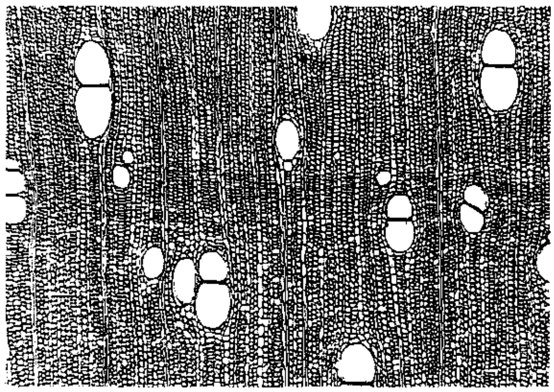
ash, and very little or no silica. The solubility is 4.7% in alcohol-benzene, 1.6% in cold water, 3.1% in hot water and 18.4% in a 1% NaOH solution. The energy value of the wood is 19 800 kJ/kg. The charcoal is odourless and does not smoke or spark, but the low yield in comparison with other species makes it uneconomic.

Description Medium-sized to large deciduous trees up to 45 m tall; bole straight and cylindrical, often branchless for more than 25 m, up to 100 (–160) cm in diameter but generally less, sometimes with small buttresses up to 2 m high and extending up to 60 cm from the trunk; outer bark very light and smooth when young, grey to grey-brown with shallow fissures when old, sometimes with small ridges, often cracked and rather coarsely flaky; crown typically umbrella-shaped, small; branches horizontally spreading and drooping at the tip, arranged in tiers, scars of fallen branches visible for several years on young stems. Leaves opposite, simple, more or less sessile to petiolate, ovate to elliptical, 15–50 cm × 8–25 cm, in young fertilized trees sometimes much larger, subcordate at base, acuminate at apex; stipules interpetiolar, narrowly triangular, deciduous. Inflorescence consisting of terminal, solitary, globose heads without bracteoles. Flowers subsessile on a glabrous receptacle, bisexual, actinomorphic, 5-merous; calyx tube funnel-shaped, with narrow lobes pubescent outside; corolla gamopetalous, saucer-shaped with a narrow tube, the narrow lobes imbricate in bud; stamens 5, inserted on the corolla tube, filaments short, anthers basifixed; ovary inferior, 2-locular, sometimes 4-locular in the upper part, style exserted, stigma spindle-shaped. Fruitlets numerous, somewhat fleshy, the upper part containing 4 hollow or solid structures. Seed somewhat trigonal or irregular-shaped, not winged. Seedling with epigeal germination; cotyledons sessile, herbaceous, acute, green; leaves opposite.

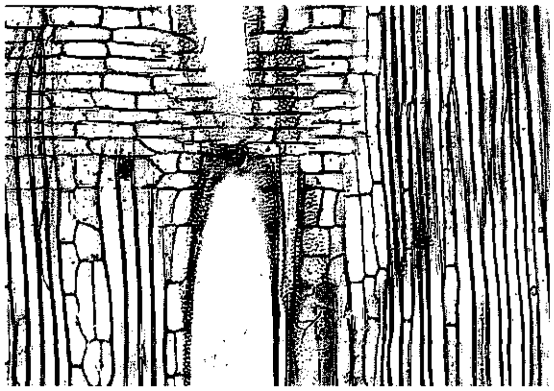
Wood anatomy

– Macroscopic characters:

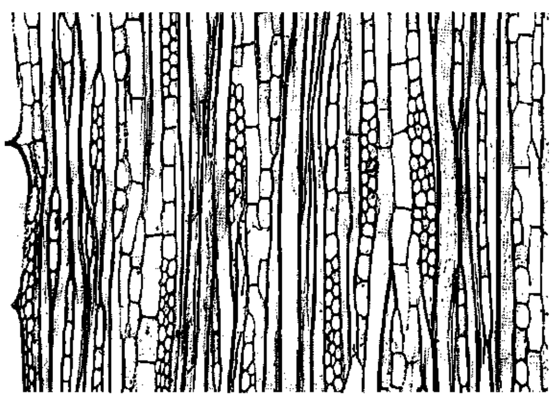
Heartwood white with a faint yellowish cast, ageing to creamy white or light yellowish-grey, indistinct from the sapwood. Grain straight. Texture fine to moderately fine and even; wood without characteristic odour or taste. Growth rings moderately distinct but not conspicuous, visible to the naked eye, usually wide (2–13 mm), delimitated by faint pink bands (on transverse section); largest vessels clearly visible to the naked eye, vessels forming conspicuous, nearly straight lines; parenchyma and rays not distinct to the naked eye; ripple marks absent.



transverse section (×25)



radial section (×75)



tangential section (×75)

Anthocephalus chinensis

– Microscopic characters:
Growth rings not conspicuous. Vessels diffuse, 4–12/mm^2, solitary and in diagonal and/or radial rows of 2–4, rarely in clusters, medium-sized, average tangential diameter 100–200 μm; perforation plates simple; intervessel pits alternate, round to polygonal, vestured, maximum diameter 6–8 μm; vessel-ray pits similar to intervessel pits; gum-like deposits and tyloses absent. Fibres (600–)1300–2200 μm long, 34–40 μm in diameter, non-septate, non-libriform to semi-libriform in the outer portion of the growth ring, walls in the earlywood 2–6 μm thick, in the latewood 6–10 μm, with comparatively abundant, orbicular to broadly oval bordered pits, confined to the radial walls. Paratracheal parenchyma extremely sparse, restricted to occasional cells and sometimes absent; apotracheal parenchyma diffuse or diffuse-in-aggregates or forming short uniseriate lines. Rays 12–17/mm, of 2 distinct sizes; narrow rays 1(–2)-seriate and consisting wholly of upright cells, 6–8 cells and c. 550 μm high, somewhat more numerous than broad rays; broad rays 2–4-seriate and composed of upright, square and procumbent cells, c. 25 cells and c. 800 μm high (Kribs type heterogeneous I). Crystals, silica and intercellular canals absent; starch deposits sometimes present in the outer growth rings.
Species studied: *A. chinensis*.

Growth and development Seeds are dispersed by wind or rain, floods and rivers. Full sunlight is required for germination. Saplings commonly form pure stands on flood-damaged river banks and surface-stripped sites along logging roads. Young seedlings do not withstand strong competition of weeds and grasses and they will only develop into trees if not overgrown by surrounding vegetation or strangled by lianas. At the age of 4 years trees may start flowering. In Indonesia flowering occurs from April to August, sometimes from March to November.

In natural stands, root anastomosis has often been observed. Cutting of some of the trees in a clump results in the production of some wood stumps that keep growing without producing leaves, comparable to 'ash trays' in young thinned Douglas-fir stands. Kadam grows rapidly. Annual increment in height up to 3 m/year, in diameter up to 7 cm/year is reported for the first 6–8 years, slowing down to about 2 m and 3 cm respectively until the 20th year. Thereafter growth is much slower. The annual volume increment is 10–20 (–26) m^3/ha. At the age of 10–15 years trees can be felled. Under optimal management (including fertilization) this rotation may be much shorter, e.g. in the STTC (Sumatra Tobacco Trade Company) plantations in North Sumatra (Indonesia) where the rotations are 4 years for match production. *A. macrophyllus* is said to grow faster, but extremely few experimental data are available. In West Java *A. macrophyllus* trees in a 10.5-year-old stand had an average height of 22 m and an average diameter of 40.5 cm.

Other botanical information The genus *Anthocephalus* belongs to the tribe *Naucleeae* within which it has a rather isolated position as the sole genus of the subtribe *Anthocephalinae*. It seems to be most closely allied to the genera of the subtribe *Naucleinae* but differs from them by the mode of placentation. There is controversy about the correct name of *Anthocephalus chinensis* and even about the legitimacy of the generic name *Anthocephalus*. The problem focuses on disagreement about the proper type specimen for the species originally described by Lamarck. Here, the solution offering nomenclatorial stability and which has recently gained more support is adopted. The other option means rejecting the name *Anthocephalus* as a synonym for *Breonia* from Madagascar and using the newly created generic name, *Neolamarckia*, to incorporate the species formerly assigned to *Anthocephalus*.

Ecology Kadam is a typical pioneer and is very common in secondary forest. Sometimes large individuals can be found in primary rain forests. The most important condition for growth is light. Kadam does not tolerate shade. In its natural habitat, maximum temperature varies from 32–43°C in the shade and minimum temperature from 3–15.5°C. Kadam is sensitive to frost. The average annual rainfall ranges from 1500–5000 mm or more. Kadam may, however, also occur locally on much drier sites with as little as 200 mm annual rainfall (e.g. in parts of central South Sulawesi). Near the equator it is found from sea-level up to 1000 m altitude. It grows on a variety of soils but is more abundant and dominant on well-aerated fertile soils. Kadam does not grow well on leached soils, even when their physical conditions are good. It occurs on river banks and in the transitional zone between swampy, permanently flooded areas and the drier loams, in areas which are periodically flooded.

Propagation and planting Propagation is possible by natural regeneration from seed, by nursery-grown seedlings, stumps and stem cuttings. Special techniques are required to extract the minute seeds from the fleshy multiple fruit. In the Philippines, fresh fruits are rubbed and macerated in water to extract the seeds; in Indonesia, fruits are dried before the seeds are rubbed out. The weight of a million air-dry seeds is about 38–56 g. The germination rate of fresh seeds is variable, but generally low (about 25%). When stored cool in airtight boxes for 2.5 months, a much higher germination rate can be obtained (up to 95%). Properly stored seeds can remain viable for about 2 years.

In the nursery, seeds are mixed with fine sand (1 : 10) and sown in seed-beds. Water is applied by irrigation or overhead as a very fine mist. In the open, seed-beds should be protected against heavy rains. Germination starts 12–21 days after sowing. A mild fungicidal spray may be used to prevent damping-off.

Seedlings 8–12 weeks old are transplanted to nursery beds or plastic bags, preferably in growing medium enriched with organic matter. When 6–7 months old and 30 cm tall, they are transplanted into the field. Sometimes, under good care seedlings are planted out at 10–15 cm. Kadam can be planted bare-rooted, without significant loss of growth and with high survival percentages. Planting saplings of about 1 cm diameter that have been topped gives satisfactory results. Planting distance in the field is 3–4 m × 3–4 m. In Indonesia and the Philippines promising results have been obtained with rows of *Leucaena leucocephala* (Lamk) de Wit between the lines. In Borneo kadam plantations have been intercropped with upland rice. Kadam has also proved to be an excellent shade tree for dipterocarp line planting.

Silviculture and management If enough seed-producing trees are available, natural regeneration from seed can be effected by clearing the soil at the time of seed ripening. In East Kalimantan, a plantation has been maintained for several years since 1938 using this system. Plantations established from nursery seedlings seldom show the same favourable growth rate as natural regeneration, for reasons still unknown but probably related to local site conditions. There is much difference in performance between trees from different seed sources as well as between plantations with a different topography. Notable differences in performace related to site conditions have been observed, even within a single plantation.

Applying about 15 g urea per plant in a ring around the seedling results in much faster growth. The trees provide only light shade. After planting, the soil around the young trees needs to be kept free from competing vegetation, especially from climbers and plants causing shade. Thinning is very easy owing to the beautifully straight stems without defects and the very regular small crowns. It should be done early and frequently. The rotation period depends upon soil characteristics. In the Philippines, economic rotations applied in plantations were 5 years for pulp wood and 7 years for the combination of pulp wood and sawn timber. A match factory in Sumatra is growing kadam on a 4-year rotation.

Diseases and pests No serious diseases or pests occur. The fungus *Gloeosporium anthocephali* may cause partial or complete defoliation and dieback. Often, leaves are eaten by a variety of insects, whereas seedlings are eaten by game. Trees with severely perforated leaves are very common, but usually recover well. Pests reported in the Philippines include the leafminer bagworm *Pyralis* sp., the borer *Pterodeplеryx* sp. and hornworms.

In Costa Rica, small soil-inhabiting ants eat the seeds from the seed-beds. Keeping a small ditch filled with water around the seed-bed or placing seedlings in trays on tables overcomes the problem. Seedlings should be placed in well-ventilated conditions to prevent damping-off disease.

Harvesting For pulpwood and matches, harvesting can start 4–5 years after sowing. For wood production, felling of trees can start from the age of 10 years when, depending upon soil conditions, trees have a diameter of 50 cm.

The wood is readily attacked by fungi causing, for example, blue stain. Therefore, the wood has to be worked up soon after cutting, or it should be treated within 48 hours or be submerged in water.

Yield In a 30-year rotation in Indonesia, the stand attained an average height of 38 m and average diameter of 65 cm, producing 350 m^3/ha in the final cut. Total production including thinnings amounted to 23 m^3/ha per year. Those data refer to all wood, including branches with a diameter of 7 cm and more. A tree of 50 cm diameter yields 2.5–3 m^3 wood.

Genetic resources The preservation of the genetic diversity of kadam seems guaranteed, as the trees are widespread and common, and are planted on a fairly large scale.

Prospects Because of its very fast growth, its ability to grow on a variety of soils, the absence of serious diseases and pests, and its favourable silvicultural characteristics, kadam is expected to become increasingly important in the near future, when supplies for plywood from natural forests are expected to decrease. The selection of and/or breeding a less site-sensitive provenance should receive priority.

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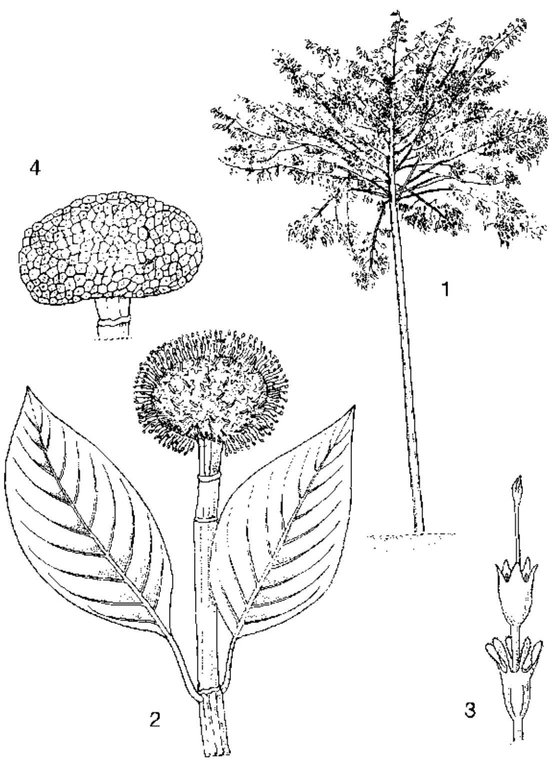
Selection of species

Anthocephalus chinensis (Lamk) A. Rich. ex Walp.

Repert. bot. syst. 2: 491 (1843).

Synonyms *Anthocephalus indicus* A. Rich. (1830), *Anthocephalus cadamba* (Roxb.) Miq. (1856), *Neolamarckia cadamba* (Roxb.) Bosser (1984).

Vernacular names Kadam, cadamba, common bur-flower tree (En). Kadam (Fr). Brunei: bangkal, kaatoan bangkal. Indonesia: jabon (Java),



Anthocephalus chinensis (Lamk) A. Rich. ex Walp. – 1, habit of young tree; 2, twig with inflorescence; 3, flower; 4, infructescence.

laran (Kalimantan), emajang (Sumatra). Malaysia: kelempayan (Peninsular), laran (Peninsular, Sabah), selimpoh (Sarawak). Papua New Guina: labula. Philippines: kaatoan bangkal (general). Burma: mau-lettan-she, maukadon, yemau. Cambodia: thkoow. Laos: koo-somz, sako. Thailand: krathum, krathum bok, takoo. Vietnam: c[aa]y g[as]o, c[af] tom, g[as]o tr[aws]ng.

Distribution Nepal, Bangladesh, India, Sri Lanka, Burma, Indo-China, southern China, Thailand, eastward through Malesia to New Guinea.

Uses The timber is used as kadam. *A. chinensis* is planted as an ornamental and shade tree or for reforestation and afforestation and agroforestry. Leaves and bark are used in traditional medicine. Inflorescences and fruits are said to be edible.

Observations A medium-sized to large tree up to 45 m tall, bole straight and cylindrical, branchless for more than 25 m, up to 100(–160) cm in diameter but generally less, sometimes with small buttresses up to 2 m high and extending up to 60 cm from the trunk; leaves 13–32 cm × 7–15 cm, with an acute to acuminate apex, distinctly petiolate with a 2.5–6 cm long petiole; flower heads 3–5 cm wide, upper part of the ovary distinctly 4-loculed with 4 hollow cartilagineous structures. *A. chinensis* occurs mainly in secondary vegetation and along rivers on fertile, often periodically flooded locations up to 1000 m altitude. The density of the wood is 290–465(–560) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 40, 50, 77, 89, 100, 102, 108, 145, 153, 175, 211, 215, 247, 248, 302, 310, 313, 359, 396, 410, 448, 462, 482, 578, 581, 582, 583, 631, 661, 712.

Anthocephalus macrophyllus (Roxb.) Havil.

Journ. Linn. Soc., Bot. 33: 23, pl. 4.32–4.37 (1897).

Synonyms *Nauclea macrophylla* Roxb. (1824), *Bancalus macrophyllus* (Roxb.) O. Kuntze (1891), *Neolamarckia macrophylla* (Roxb.) Bosser (1984).

Vernacular names Indonesia: samama (Ambon).

Distribution Sulawesi and the Moluccas.

Uses The wood is probably used as kadam. The bark has been applied in traditional medicine. The large leaves may be used as plates and serviettes.

Observations A large tree; leaves 20–60 cm long, with a blunt apex, sessile; flower heads about 7 cm wide, upper part of the ovary 2-loculed with 4 solid small cartilagineous structures. *A. macrophyllus* occurs in both lowland and lower montane forest and grows in a slightly seasonal climate.

Selected sources 60, 77, 313, 318, 582.

W.T.M. Smits (general part),
J.W. Hildebrand (general part),
W.G. Keating (properties),
J.M. Fundter (wood anatomy),
M.S.M. Sosef (selection of species)

Araucaria A.L. Juss.

Gen. pl. 413 (1789).

ARAUCARIACEAE

$x = 13$; *A. cunninghamii* and many other species: $2n = 26$

Trade groups Araucaria: lightweight softwood, *Araucaria cunninghamii* Aiton ex D. Don, *A. hunsteinii* K. Schumann.

Vernacular names Papua New Guinea: araucaria. Thailand: son-nam (Bangkok).

Origin and geographic distribution *Araucaria* consists of 19 species and has a disjunct distribution composed of New Guinea (2 species), eastern Australia (2 species), Norfolk Island (1 species), New Caledonia (13 species), southern and central Chile and adjacent Argentina (1 species) and southern Brazil (1 species). The present disjunct distribution is thought to be related to the breaking up of Gondwanaland. In Jurassic times an important centre of diversity was situated in the India-Australia-Antarctic region, from which species spread to the Cape Province and South America. The oldest find of *Araucaria* fossils is from India and dates back to the Triassic (190 million years ago). The present occurrence is looked upon as the remnant of a once much wider distribution.

Plantations of Malesian *Araucaria* species have been established in Papua New Guinea, Irian Jaya, Australia and South Africa, and trial plots have been laid out in Malaysia, Thailand and the Philippines.

Uses *Araucaria* yields an excellent timber which is used for all kinds of light construction and interior work including mouldings, linings, panelling, domestic flooring, shelves, cupboards, general joinery, furniture and cabinet work. Special applications are matches, match boxes, broom handles, battery separators, chopsticks, agricultural implements, aircraft frames, cask heads and laminated fixed-pitch propellers.

A high-quality plywood can be manufactured from *Araucaria*. Plantation material yields a premium grade pulp which is useful in mixtures with hardwood pulp. Within the Malesian area, several species are used as ornamentals and Christmas trees. The seeds of *A. cunninghamii* and several other species from outside Malesia are reported as edible.

Production and international trade *Araucaria* timber is commercially important, although mainly locally. *Araucaria* plywood was a major export item from Papua New Guinea until 1980, but declining supplies of logs from the natural forests resulted in a decline in plywood production; the plywood is now mainly for the domestic market. In Papua New Guinea approximately 8000 ha of both *A. cunninghamii* and *A. hunsteinii* have been planted, the oldest plantations being established in 1949–1950. This is much less than the plantation area in Australia, which amounts to 44 500 ha (*A. cunninghamii*) with an annual timber production of 211 000 m^3 in 1988–1989 and 248 000 m^3 in 1989–1990. The export of *Araucaria* logs from Papua New Guinea has been banned to obtain added value from the processed product.

Properties The wood is lightweight and soft. The heartwood is pale yellowish-brown, occasionally with a pinkish tinge and not sharply demarcated from the straw-coloured sapwood which may be up to 150 mm thick. The wood has a natural sheen and lustre. The density is 450–530(–570) kg/m^3 at 12% moisture content. The grain is typically straight, texture outstandingly fine and even.

At 12% moisture content the modulus of rupture is 77–90 N/mm^2, modulus of elasticity 11 900–13 000 N/mm^2, compression parallel to grain 44–49 N/mm^2, compression perpendicular to grain about 4.5 N/mm^2, shear 9–9.5 N/mm^2, cleavage 38–39 N/mm radial and 54–56 N/mm tangential, Janka side hardness 2380–3490 N and Janka end hardness 3940–5430 N.

The rates of shrinkage are small to moderate, from green to 12% moisture content 2.2–2.5% radial and 3.8–4.0% tangential. The timber seasons satisfactorily with little or no degrade, although precautions must be taken to prevent blue stain. The recommended temperatures for kiln drying 25 mm thick boards from green to 15% moisture content are dry bulb 80–90°C and wet bulb 55–65°C.

Araucaria wood is easy to work with hand and machine tools, it finishes well and takes paint, stains, varnishes and lacquers uniformly without requiring the use of a filler. The attractive colour makes the wood particularly suitable for the application of clear finishes. The wood nails and glues well, and it is easy to peel, making excellent veneer and plywood. Compression wood is sometimes troublesome in *A. cunninghamii* grown in plantations.

The wood is considered to be non-durable in contact with the ground and is susceptible to termite, pinhole borer and marine borer attack. It is, however, resistant to *Lyctus* attack. *A. hunsteinii* is relatively easy to penetrate with preservatives but *A. cunninghamii* is reported to be variable in its resistance to impregnation; the heartwood is often moderately resistant to impregnation.

Although the basic density is slightly lower in *A. hunsteinii*, the wood of *A. cunninghamii* and *A. hunsteinii* is almost identical. However, *A. hunsteinii* wood can be differentiated by applying a few drops of concentrated hydrochloric acid which produces an intense green colour.

Description Large or very large, monoecious or sometimes dioecious, evergreen trees up to 60(–90) m tall; bole straight, cylindrical, often branchless for a considerable height, up to 200 cm in diameter, with a cylindrical base; bark almost black, dark brown or reddish-brown, transversely wrinkled, fissured, ridged or plate-like, peeling either horizontally or in slabs; branches in whorls of 4 or 8, horizontally displayed with the apex turned upwards. Leaves simple, entire, spirally arranged, sessile and broadly attached, crowded, broad and flattened to needle-shaped, many-veined, heteromorphic, changing in form with the age of the tree, tips often pungent. Pollen cones solitary, terminal or lateral, on branches separate from the seed cones, subtended by a cluster of reduced sterile bracts. Seed cones large, disintegrating when mature, terminal on a shoot with modified leaves; fertile bracts closely packed, broad and often extended laterally into membranous wings, the apex with a prominent spur; seed-bearing scale 1-ovuled, partly fused with the associated bract, the apex free and acute. Seed-coat fused with its scale. Seedlings with hypogeal (section *Araucaria*: *A. hunsteinii*) or epigeal (section *Eutacta* Endl.: *A. cunninghamii*) germination.

Wood anatomy

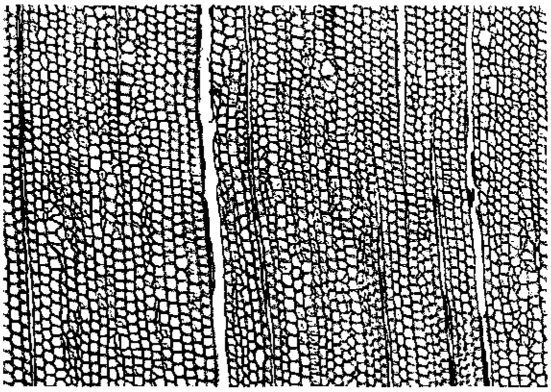
– Macroscopic characters:

A. cunninghamii: Sapwood straw-coloured or pale yellow-brown, heartwood a little darker with a slight pinkish tinge. Grain straight. Texture fine and uniform; persistent leaf traces often produce a mottled or dimpled pattern on longitudinal faces; bands of compression wood often present, sometimes showing up as yellow or brown streaks on longitudinal faces. Growth rings often just visible, seldom distinct, earlywood forming most of the ring and transition to latewood very gradual; rays barely visible to the naked eye, usually pale and not very prominent on the radial surface.

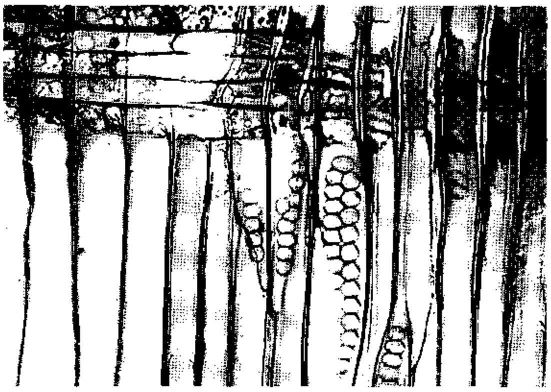
A. hunsteinii sometimes differs in having pale purplish streaks. Growth rings generally indistinct and figure not marked.

– Microscopic characters:

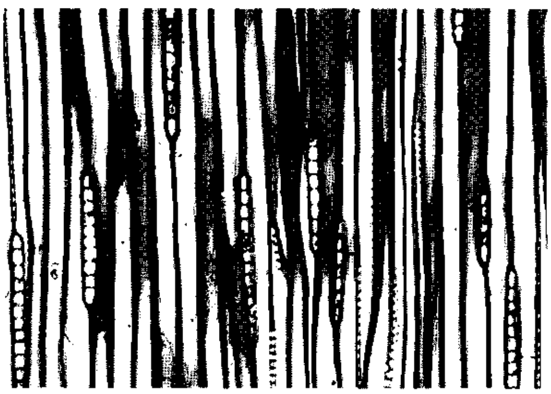
A. cunninghamii: tracheids rounded to square, irregular in outline, 25–55 μm in diameter, thicker walled in the latewood and poorly aligned in radial rows, 3.5–6 mm long, with little resin; intertracheid pits alternate in 1–2(–3) rows, mainly in radial walls, more frequent near tracheid ends, rounded in outline when solitary, tending to hexagonal when in groups, with rounded apertures; pits on tangential walls rare, small and solitary; crossfield pits 2–8 per cell, half-bordered, circular or slightly distorted when crowded, apertures lens-shaped. Rays 6–8/mm, almost exclu-



transverse section (×25)



radial section (×150)



tangential section (×75)

Araucaria hunsteinii

sively uniseriate, sometimes biseriate, up to 20 cells high (up to 15 cells high in *A. hunsteinii*). Resin more frequently found in cells of *A. hunsteinii*.

Species studied: *A. cunninghamii, A. hunsteinii*.

Wood of *Araucaria* spp. and *Agathis* spp. can be distinguished from all other conifers by their characteristic alternate intertracheid pitting. *Agathis* wood never has the very small pin knots usually seen in *Araucaria*; ray height in *Araucaria* is often greater than in *Agathis*, but anatomically it is very difficult to distinguish the two genera.

Growth and development Trees usually start bearing cones at 15–25 years of age. Cones of *A. cunninghamii* and *A. hunsteinii* take 21–27 months to ripen after pollination. The mature cones fragment, and the seeds, having membraneous wings, are dispersed by wind. Seeds of *A. hunsteinii* are reported to be dispersed over 5 km from the mother tree, although this distance is questionable. During germination, the thick radicle penetrates the litter and soil, and the cotyledons gradually emerge from the seed-coat. The growth and development of seedlings depend on the amount of available sunlight and the density of the canopy.

Juvenile growth of *A. cunninghamii* is generally slow, but trees in Queensland reached a height of 33 m and an average diameter of 42 cm in 34 years and in Peninsular Malaysia the same height was reached after 30 years. Young trees of *A. hunsteinii* grow slower, but they outgrow those of *A. cunninghamii* when maturing, and their form is better.

Other botanical information Together with the genus *Agathis* Salisb., *Araucaria* constitutes the family *Araucariaceae*. *Araucaria* is much more heteromorphic than *Agathis* and is often regarded as the more primitive genus. *Araucaria* is divided into two sections, section *Araucaria* (4 spp.) and section *Eutacta* Endl. (15 spp.), which differ in the pollen cones being lateral or terminal and the juvenile leaves being flattened or acicular, respectively. Several other sections have been proposed in the past but are now considered as synonyms of the two mentioned. The occurrence of glaucous forms within *A. cunninghamii* and *A. hunsteinii* deserves attention and needs further study. *A. angustifolia* (Bert.) O. Kuntze yields an important timber in South America, particularly Brazil, and the timber of *A. bidwillii* W.J. Hooker is used in Australia.

Ecology The Malesian species of *Araucaria* are tall emergent trees of lowland but more often submontane or montane rain forest. They are regarded as pioneer species, regeneration taking place in disturbed habitats. They are often dominant in the forests where they occur and are distributed from sea-level up to 2750(–4000) m altitude. In the areas they occur, the annual precipitation is 1000–4000 mm, and there may or may not be several dry months.

A. cunninghamii is more common above 1000 m altitude in areas with high rainfall and a temperature range of 9–26°C. It occurs on a variety of rain forest soils and may grow on very nutrient-poor, severely leached and podzolized soils with a pH of less than 5.0 and a thick layer of semi-decomposed litter, although it shows poor growth on such soils in plantations. In Papua New Guinea it is commonly associated with *Castanopsis acuminatissima* (Blume) A.DC., *Cinnamomum* sp., *Podocarpus neriifolius* D. Don, *Prumnopitys amara* (Blume) de Laubenf. and *Schizomeria* sp.

A. hunsteinii is mainly distributed between 700 m and 1000 m altitude in areas with high rainfall and where the temperature in the coldest month ranges between 10–28°C, the lower temperature occurring only a few times in a season. It is not resistant to frost and occurs especially on alluvial and volcanic, heavily textured, clayey or loamy soils with a pH of 5.5–6.5. It is commonly associated with *Acmena acuminatissima* (Blume) Merr. & Perry, *Elmerillia tsiampacca* (L.) Dandy, *Ficus* sp., *Flindersia amboinensis* Poir., *F. pimenteliana* F. v. Mueller, *Pometia pinnata* J.R. Forster & J.G. Forster and *Xanthophyllum papuanum* Whitm. & v.d. Meijden.

Propagation and planting *Araucaria* can be propagated by seeds sown in beds of well-rotted sawdust or friable sandy loam, under 70–90% shade. Pre-germination and tubing as well as direct sowing may be feasible. Fresh seeds give up to 90% germination. Viability of seed of *A. hunsteinii* drops to zero after 4 months when stored at 25°C, but when stored in airtight containers at a constant temperature of 3.5°C, viability can be maintained for at least 6 months and sometimes up to 18 months. However, seeds of this species cannot be safely dried to below 30% moisture content without damage. Furthermore, viability of seed drops rapidly when removed from storage at 3.5°C. *A cunninghamii* seeds can be dried to 2% moisture content without damage, and can be kept at temperatures of −18°C or lower; seeds may be stored for 6 years. To obtain the seeds, cones are collected before they disintegrate on the trees. Cones that do not disintegrate within 10 days of harvesting are immature. Cone maturity can also be determined by sampling the length of the embryo, which should be 16 mm long for *A. hunsteinii*, and the endosperm, which should be well-developed and hard. Often, less than 1% of the seeds collected from a tree are viable. Filled and unfilled seeds may be separated by flotation, but the appropriate liquid mixture varies according to the clone.

Cuttings of 6–7 cm long (with a whorl of branches) taken from leaders of 3-year-old seedlings of *A. hunsteinii* show up to 90% rooting. Lateral shoots root well but remain plagiotropic. Rooted cuttings outgrow seedlings of the same age.

In vitro propagation can be practised successfully. Stem segments with 3–5 leaf axils, excised from the upper portion of the main stem of 2-year-old seedlings of *A. cunninghamii*, produce orthotropic buds from the concealed axillary meristems when cultured on a medium of half-strength Murashige and Skoog inorganic salts. This procedure is also successful with *A. hunsteinii*. Up to 80% rooting is obtained, and after 2 weeks the plantlets are transferred to a mixture of peat and perlite and maintained at a relative humidity of 90–95%. The young plants are subsequently transferred to normal greenhouse conditions and then to the field, with less than 5% mortality.

Mycorrhiza inoculation is necessary. Seedlings reach plantable size in 18–24 months. When planted into the field, spacing is usually 2.5(–3) m × 2.8(–3) m, but wider spacings of up to 7 m × 7 m have also been practised.

Silviculture and management The main form of planting is in monoculture plantations. Underplanting in *Pinus* plantations has been tried with varying results in Papua New Guinea and Australia, but should be tested further. Enrichment planting has been tried on a large scale in Papua New Guinea, but was not considered economically viable because of management problems. However, the system should be tried again and adjusted on a pilot trial basis. For successful establishment in this situation, the objective is to release the striplines as soon as possible.

A. cunninghamii has shown good regeneration under the parent canopy and within gaps, and is regarded as a shade-tolerant species.

In plantations, weed control during juvenile stages is essential and the plants respond well to fertilizers. Pruning is usually first done when the trees are about 6 years old. In 35-year-old plantations, about 100 stems per ha are maintained.

Diseases and pests Seeds of *A. cunninghamii* and *A. hunsteinii* imported from Papua New Guinea into Malaysia show poor germinative capacity and high seedling mortality, mainly as a result of transport difficulties. During storage, seeds are often infested by *Penicillium* fungi (in *A. hunsteinii* up to 75% of the seeds). Seedlings may be infested by *Fusarium* fungi. Treating seeds and seedlings with fungicides such as Demosan does reduce mortality somewhat. Seedlings are susceptible to damping-off and root rot.

The most significant disease of plantation-grown *A. cunninghamii* in Papua New Guinea and Australia is root and heart rot caused by *Phellinus noxius*. Seedlings of *A. hunsteinii* are very susceptible to bud dieback associated with *Colletotrichum derridis*. In Papua New Guinea the most serious pests of plantation-grown *A. cunninghamii* are the branchlet-mining *Hylurdrectonus araucariae* (*Scolytidae, Coleoptera*) and the weevil *Vanapa oberthuri* (*Curculionidae, Coleoptera*). Trees of 2.5–12 years old are most susceptible to *Hylurdrectonus* attack. Minor pests include the termite *Coptotermes elisae* and a caterpillar defoliator *Millonia isodoxa*. No serious pests of *A. hunsteinii* have been recorded and only *Coptotermes elisae* has been of any consequence.

The principal termite pests in Peninsular Malaysia in *Araucaria* plantations are subterranean species of the genus *Coptotermes*, particularly *C. curvignathus*. They can be controlled by chemical soil treatment with aldrin, dieldrin or heptachlor and by immediate removal of felled trees and stumps and they are one of the reasons why *Araucaria* has not been planted more extensively in Malaysia.

After fire, trees are much more susceptible to termite attack, and also to attack by ambrosia beetles (mainly *Diapus pusillimus* and *Xyleborus perforans*). *Araucaria* is intolerant to fire.

Harvesting In Irian Jaya *Araucaria* trees are logged selectively with a diameter limit of 60 cm at breast height. Care must be taken to prevent damage to trees selected for retention during thinning operations, as removal of bark will result in rapid colonization by insects and decay fungi. The timber is prone to blue stain infection and should be treated with fungicides and removed rapidly from the logging areas.

Yield Total production of 34-year-old plantations of *A. cunninghamii* in Queensland (Australia) was 977 m^3/ha, i.e. 29 m^3/ha annually. A stand in Papua New Guinea of 55 years old had produced 835 m^3/ha, of which 707 m^3 sawn timber logs. Generally, the average annual volume increment is 11–14 m^3/ha, but in successful plantations 20–30(–35) m^3/ha may be reached.

Genetic resources and breeding Maiden stands of both species in New Guinea have been and are being exploited heavily for their high-quality timber (particularly for the plywood industry) and are endangered in parts of their natural range. Areas with once large stands, such as Bulolo (Papua New Guinea), are already exhausted. A large number of very small stands, on a wide range of ecological habitats, still exists in Papua New Guinea.

Extensive genetic improvement research is being conducted on *A. cunninghamii* in eastern Australia and a research programme on *A. cunninghamii* and *A. hunsteinii* has been established in Papua New Guinea. Brazil has established a similar research project on *A. angustifolia*. The research projects encompass provenance and progeny trials. Provenance hybrid trials and clonal seed orchards have been established in eastern Australia and Papua New Guinea. It appears that the better stem quality and overall growth of the southern provenances can be combined with the more rapid early growth of northern ones into superior hybrids.

Prospects By comparison with many other timber species, much is known about propagation and silviculture of *Araucaria*. Extensive plantations have already been established and they produce large amounts of timber, especially in Australia. In New Guinea natural stands are no longer being logged on a large scale, and the plantation area is still comparatively small. Protection of natural stands and extension of plantation establishment of this useful and comparatively fast-growing timber is desirable.

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Selection of species

Araucaria cunninghamii Aiton ex D. Don

Lambert, Pinus ed. 2, 3: t. 79 (1837).

Synonyms *Araucaria beccarii* Warb. (1900).

Vernacular names Hoop pine, colonial pine, Richmond river pine (En). Indonesia: alloa, ningwik, pien (Irian Jaya).

Distribution Coastal regions of New South Wales and south-eastern Queensland to Papua New Guinea and Irian Jaya. Large-scale plantations have been established in South Africa, Papua New Guinea and Australia.

Uses The timber is used for various purposes. The tree is cultivated as an ornamental. The seeds are edible.

Observations A very large, symmetrical tree up to 60(–70) m tall, bole straight, cylindrical and self-pruning up to 40 m high and up to 200 cm in diameter, leaf-bearing twigs all along the length of the branches; leaves lanceolate to triangular, curved with the pointed apices directed slightly inwards, green or glaucous, juvenile leaves acicular; pollen cones up to 8 cm long, mature seed cone terminal, 6–10 cm × 5–8 cm, with spiny, winged cone scales; seed triangular, 20–30 mm × 9–10 mm excluding the membraneous wings. Two varieties are distinguished: var. *papuana* Lauterb. occurring in New Guinea, var. *cunninghamii* in Australia. *A. cunninghamii* occurs most often in submontane *Fagaceae* forest on leached soils up to 2750(–4000) m altitude. The density of the wood is about 530 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 66, 105, 111, 161, 163, 205, 208, 209, 210, 285, 286, 287, 301, 326, 359, 362, 530, 577, 652, 688, 705, 748, 765, 776, 808.

Araucaria hunsteinii K. Schumann

Fl. Kaiser Wilhelms Land 11, t. 4, f. 8 (1889).

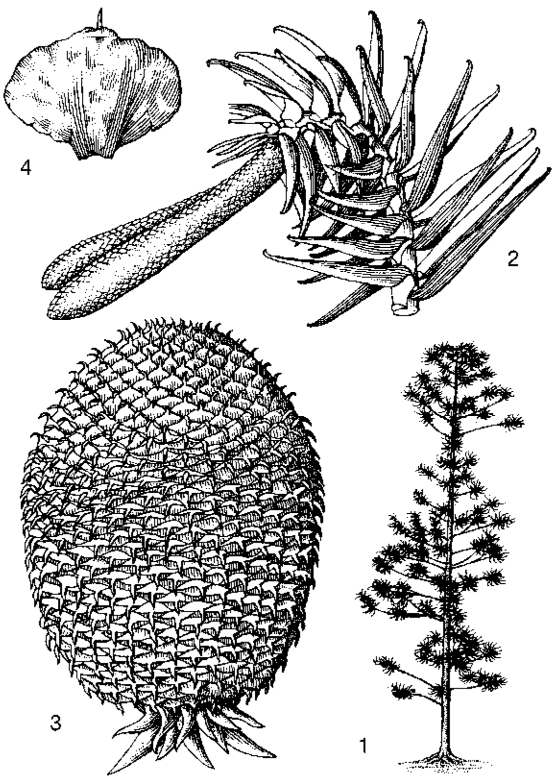
Synonyms *Araucaria schumanniana* Warb. (1900), *Araucaria klinkii* Lauterb. (1913).

Vernacular names Klinkii pine (En).

Distribution Papua New Guinea. Introduced on an experimental scale in Australia, Fiji and Peninsular Malaysia.

Uses The wood is used for various purposes and is recommended for aircraft frame manufacturing. The tree is used as an ornamental.

Observations A very large, symmetrical tree up to 90 m tall, bole straight, cylindrical and self-pruning up to 35 m and more and up to 300 cm in diameter, leaf-bearing twigs crowded at the end of the branches; leaves lanceolate or ovate, rather



Araucaria hunsteinii K. Schumann – 1, tree habit; 2, twig with male cones; 3, mature female cone; 4, seed scale.

sharply pointed with the tip curved, green or glaucous, juvenile leaves flattened; pollen cones up to 22 cm long, mature seed cone terminal, 18–25 cm × 12.5–16 cm, with spiny, winged cone scales; seed oblong, 30–40 mm × 8–10 mm excluding the membraneous wings. *A. hunsteinii* occurs on well-drained sites on a variety of soils, often in submontane *Fagaceae* forest at 520–2100 m altitude. It is the tallest tree of Malesia. The density of the wood is about 450 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 67, 164, 207, 208, 209, 275, 285, 286, 287, 311, 326, 329, 359, 362, 530, 652, 688, 705, 748, 765, 776.

F. Arentz (general part, selection of species),
W.G. Keating (properties),
J. Ilic (wood anatomy)

Calophyllum L.

Sp. pl.: 513 (1753); Gen. pl. (ed. 5): 229 (1754).
GUTTIFERAE
x = unknown; *C. inophyllum*: $2n = 32$

Trade groups Bintangor: lightweight to medium-heavy timbers, e.g. *Calophyllum calaba* L., *C. inophyllum* L., *C. papuanum* Lauterb., *C. pulcherrimum* Wallich ex Choisy, *C. soulattri* Burm.f., *C. teysmannii* Miq.
The timber of *C. inophyllum* is often traded separately as 'beach calophyllum'.

Vernacular names Bintangor. Indonesia: bintangur. Malaysia: penaga (Peninsular, Sabah), bakakol, entangor (Sarawak). Papua New Guinea: calophyllum. Philippines: bintanghol. Burma: tharapi, poon. Thailand: krathing (central), tanghonbaiyai (Surat Thani). Vietnam: m[uf] u, c[oof]ng.

Origin and geographic distribution *Calophyllum* is a very large genus comprising about 190 species. Most of the species are found in the Indo-Malesian region, Micronesia, Melanesia and northern Australia. Only approximately 8 species occur in Central and South America; about 20 occur in Madagascar and surrounding islands. Peninsular Malaysia, Sumatra, Borneo and New Guinea are very rich in species, about 40, 35, 65 and 35, respectively. New Guinea has the largest proportion of endemic species, about 75%. Some species are widespread, e.g. *C. calaba* (Sri Lanka and Indo-China to central Malesia and northern Australia), *C. soulattri* (Indo-China and Thailand, through the whole of Malesia, to northern Australia and Melanesia), and *C. inophyllum* (eastern Africa and Madagascar, India to northern Australia and Polynesia). The latter species is often planted as an ornamental within its range and also in western Africa and tropical America.

Uses Bintangor is a good general purpose timber. It is suitable for light construction, flooring, moulding, decking, panelling, joinery, furniture, veneer and plywood, wooden pallets, boat construction and diving boards. In several regions the wood is much sought after for masts, spars, bridge work and scaffolding because of the tall slender forms of the poles of several species. Sometimes the wood is also used for cartwheels and axles, musical instruments and blowpipes. Heavier wood is sometimes used for beams and columns, for railway carriages and crane shafts. Timber of *C. papuanum* and *C. pauciflorum* from Papua New Guinea is considered a decorative substitute for dark-coloured mahogany if suitably stained, and for all kinds of mahogany if transparently coated. It is also sometimes considered a good substitute for dark red meranti.
The poisonous latex from the bark of several species is used to stupefy fish and, mixed with rice, to kill rats. A decoction of the bark and the latex of some species (e.g. *C. inophyllum*) is used medicinally, internally against diarrhoea and after childbirth, externally against skin and eye diseases and rheumatism; leaves, flowers and seeds are sometimes also used in local medicine. The fruits of some species are edible but often sour. Usually they are pickled, but caution is necessary as they contain toxins. The oil from the seeds is sometimes used as illuminant and in soap making. The seed-oil and the latex from the bark have occasionally been used in dyeing 'batik' cloth in Java. A decoction of the bark (e.g. of *C. inophyllum*) is sometimes used to toughen and dye fishing-nets. *C. inophyllum* is commonly planted as an ornamental.

Production and international trade In several areas (e.g. Peninsular Malaysia, Borneo, New Guinea) bintangor may be very abundant and of considerable importance for its timber. The timber is exported in fairly large quantities to Japan, especially from Borneo and New Guinea. The export of round logs from Sabah in 1987 was 42 000 m^3 with a value of US$ 2.8 million and in 1992 17 500 m^3 of logs and 41 500 m^3 of sawn timber with a total value of US$ 10.3 million. In Papua New Guinea *Calophyllum* timber is ranked in the MEP (Minimum Export Price) group 1 and fetched a minimum export price of US$ 80/m^3 for saw logs in 1992.

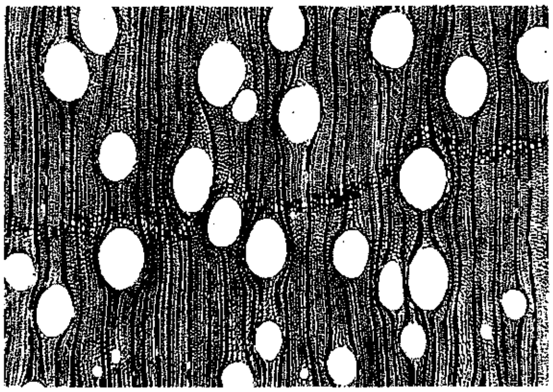
Properties Bintangor is a light to medium-weight, moderately hard wood. The heartwood is red-brown, pink-brown or orange-brown. The sapwood is yellow-brown with a pink tinge and well defined. The density is (400–)450–850(–900) kg/m^3 at 15% moisture content (average 680 kg/m^3). The grain is interlocked, spiral or wavy, texture moderately coarse to coarse and uneven.
At 15% moisture content the modulus of rupture is 48–94 N/mm^2, the modulus of elasticity 7550–15 300 N/mm^2, compression parallel to grain 37–55 N/mm^2, compression perpendicular to grain 3–4 N/mm^2, shear (5–)6–9 N/mm^2, cleavage 44–60 N/mm radial and 58–72 N/mm tangential, Janka side hardness 2580–4820 N and Janka end hardness 4090–6050 N.
The rates of shrinkage are medium, from green to 15% moisture content 1.4–2.1% radial and 2.0–3.7% tangential, from green to oven dry 3.9–4.4% radial and 5.3–6.3% tangential. Drying is easy to moderately difficult; some seasoning degrade may occur. Generally bintangor timber seasons fairly slowly with moderate defects such as end checking, splitting, cupping and springing. The rate of drying is rather similar to light red meranti. It takes about 2.5–3.5 months to air dry 25 mm thick boards, and 4–5 months for 40 mm thick boards. Weighting down of stacks during air drying is recommended as this will reduce the tendency of the timber to warp and twist. Mild kiln schedules are required in drying. In Malaysia kiln schedule C is considered most suitable. Kiln drying of 25 mm thick boards from 50% to 10% moisture content takes approximately 8 days under favourable conditions, but in Papua New Guinea a kiln drying time of 5 days for flat grain and 6 days for edge grain has been reported for 27.5 mm thick boards of wood from *C. vexans*.
The sawing properties are rated as good; the timber is non-siliceous. For timber from Papua New Guinea, a normal ripping saw having 24 teeth with a 20° rake angle is satisfactory, whereas for cross cutting, a saw with crosswise sharpened teeth with 20° rake angle can be used. Bintangor is generally easy to bore but sometimes liable to burning in boring and mortising. Planing is usually easy and the planed surface is smooth to moderately smooth, but sometimes the wood is difficult to plane because of strongly spiral or interlocked grain. When the grain is properly filled, the timber takes a high polish. The nailing properties are rated as moderate to poor, but as satisfactory for Papua New Guinea timbers. Bintangor timber can be peeled without pretreatment at a 90° peeling angle to produce good veneer. For instance, *C. vexans* from Papua New Guinea produces a good-quality veneer with no woolly surface; it dries well with a tangential shrinkage of 6%, and it glues well with a bond strength of 1.5 N/mm^2 for phenolic and 1.6 N/mm^2 for urea resin. Bintangor veneer glued with urea formaldehyde extended with 20% wheat gives plywood of good quality. However, the veneering qualities of *C. apetalum* Willd. from India and *C. tomentosum* Wight from Sri Lanka have been found to be unsatisfactory. Bintangor may produce a high grade particle board and hardboard with good water resistance (e.g. *C. vexans* in Papua New Guinea). Paper and pulping qualities of *C. vexans* are also rated as good.
Most bintangor timber is rated as moderately durable or non-durable under exposed conditions. Stake tests showed an average service life in contact with the ground of 0.5–2 years under tropical conditions. However, the timber from some species is rather more durable. Graveyard tests in Indonesia showed an average service life in contact with the ground for wood of *C. pulcherrimum* of 3.5 years. The resistance to wood-rotting fungi varies from good to very poor. The heartwood is fairly resistant to preservative treatment, and absorbs only about 65 kg/m^3 of preservative using an open tank system.
The timber of *C. inophyllum* differs from this description in several characteristics. It is often heavier, stronger and more durable, more difficult to saw, and sawn surfaces tend to be woolly. It is recommended not to use this timber for lengths over 3 m because it is often bent.
The wood of *C. inophyllum* contains 58% cellulose, 31.5% lignin, 17% pentosan and no silica. The solubility is 4.4% in alcohol-benzene, 1.0% in cold water, 4.5% in hot water and 12.4% in a 1% NaOH solution. The energy value is about 19 100 kJ/kg.
The main compounds of the seed oil are oleic, linoleic, stearic and palmatic acid. Tannins are commonly present, especially in the bark but often also in the leaves. Saponins and cyanogenetic glucosides have been reported to occur in the leaves of some species (e.g. *C. inophyllum*).
A considerable variety of xanthones is found in the wood and bark. One of the xanthones, called jacareubin, is nearly always present in *Calophyllum* but is extremely rare outside this genus. The latex is very rich in complex coumarin derivates, some of which are piscicidal, while others are insecticidal.

Description Evergreen trees, rarely shrubs, up to 40(–60) m tall, with sticky latex either clear or opaque and white, cream or yellow; bole often straight and cylindrical, but occasionally twisted (*C. inophyllum*), up to 100(–240) cm in diameter; buttresses usually absent, rarely small, some species with stilt or loop roots; outer bark often with characteristic diamond to boat-shaped fissures becoming confluent with age, smooth, often with a yellowish or ochre tint, inner bark usually thick, soft, firm, fibrous and laminated, pink to red, darkening to brownish on exposure; crown evenly conical to narrowly hemispherical; twigs more or less flattened and angled, usually with naked, often elongate terminal buds. Leaves decussate, simple and entire, leathery, glabrous and petiolate, with closely parallel secondary venation alternating with latex canals which are usually less prominent; stipules absent. Inflorescences terminal or axillary, racemose, branched or simple, (1–)3–many-flowered and usually with small, deciduous bracts. Flowers usually bisexual, but sometimes functionally unisexual, sweetly scented, with perianth of 4–16 tepals in several whorls, usually whitish; stamens numerous, with filaments usually only slightly connate at base and with small basifixed anthers dehiscing by long, lateral slits; pistil 1, with unilocular ovary having a single, basal ovule, one style and often a peltate stigma. Fruit a drupe, with pericarp consisting of an exocarp, a fleshy to fibrous mesocarp and a stony endocarp (stone); outer layer (exocarp + mesocarp) often with large air spaces; stone with a hard layer and often with a spongy layer, containing a single seed. Seed with large cotyledons and radicle pointing to the base of the fruit; endosperm absent. Seedling with cryptocotylar germination (cotyledons remaining enclosed in stone) and short epicotyl; seedling leaves opposite, sometimes first two pairs of leaves pseudo-verticillate or lowest pairs of seedling leaves small and soon falling off.

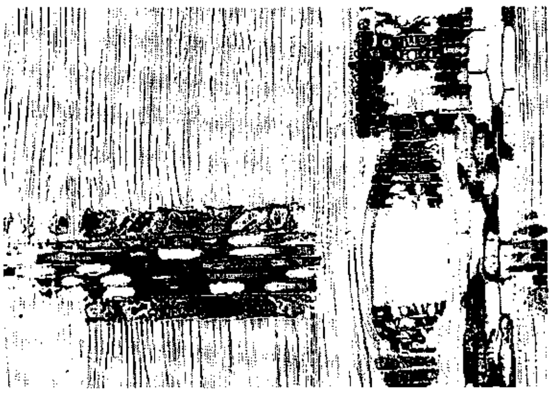
Wood anatomy

– Macroscopic characters:

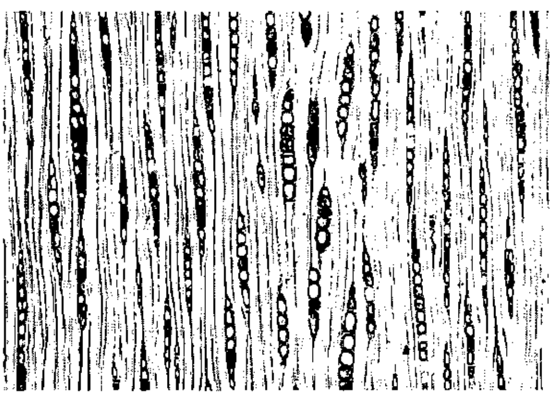
Sapwood yellow-brown with a pink tinge and well defined from the heartwood, which is red-brown, pink-brown or orange-brown. Grain interlocked, spiral or wavy. Texture moderately coarse to coarse and uneven; planed surface very lustrous; stripe figure present on radial surface and darker coloured zig-zag markings on tangential surface. Growth rings usually inconspicuous but sometimes marked by zones of denser wood or by narrow bands of parenchyma tissue; vessels visible to the naked eye, mostly solitary but arranged in irregularly radial chains; parenchyma distinct in



transverse section (×25)



radial section (×75)



tangential section (×75)

Calophyllum inophyllum

narrow, widely spaced, dark-coloured lines; rays very fine and not distinct to the naked eye; end surfaces dull.

– Microscopic characters:

Growth rings usually inconspicuous but sometimes marked by zones of denser wood or by narrow parenchyma bands. Vessels diffuse, (1–)2–9 (–12)/mm^2, almost exclusively solitary, in a marked diagonal to radial pattern, round to oval, average tangential diameter 100–200 μm; perforations simple; intervessel pits alternate, round to oval, 2–6 μm; vessel-ray pits vertically to horizontally elongate and simple; vessel-parenchyma pits half-bordered or with reduced borders, sometimes almost simple; helical thickenings absent; tyloses sometimes present. Vasicentric tracheids present. Fibres 0.4–1.4 mm long, non-septate, thin- to thick-walled, variable within and between species, with minutely bordered or simple pits confined to the radial walls. Parenchyma in (1–)4–5(–9) cells wide, often widely spaced, continuous or irregularly broken apotracheal bands. Rays 8–17/mm, 1–2-seriate, mostly uniseriate, but a varying number of biseriate rays also present, much less than 1 mm high, usually composed of both upright and procumbent cells, heterogeneous (Kribs type IIB). Prismatic crystals present in ray and axial parenchyma cells in some species. Silica absent. Reddish-brown deposits present in ray cells.

Growth and development At germination the radicle breaks through on one side of the base of the stone in the majority of species. In species with a thin stone wall, the radicle may emerge as soon as 10 days after the fruit falls to the ground. In species with a thick stone wall this may take 3 months. Usually the seedling shows intermittent growth. The terminal bud of the sapling is usually functional and growth is monopodial, but sometimes sympodial. All leaves are fully expanded and often very large, and each pair of leaves is separated by a well-developed internode.

Growth of the young trees appears to be discontinuous and branching is rhythmic. The trunk and the branches are orthotropic. Older trees generally show sympodial growth; usually each innovation consists of several pairs of leaves, but sometimes it has only a single pair. Sometimes the first pairs of leaves of the axillary innovations are reduced to scales with very short internodes.

Little is known about the developmental stages between the young plant and the flowering and fruiting adult plant. Data from a few sample plots in Peninsular Malaysia indicate that growth may be rather slow, and that trees may take about 70 years to attain a diameter of 50 cm. However, there is reason to believe that growth may be considerably faster under favourable conditions.

The flowers are insect-pollinated, e.g. by bees. It has been suggested that apomixis may occur in *Calophyllum*, resulting in polyembryony; the occurrence of up to 6 embryos forming a close-knit mass instead of the normal single embryo has been reported. Hybridization may occur, often with *C. inophyllum* as one of the parents.

Trees often bear fruits throughout the year. The fruits are eaten and dispersed by mammals (bats, squirrels, monkeys) and birds. However, the fruits of some species are dispersed by water.

Other botanical information The immediate relatives of *Calophyllum* in South-East Asia are *Mammea* and *Mesua*. These 3 genera are usually placed in the subfamily *Calophylloideae* and tribe *Calophylleae* together with some small genera of Madagascar and India. *Calophyllum* is easily distinguishable by its single basal ovule and particularly by its nearly always strictly parallel and close venation of the leaves.

All *Calophyllum* species look very similar. Only close examination of comparatively small differences in leaf, twig, bud, inflorescence and fruit enables species to be distinguished. Floral characteristics are of less use for determination, except sometimes the size of the flowers, the number of whorls of tepals, and the indumentum of the outer tepals. Several floral characteristics are variable in some species, and their diagnostic use is limited by the paucity of available herbarium material at anthesis and the often considerable distortion that occurs on drying. Characters of the living tree, especially the bark, the colour of the exudate, and the habitat are useful for distinguishing species, and with some experience *Calophyllum* species are probably easier to identify in the forest than from herbarium specimens.

Most species are already recognizable when very young, as they show different growth patterns in their initial stages, and differ in leaf shape, size and colour.

The timber of *C. brasiliense* Cambess. is important in South and Central America and traded as 'Santa Maria' or 'jacareuba'. Timber of *Calophyllum* species from Madagascar is known as 'vintanina', and that of the Indian *C. polyanthum* Wallich ex Choisy as 'poon'.

Ecology *Calophyllum* is a genus of lowland tropical rain forest from the seashore to more inland, but a few species occur in montane rain forest. Only a few species grow in drier or more open habitats; *C. inophyllum* is a species of sandy beaches. Some species (e.g. *C. canum*, *C. pisiferum*, *C. sil*, *C. soulattri*, *C. teysmannii* and *C. venulosum*) show considerable morphological variation, which is at least partly correlated with their wide ecological ranges. Most species, however, have a rather restricted ecological range; many grow in more or less well-drained, mixed dipterocarp forest, some prefer stream sides (e.g. *C. macrocarpum*) whereas others grow most commonly in forests on acid soils (e.g. *C. nodosum*, *C. obliquinervium*). A group of species occurs in hill forest up to 1300 m altitude (e.g. *C. collinum*, *C. exiticostatum*, *C. papuanum* and *C. symingtonianum*), and some species even occur predominantly above 1300 m (e.g. *C. garcinioides*, *C. pauciflorum*). Still others prefer peat swamps or periodically inundated forest (e.g. *C. suberosum*). In some areas, e.g. Johor (Peninsular Malaysia) and around Kuching (Sarawak), several *Calophyllum* species grow together in swamp forests. Elsewhere there may be concentrations of species in ridge forests (throughout Malesia) and in mixed lowland forests (e.g. in Papua New Guinea).

Locally, some species may be abundant, e.g. *C. sundaicum* and *C. scriblitifolium*, having an average of 1.5 trees or even more (up to 5.5) per ha in peat-swamp forest in Peninsular Malaysia. In lowland and lower montane forest, bintangor trees often reach to the top of the main canopy at maturity, but are not emergent.

Propagation and planting Natural regeneration usually occurs near the mother tree. Seedlings grown in nurseries require shade. In plantation trials in Indonesia the spacing of seedlings is usually 2 m × 3 m.

Silviculture and management The selective cutting system and removal of undesirable trees can enhance the natural regeneration of bintangor.

Diseases and pests Leaves and young shoots are susceptible to attack by various insects.

Harvesting The main defects of logs are slight spongy heart and pinhole borer damage, but generally the logs are sound.

For seed-oil extraction, the seeds are shelled, chopped, dried, pounded and then boiled. The oil is skimmed from the top of the boiling water. The seeds may also be crushed to a paste and the oil is then drained off.

Genetic resources In several areas bintangor is abundant, e.g. in dry lowland forest and particularly in peat-swamp forest in Peninsular Malaysia. In Borneo and New Guinea several species are also common and widespread. In many other areas bintangor is much less common and occurs scattered in the forest. When bintangor timber becomes more popular, the rarer species will become liable to genetic erosion.

Prospects The timber of *Calophyllum* is expected to be more fully utilized in the future in view of decreasing supplies of more popular and expensive timbers such as red meranti (*Shorea* spp.). Bintangor often produces rather decorative figures on flat-sawn boards, and the distinctive colours of the timber are attractive for decorative purposes, such as furniture, parquet flooring, solid door construction, and for veneer and plywood. If properly promoted, *Calophyllum* timber from South-East Asia could become as popular as that from South and Central America ('Santa Maria') or India ('poon').

Research on all silvicultural aspects is urgently required to ensure a continuous supply of bintangor. Research on handling of the timber after harvesting is also important to support its marketability. More detailed information on working properties, drying, preservative treatment and mechanical properties is required to enhance the usability of the timber.

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Selection of species

Calophyllum bicolor P.F. Stevens

Journ. Arn. Arb. 61: 536 (1980).

Synonyms *Calophyllum caudatum* auct. non Kanehira & Hatusima.

Distribution Eastern Indonesia (Aru Islands, Irian Jaya), western Papua New Guinea and northern Australia (Queensland).

Uses The timber is probably used as bintangor, and traded as 'calophyllum' in New Guinea.

Observations A medium-sized tree up to 30 m tall with bole up to 50 cm in diameter, without buttresses; twigs slightly 4-angled or rounded, terminal bud plump, 4–7 mm long; leaves ovate to elliptical, (2–)4–8(–13) cm long, rounded, truncate or cuneate at base, acute or acuminate at apex, with 4–9 veins per 5 mm; inflorescences axillary, unbranched, 3-5-flowered; flowers with 4 tepals; fruit ovoid to ellipsoid, 7–11 mm long, with thin outer layer having large air spaces, deep blue to black. *C. bicolor* occurs in seasonally inundated or well-drained rain forest, often together with *Melaleuca* spp. and *Acacia* spp., sometimes in secondary forest, up to 100(–250) m altitude.

Selected sources 648.

Calophyllum biflorum M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 349 (1956).

Distribution Southern Peninsular Malaysia, Singapore and Borneo.

Uses The timber is used as bintangor, e.g. to make planks.

Observations A medium-sized to fairly large tree up to 36 m tall, with bole up to 95 cm in diameter, without buttresses; twigs more or less 4-angled or rounded, terminal bud plump to conical, 2.5–10 mm long; leaves oblong to subelliptical or obovate, 3.5–12.5 cm long, cuneate at base, retuse to rounded at apex, with 7–15(–18) veins per 5 mm; inflorescences axillary, branched or not, 5–21-flowered; flowers with 4 tepals; fruit ellipsoid, spherical or ovoid, 11–23 mm long, with thick, compact outer layer, pale green. *C. biflorum* is a variable species, especially in Borneo, and is closely related to *C. ferrugineum*. It is usually found in well-drained mixed dipterocarp forest up to 1100(–1400) m altitude.

Selected sources 1, 33, 648, 779.

Calophyllum blancoi Planchon & Triana

Ann. Sci. Nat. Bot. 4, 15: 262 (1862).

Synonyms *Calophyllum racemosum* Merr. (1910), *Calophyllum glabrum* Merr. (1912), *Calophyllum mindanaense* Elmer (1915).

Vernacular names Philippines: bitanghol (general).

Distribution The Philippines and Borneo (Sabah, East Kalimantan); also in Taiwan (Lanyu Islands).

Uses The timber is used in the Philippines as bintangor. The latex is used to treat wounds, boils and swellings and to alleviate asthma.

Observations A medium-sized to large tree up to 40 m tall with bole up to 60 cm in diameter, without buttresses; twigs 4-angled, terminal bud plump, 6–20 mm long; leaves elliptical to suboblong, rarely obovate, (3–)5–25(–30) cm long, cuneate or abruptly attenuate at base, acuminate at apex, with 5–18(–22) veins per 5 mm; inflorescences terminal and/or axillary, branched up to 2 times, 9–many-flowered; flowers with 8–16 tepals; fruit ovoid to subspherical, 12–22 mm long, with fairly thin, compact outer layer, green, bluish or black. *C. blancoi* is a variable species. It occurs usually in well-drained primary forest up to 1900 m altitude. The supply of 'bitanghol' in the Philippines is not abundant, and the stands are depleted due to logging and shifting cultivation. The heartwood is reddish-brown; the density is 500–650 kg/m^3 at 15% moisture content.

Selected sources 175, 484, 579, 648.

Calophyllum calaba L.

Sp. pl.: 514 (1753).

Vernacular names Indonesia: balud, kayu paku, kayu bangkur (Sumatra). Malaysia: bintangor bunga (Peninsular). Thailand: ta ngo (Phangnga, Yala), mu-ta-ngoh (Malay, Yala).

Distribution Sri Lanka, Indo-China (Laos, Cambodia, Vietnam), Thailand, the Andaman and Nicobar Islands, Peninsular Malaysia, Singapore, Sumatra, Borneo, Java and the Lesser Sunda Islands; also in north-eastern Australia (Queensland).

Uses The timber is used as bintangor. The latex is used as a fish poison, and in Cambodia for shampoo. The fruits are edible.

Observations A small to large tree up to 40(–50) m tall with bole up to 80(–160) cm in diameter, usually without buttresses; twigs (2–)4(–6)-angled or rounded, usually strongly flattened, terminal bud plump to conical, (1.5–)3–11 mm long; leaves usually elliptical to ovate, (1.5–)3–13 cm long, cuneate to cordate at base, subacuminate to retuse at apex, with (8–)10–20 (–28) veins per 5 mm; inflorescences axillary, unbranched or with 3-flowered branches, (3–)5–15-flowered; flowers with 4(–6) tepals; fruit spherical, ovoid or ellipsoid, 6–16 mm long, with fairly thin outer layer having air spaces, yellowish-green, pale chestnut or purplish-black. *C. calaba* is a very variable species. Several varieties are distinguished, the most important in Malesia being var. *bracteatum* (Wight) P.F. Stevens (synonyms: *C. amoenum* auct., *C. curtisii* King). *C. calaba* is common in lowland or lower montane mixed dipterocarp forest, up to 1500 m altitude.

Selected sources 1, 318, 648, 779.

Calophyllum canum Hook.f.

Fl. Brit. India 1: 271 (1874).

Synonyms *Calophyllum borneense* Vesque (1889).

Vernacular names Malaysia: bintangor merah (Peninsular).

Distribution Peninsular Malaysia, Sumatra, the Riau Archipelago and Borneo.

Uses This species is one of the most important sources of bintangor timber in Sarawak; the latex is used to stupefy fish.

Observations A medium-sized to fairly large tree up to 35 m tall with bole up to 75 cm in diameter, without buttresses; twigs more or less strongly 4-angled, terminal bud plump to narrowly conical, (3–)10–22 mm long; leaves ovate, elliptical or suboblong, (3.5–)9–22 cm long, rounded or cuneate at base, acuminate at apex, undulate at margin, with 10–18(–21) veins per 5 mm; inflorescences axillary, usually unbranched, 7–many-flowered; flowers with 4(–8) tepals; fruit spherical or ovoid, 15–22 mm long, with fairly thick, compact outer layer, greenish. *C. canum* grows in well-drained mixed dipterocarp forest on clay-rich soils, but also in peat swamps, up to 1200 m altitude.

Selected sources 1, 33, 318, 648, 779.

Calophyllum collinum P.F. Stevens

Journ. Arn. Arb. 61: 571 (1980).

Distribution Central and eastern New Guinea.

Uses The timber is possibly traded as 'calophyllum' in Papua New Guinea.

Observations A medium-sized to fairly large tree up to 36 m tall, with bole up to 85 cm in diameter, without buttresses; twigs strongly 4-angled, terminal bud plump, 6–9 mm long; leaves obovate or elliptical, 2–8 cm long, cuneate at base, more or less rounded at apex, with 11–20 veins per 5 mm; inflorescences axillary, unbranched, 7–many-flowered; flowers unknown; fruit subspherical, 12–18 mm long, with thick outer layer, compact but with air spaces under skin, blue to blackish. *C. collinum* occurs in hill forest up to 500 m altitude and is locally fairly common (e.g. near Kiunga, Papua New Guinea).

Selected sources 648.

Calophyllum coriaceum Symington ex M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 323 (1956).

Vernacular names Malaysia: bintangor gunong daun besar (Peninsular).

Distribution Peninsular Malaysia (Selangor, Pahang).

Uses The timber is used as bintangor.

Observations A medium-sized tree up to 30 m tall with bole up to 60 cm in diameter, without buttresses; twigs 4-angled, terminal bud plump, 10–18(–27) mm long; leaves very stiffly leathery, elliptical to oblong, 8–18.5 cm long, rounded to slightly cuneate at base, obtuse to shallowly retuse at apex, with 5–12 veins per 5 mm; inflorescences terminal and axillary, branched, with many flowers; flowers with 8 tepals; fruit ellipsoid, 30–45 mm long, with thick outer layer, compact but with air spaces under skin, green. *C. coriaceum* is sometimes confused with *C. wallichianum*. It grows in montane rain forest at 1200–1450 m altitude and is locally common.

Selected sources 1, 648, 779.

Calophyllum dasypodum Miq.

Fl. Ind. Bat. 1(2): 511 (1859).

Synonyms *Calophyllum lanceolatum* Teijsm. & Binnend. (1853) non Blume, *Calophyllum hasskarlii* Teijsm. & Binnend. ex Planchon & Triana (1862).

Vernacular names Indonesia: mersaweu (Sumatra), ki putri (Sundanese, Java).

Distribution Southern Sumatra, western Java and southern Kalimantan; possibly also the Philippines (Calamian Group).

Uses The timber is used in house construction.

Observations A medium-sized tree up to 30 m tall with bole up to 50 cm in diameter, without buttresses; twigs initially strongly 4-angled, but soon becoming subterete, terminal bud plump, 6–8 mm long; leaves ovate to elliptical, 5.5–12.5 cm long, cuneate at base, acute or acuminate at apex, undulate at margin, with 8–15 veins per 5 mm; inflorescences axillary, unbranched, 7–11-flowered; flowers with 4, 6 or 8 tepals; fruit spherical, 14–17 mm long, with thin, compact outer layer. In Java *C. dasypodum* has often been confused with *C. calaba*. *C. dasypodum* occurs in lowland forest up to 150 m altitude.

Selected sources 35, 318, 648.

Calophyllum depressinervosum M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 335 (1956).

Vernacular names Malaysia: bintangor lekok (Peninsular). Thailand: phanghan bailek (Chanthaburi).

Distribution Cambodia, Thailand, Peninsular Malaysia, Sumatra, the Riau Archipelago, Bangka and Borneo.

Uses The timber is used as bintangor.

Observations A medium-sized to fairly large tree up to 35 m tall with bole up to 85 cm in diameter, without buttresses; twigs obscurely 4-angled, terminal bud plump to conical, very small, 1.5–3 mm long (usually not functional); leaves ovate or obovate to subelliptical, 3–10 cm long, cuneate at base, acuminate at apex, with 4–10 veins per 5 mm; inflorescences axillary, unbranched, 7–13-flowered; flowers with 4 tepals; fruit spherical, 8–11 mm long, with fairly thin outer layer with large air spaces, yellowish. *C. depressinervosum* usually grows in mixed dipterocarp forest on well-drained sites up to 750 m altitude.

Selected sources 100, 648, 779.

Calophyllum dioscurii P.F. Stevens

Journ. Arn. Arb. 61: 530 (1980).

Distribution Peninsular Malaysia, Sumatra and Bangka; perhaps also in Java and eastern Borneo.

Uses The timber is probably used as bintangor; in Pahang (Peninsular Malaysia) a decoction of the roots is used medicinally after childbirth.

Observations A medium-sized tree up to 33 m tall with bole up to 55 cm in diameter, without buttresses; twigs obscurely 4-angled, terminal bud plump to conical, 2.5–6 mm long; leaves elliptical to ovate, 3–10 cm long, cuneate at base, prominently acuminate at apex, with (7–)12–20(–28) veins per 5 mm; inflorescences axillary, unbranched, 5–7-flowered; flowers (probably) with 4 tepals; fruit spherical, 12–16 mm long, with thin outer layer with large air spaces, green, finely mottled with yellow, or bronzed. *C. dioscurii* usually grows in mixed dipterocarp hill forest up to 650 m altitude.

Selected sources 648.

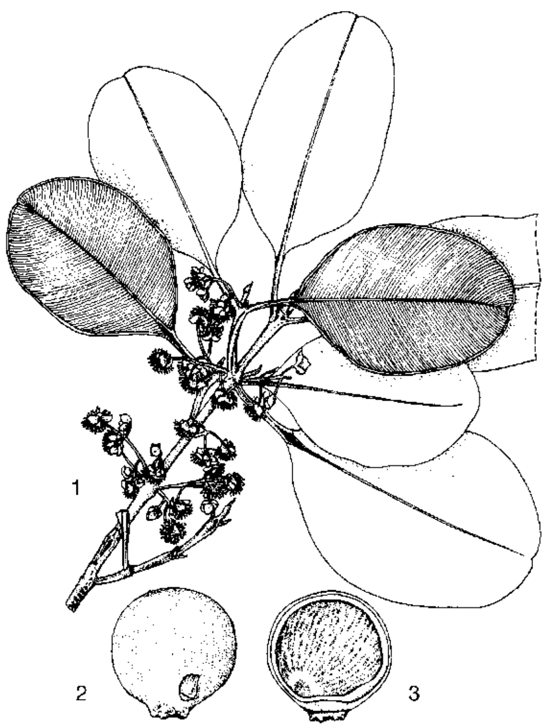
Calophyllum euryphyllum Lauterb.

Bot. Jahrb. Syst. 58: 14 (1922).

Distribution Northern New Guinea including the Bismarck Archipelago and the Aru Islands.

Uses The timber is probably used as bintangor, and traded as 'calophyllum' in Papua New Guinea.

Observations A medium-sized tree up to 26 m tall with bole up to 100 cm in diameter, buttresses absent or very short; twigs 4-angled and with 2 additional ridges, strongly flattened, terminal bud subconical, 7–16 mm long; leaves ovate to subelliptical, (6–)8.5–19 cm long, rounded or cuneate at base, subretuse to subacuminate at apex, with 9–13 veins per 5 mm; inflorescences axillary, usually unbranched, 5–15-flowered; flowers with 4



Calophyllum euryphyllum Lauterb. – 1, flowering twig; 2, stone fruit; 3, sectioned fruit.

tepals; fruit subspherical, large, 30–60 mm long, with fairly thin, compact outer layer, greenish. *C. euryphyllum* usually occurs in primary rain forest up to 600 m altitude.

Selected sources 648.

Calophyllum exiticostatum P.F. Stevens

Journ. Arn. Arb. 61: 676 (1980).

Distribution Sumatra and Borneo (Sabah).

Uses The timber is possibly used as bintangor.

Observations A large tree up to 45 m tall with bole up to 140 cm in diameter, without buttresses; twigs strongly 4-angled, terminal bud plump to conical, 2.5–3 mm long; leaves ovate to elliptical, 2–5(–7.5) cm long, rounded or cuneate at base, rounded at apex, with 14–23 veins per 5 mm; inflorescences axillary, unbranched, 5–7-flowered; flowers with 4 tepals; fruit spherical, c. 7 mm long, with very thin outer layer having large air spaces beneath skin. This species is closely related to *C. calaba* and is found in evergreen hill forest up to 900 m altitude.

Selected sources 648.

Calophyllum ferrugineum Ridley

Journ. Roy. As. Soc. Straits Br. 54: 17 (1910).

Distribution Peninsular Malaysia, Singapore, the Riau Archipelago and northern Borneo (Sarawak, Brunei, Sabah).

Uses The timber is used as bintangor for house construction and masts.

Observations A medium-sized tree up to 30 m tall with bole up to 50 cm in diameter, without buttresses; twigs obscurely to strongly 4-angled, terminal bud plump to stoutly conical, 2.5–7 mm long; leaves oblong to elliptical, (3–)4–12(–15) cm long, acute at base, retuse to shortly acuminate at apex, with (10–)12–21(–26) veins per 5 mm; inflorescences axillary, usually unbranched, 3–13-flowered; flowers with 4 (rarely 8) tepals; fruit ovoid to ellipsoid, 16–26 mm long, with thin, compact outer layer, greenish or whitish. Three varieties are distinguished: var. *ferrugineum* in southern Peninsular Malaysia, Singapore and the Riau Archipelago, var. *oblongifolium* (T. Anderson) P.F. Stevens (synonyms: *C. oblongifolium* (T. Anderson) Ridley, *C. ferrugineum* Ridley var. *neriifolium* (Ridley) M.R. Henderson & Wyatt-Smith, *C. kunstleri* auct. non King) from central and north-eastern Peninsular Malaysia, and var. *orientale* P.F. Stevens from north-western Borneo. *C. ferrugineum* occurs in mixed dipterocarp forest, sometimes in seasonally inundated forest, up to 750 m altitude and it is locally common, sometimes even co-dominant (e.g. in Borneo with *Casuarina* and *Dacrydium* species).

Selected sources 1, 33, 100, 102, 648, 779.

Calophyllum flavo-ramulum M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 310 (1956).

Distribution Peninsular Malaysia and the Riau Archipelago; perhaps also in Sumatra.

Uses The timber is used as bintangor.

Observations A fairly large tree up to 38 m tall with bole up to 90 cm in diameter, without buttresses; twigs rounded or obscurely 4-angled, terminal bud plump, 2.5–6 mm long; leaves oblong, 7.5–16 cm long, cuneate or attenuate at base, acuminate at apex, with 10–19 veins per 5 mm; inflorescences terminal and axillary, unbranched, 7–many-flowered; flowers with 8 tepals; fruit ellipsoid to subspherical, 25–35 mm long, with fairly thin, compact outer layer, purplish-black. *C. flavo-ramulum* grows in mixed dipterocarp forest up to 450 m altitude and is locally common.

Selected sources 648, 779.

Calophyllum fraseri M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 344 (1956).

Distribution Peninsular Malaysia.

Uses The timber is used as bintangor.

Observations A fairly large tree up to 36 m tall with bole up to 60 cm in diameter, without buttresses; twigs slightly 4-angled or rounded, terminal bud plump, 4.5–7 mm long; leaves ovate to elliptical, 5–13 cm long, cuneate at base, acuminate at apex, with (7–)9–14 veins per 5 mm; inflorescences axillary, unbranched, up to 11-flowered; flowers with 4 or 8 tepals; fruit ellipsoid, 26–33 mm long, with thin, compact outer layer. *C. fraseri* grows in hill forest or montane rain forest at 750–1300 m altitude and is only very locally common.

Selected sources 648, 779.

Calophyllum garcinioides P.F. Stevens

Journ. Arn. Arb. 61: 412 (1980).

Distribution Northern Borneo (Brunei, Sarawak, Sabah).

Uses The timber is possibly used as bintangor.

Observations A medium-sized tree up to 25 m tall, but sometimes much larger (up to 40 m), with bole up to 65 cm in diameter, without buttresses; twigs at first slightly 2-, 4-, or 6-angled, soon becoming rounded, terminal bud plump, 2.5–6 mm long; leaves obovate, trapeziform or elliptical, 2.5–9.5 cm long, rounded to cuneate at base, subacuminate or acute at apex, with 7–15 veins per 5 mm; inflorescences terminal and from adjacent axils of leaves, branched when terminal, 7–17-flowered; flowers with 12–16 tepals; fruit subspherical, 16–20 mm long, with thin, compact outer layer, greenish. *C. garcinioides* occurs in lower montane and montane forest at 1000–2450 m altitude and is locally common. The latex may be white as well as yellow.

Selected sources 648.

Calophyllum goniocarpum P.F. Stevens

Austr. Journ. Bot. 22: 369 (1974).

Distribution The Moluccas (Morotai) and New Guinea.

Uses The timber is possibly traded as 'calophyllum' in Papua New Guinea.

Observations A fairly large tree up to 36 m tall with bole up to 60 cm in diameter, without buttresses; twigs usually rather strongly 4-angled, terminal bud plump, 5–14 mm long; leaves obovate to oblong or elliptical, (4–)6–23 cm long, acute to cordate at base, obscurely acuminate to retuse at apex, with 9–17 veins per 5 mm; inflorescences axillary, 5–17-flowered and branched with 3-flowered branches; flowers with 4(–5) tepals; fruit ellipsoid to spherical, 17–28 mm long, with fairly thick outer layer often having air spaces under the skin, usually bluish to blackish. *C. goniocarpum* usually grows in well-drained forest up to 800 m altitude.

Selected sources 648.

Calophyllum griseum P.F. Stevens

Journ. Arn. Arb. 61: 661 (1980).

Distribution North-western Borneo (Sarawak, Sabah, Brunei, Kalimantan).

Uses The timber is possibly used as bintangor.

Observations A medium-sized tree up to 30 m tall with bole up to 40 cm in diameter, without buttresses; twigs usually strongly 4-angled, terminal bud plump, 4.5–7 mm long; leaves ovate or suboblong to elliptical, 8.5–16 cm long, cuneate at base, subrounded, acute or acuminate at apex, with 4–8 veins per 5 mm, upper surface usually with greyish, waxy covering; inflorescences terminal and from adjacent leaf axils, branched, up to 20-flowered; flowers with 8 tepals; fruit spherical to ellipsoid, 17–22 mm long, with fairly thick, subcompact outer layer having air spaces under the skin, pale greyish-brown. *C. griseum* grows in well-drained mixed dipterocarp forest up to 400 m altitude.

Selected sources 648.

Calophyllum havilandii P.F. Stevens

Journ. Arn. Arb. 61: 450 (1980).

Synonyms *Calophyllum rhizophorum* auct. non Boerl. & Koord.

Distribution North-western Borneo (Sarawak, Sabah, Brunei).

Uses The timber is used as bintangor. Locally it is used for planks.

Observations A medium-sized tree up to 27 m tall, bole without buttresses; twigs 4-angled, terminal bud conical, 2–4 mm long; leaves obovate to suboblong, 5.5–14.5 cm long, broadly rounded to cuneate at base, slightly retuse at apex, with 4–7 veins per 5 mm; inflorescences axillary, unbranched, 5–9-flowered; flowers with 4 tepals; fruit ellipsoid, c. 20 mm long, with fairly thin outer layer, compact except for air spaces under the skin. *C. havilandii* usually grows in peat swamps at low altitudes.

Selected sources 648.

Calophyllum hosei Ridley

Kew Bull.: 120 (1938).

Distribution South-eastern Sumatra and Borneo.

Uses The timber is possibly used as bintangor.

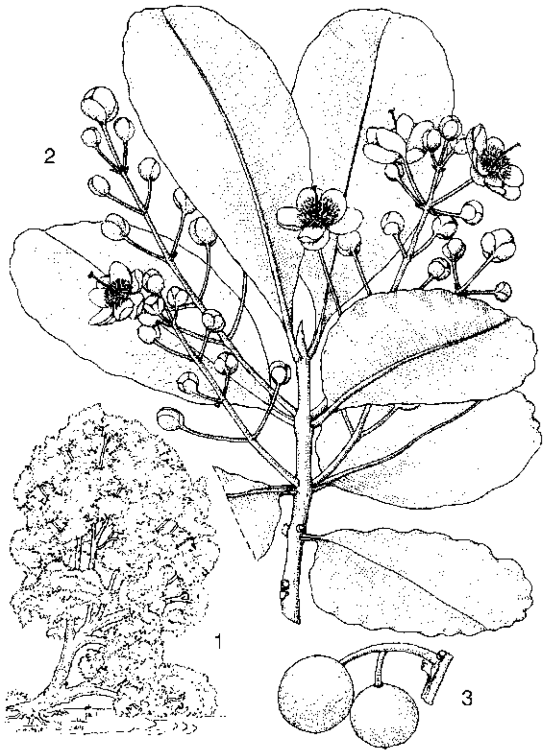
Observations A medium-sized tree up to 18 m tall, but sometimes much larger (up to 36 m), with bole up to 45 cm in diameter, without buttresses; twigs usually rounded, terminal bud plump, 2–4 mm long; leaves oblong to elliptical, (3–)4–9.5 cm long, acute at base, usually retuse at apex, with (9–)11–17(–22) veins per 5 mm; inflorescences axillary, unbranched, 7–13-flowered; flowers with 4 tepals; fruit ovoid to ellipsoid, c. 20 mm long, with thin, compact outer layer. *C. hosei* generally grows in freshwater peat swamps in the lowland.

Selected sources 648.

Calophyllum inophyllum L.

Sp. pl. 1: 513 (1753).

Vernacular names Alexandrian laurel, Borneo mahogany (En). Indonesia: njamplung (Java), dingkaran (Sulawesi). Malaysia: bintangor laut, penaga laut (Peninsular), penaga (Sabah). Papua New Guinea: beach calophyllum. Philippines: palo maria (Sp), bitaog (general). Burma: ponnyet, ph'ông. Thailand: krathing (general), saraphee naen (northern), naowakan (Nan). Vietnam: c[aa]y m[uf] u.



Calophyllum inophyllum L. – 1, typical habit of tree along beach; 2, flowering twig; 3, fruits.

Distribution Eastern Africa, Madagascar, islands of the Indian Ocean, India, Sri Lanka, Burma, Indo-China, Thailand, Taiwan and the Ryukyu Islands, throughout Malesia, northern Australia and the islands of the Pacific Ocean; often planted within its range, in western Africa and in the tropics of America.

Uses The timber is obtained in many places in fairly large quantities and used for many purposes: construction, furniture and cabinet work, cartwheel hubs, vessels, musical instruments, canoes and boats. The oil from the seeds is used for illumination, soap making, and medicinal purposes. The latex and pounded bark are also used medicinally. The tree is planted as ornamental and shade tree, and for reforestation and afforestation. The fruit is edible.

Observations A medium-sized tree up to 25 m tall, but sometimes as large as 35 m, usually with twisted or leaning bole up to 150 cm in diameter, without buttresses; twigs 4-angled or rounded, terminal bud plump, 4–9 mm long; leaves elliptical, ovate, obovate or oblong, (5.5–)8–20(–23) cm long, rounded to cuneate at base, rounded, retuse or subacute at apex, with 4–10 veins per 5 mm; inflorescences axillary, usually unbranched but occasionally with 3-flowered branches, 5–15(–30)-flowered; flowers with 8(–13) tepals; fruit spherical to obovoid, 25–50 mm long, with fairly thin, compact outer layer, greyish-green. *C. inophyllum* is often common on the seashore (sandy beaches), but is sometimes found inland on sandy soils up to 200 m altitude. The fruits are dispersed by sea currents, but also by fruit bats. The timber is generally slightly heavier, stronger and more durable than that of other *Calophyllum* species and the wood is often finer-textured, and the grain is more interlocked. The density is 560–800 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 1, 33, 35, 100, 102, 175, 190, 318, 359, 461, 484, 534, 578, 579, 648, 779.

Calophyllum lanigerum Miq.

Fl. Ind. Bat., Suppl. 1(3): 498 (1861).

Vernacular names Indonesia: betur belulang, bintangur belulang (Bangka, Belitung).

Distribution Southern Peninsular Malaysia, Singapore, the Riau Archipelago, Bangka, Belitung and Borneo.

Uses The timber is used as bintangor, especially for house and ship building.

Observations A small or medium-sized tree up to 25 m tall, with bole up to 50 cm in diameter, usually without buttresses; twigs strongly 4-angled to rounded, terminal bud plump, 5–30 mm long; leaves ovate to oblong, 4–20 cm long, rounded to cuneate at base, retuse, rounded or subacute at apex, with 6–13(–15) veins per 5 mm; inflorescences axillary, generally unbranched, 3–21-flowered; flowers with 8 tepals (rarely 6); fruit usually spherical, 12–29 mm long, with fairly thick, compact outer layer. Two varieties are distinguished: var. *lanigerum* from Bangka, Belitung and south-eastern Borneo and var. *austrocoriaceum* (Whitm.) P.F. Stevens (synonym: *Calophyllum austrocoriaceum* Whitm.) from Peninsular Malaysia to the Riau Archipelago and north-western Borneo. *C. lanigerum* grows in mixed dipterocarp rain forest, in hill forest, heath forest, and in peat swamps; often on sandy soils. It occurs up to 950 m altitude, and is locally abundant.

Selected sources 318, 648, 779.

Calophyllum laticostatum P.F. Stevens

Austr. Journ. Bot. 22: 375 (1974).

Distribution Papua New Guinea including

New Britain; possibly also in the Philippines (Luzon).

Uses The timber is possibly traded as 'calophyllum' in Papua New Guinea.

Observations A large tree up to 43 m tall, with bole up to 90 cm in diameter, without buttresses; twigs 4-angled, terminal bud elliptical to narrowly obovate, (3–)6.5–16 cm long, cuneate at base, acute at apex, with (9–)11–20 veins per 5 mm; inflorescences axillary, usually unbranched, 5–21-flowered; flowers with 4 or 6 tepals; fruit ovoid to subspherical, 13–19 mm long, with thin outer layer having air spaces under the skin, bluish. *C. laticostatum* occurs in well-drained lowland or lower montane rain forest up to 1400 m altitude.

Selected sources 648.

Calophyllum leleanii P.F. Stevens

Journ. Arn. Arb. 61: 587 (1980).

Synonyms *Calophyllum solomonense* auct. non A.C. Smith.

Distribution Papua New Guinea (New Britain) and the Solomon Islands; probably also in Sulawesi.

Uses The timber is traded as 'calophyllum' in Papua New Guinea; it is also used for making spears.

Observations A medium-sized tree up to 25 m tall with bole up to 55 cm in diameter, without buttresses; twigs slightly 2-, 4- or 6-angled, terminal bud usually narrowly conical, 8–20 mm long; leaves elliptical, ovate or suboblong, (5.5–)10–28 cm long, cuneate at base, obtuse to shortly acuminate at apex, with 5–10 veins per 5 mm; inflorescences axillary, often branched, 5–11-flowered; flowers with 4, 7 or 8 tepals; fruit subspherical, 18–35 mm long, with fairly thick, compact outer layer, greenish. *C. leleanii* is locally common in primary forest on slopes and ridges up to 900 m altitude.

Selected sources 648.

Calophyllum macrocarpum Hook.f.

Fl. Brit. India 1: 273 (1874).

Vernacular names Malaysia: bintangor bunut, bintangor rimba (Peninsular), bunut (Sarawak). Thailand: chuat (Trang).

Distribution Southern Thailand, Peninsular Malaysia, Singapore, Sumatra and Borneo.

Uses The timber is used as bintangor; it is used to build houses and for the manufacture of furniture. The fruit is edible.

Observations A large tree up to 45 m tall (trees of 60 m have been reported), with bole up to 160 cm in diameter, buttresses usually absent or present but small; twigs sharply 4-angled, terminal bud plump, (2–)3.5–5.5(–9) mm long; leaves usually oblong to elliptical, 8–25(–35) cm long, acute at base, usually shortly acuminate at apex, with (4–)5–10(–13) veins per 5 mm; inflorescences axillary, usually unbranched but occasionally with 3-flowered branches, (3–)7–15-flowered; flowers with 8 (rarely 10) tepals; fruit ellipsoid, very large, 80–130 mm long, with thick outer layer having large air spaces under the skin, dark green. *C. macrocarpum* occurs in mixed dipterocarp forest (often near streams), on ridges in hill forest, in periodically inundated forest on acid and sandy soil. It grows up to 800 m altitude. The timber is hard and reportedly durable. The outer layer of the fruit is edible but fibrous.

Selected sources 1, 33, 102, 648, 779.

Calophyllum molle King

Journ. As. Soc. Beng. 59: 177 (1890).

Vernacular names Thailand: tanghon lawkaw (Trang).

Distribution Southern Thailand and Peninsular Malaysia; perhaps also in Borneo.

Uses The timber is used as bintangor.

Observations A medium-sized tree up to 30 m tall, with bole up to 50 cm in diameter, without buttresses; twigs obscurely 4-angled, terminal bud plump to elliptical, 4–10 mm long; leaves ovate to suboblong or subelliptical, 6–18.5 cm long, rounded to cuneate at base, acute or acuminate at apex, with (8–)11–17 veins per 5 mm, rusty tomentose beneath; inflorescences axillary, unbranched, 3–5-flowered; flowers with 4 (rarely 6) tepals; fruit subspherical to ellipsoid, 22–34 mm long, with thick, compact outer layer, brownish. *C. molle* grows in mixed dipterocarp forest, often on ridges and hillsides, up to 700 m altitude. The wood has a density of 600–720 kg/m^3 at 15% moisture content.

Selected sources 100, 190, 648, 779.

Calophyllum neo-ebudicum Guillaumin

Journ. Arn. Arb. 12: 227 (1931).

Synonyms *Calophyllum samoense* Christophersen (1935), *Calophyllum pseudovitiense* P.F. Stevens (1974), *Calophyllum spectabile* auct. non Willd., *Calophyllum vitiense* auct. non Turrill.

Distribution North-eastern Papua New Guinea (New Britain, Bougainville), Solomon Islands, Vanuatu, Fiji, Samoa and Tonga.

Uses The timber is often used for making canoes, and locally also for building houses and making spears and bowls.

Observations A very large tree up to 58 m tall with bole up to 185 cm in diameter, usually without buttresses; twigs obscurely 4-angled, terminal bud plump, rarely conical, 4–15 mm long; leaves (narrowly) ovate to elliptical, (4–)5–19.5 cm long, cuneate at base, acuminate at apex, with 7–14 veins per 5 mm; inflorescences axillary, rarely terminal, usually unbranched, 7–17-flowered; flowers with 8(–12) tepals; fruit ovoid or ellipsoid to subspherical, 21–37(–43) mm long, with thin to fairly thick outer layer, compact but usually having air spaces under the skin, bluish to purplish-black when ripe. *C. neo-ebudicum* usually occurs in well-drained, primary rain forest, preferably on ridges, up to 800 m altitude. It is often abundant, especially in the Solomon Islands and Vanuatu.

Selected sources 648.

Calophyllum nodosum Vesque

Epharmosis 2: pl. 10, 11 (1889).

Synonyms *Calophyllum parvifolium* Vesque (1893) non Choisy, *Calophyllum depressinervosum* auct. non M.R. Henderson & Wyatt-Smith.

Distribution Peninsular Malaysia (Johor) and northern Borneo.

Uses The timber is used as bintangor.

Observations A shrub to medium-sized tree up to 25 m tall, but sometimes much larger (up to 36 m), with bole up to 45 cm in diameter, without buttresses; twigs 4-angled or 4-alate, terminal bud rather plump, 0.5–1 mm long, usually not functional; leaves obovate to elliptical or narrowly elliptical, 1–6.5(–10) cm long, narrowly cuneate at base, rounded to shortly acuminate at apex, with 6–13(–15) veins per 5 mm; inflorescences axillary, unbranched, 1–9(–13)-flowered; flowers with 4(–8) tepals; fruit spherical, (4–)5.5–10 mm long, with thin outer layer having large air spaces under the skin, yellowish to greyish. In Borneo *C. nodosum* is common in heath forest (kerangas) on acid and often sandy soils up to 1900 m altitude. In Peninsular Malaysia it occurs only very locally.

Selected sources 648, 779.

Calophyllum obliquinervium Merr.

Philipp. Journ. Sc. 20: 409 (1922).

Synonyms *Calophyllum benjamina* Ridley (1938).

Vernacular names Brunei: bintangor kuning, kayu api. Philippines: dangkalan (general).

Distribution The Philippines (Luzon, Palawan, Calamian, Panay, Samar) and northern Borneo (Brunei, Sabah).

Uses The timber is used as bintangor for building and other purposes.

Observations A medium-sized to fairly large tree up to 40 m tall, with bole up to 65 cm in diameter, without buttresses but often with pneumatophores; twigs 4-angled or 4-alate, terminal bud plump, 1.5–2.5 mm long; leaves elliptical to subobovate, (4–)6–14.5 cm long, cuneate at base, acute or acuminate at apex, with 9–19 veins per 5 mm; inflorescences terminal and in adjacent leaf axils, usually unbranched, 7–13-flowered; flowers with 8 or 10 tepals; fruit spherical to ellipsoid, 9–13 mm long, with thin outer layer having air spaces under the skin, bluish or reddish-black. *C. obliquinervium* has a wide ecological range; it grows in many types of lowland forest, often in peat swamps and also on the seashore. In the Philippines it is a rare tree. The wood is reddish-brown and has a density of about 800 kg/m^3 at 15% moisture content.

Selected sources 33, 100, 484, 648.

Calophyllum papuanum Lauterb.

Bot. Jahrb. Syst. 58: 9 (1922).

Distribution The Moluccas (Morotai) and New Guinea.

Uses The timber is traded in Papua New Guinea as 'calophyllum'. It is used in building.

Observations A medium-sized to large, probably dioecious tree up to 40 m tall with bole up to 90 cm in diameter, usually without buttresses but sometimes with buttresses; twigs (2–)4–6-angled, terminal bud strongly flattened, 7–15 mm long; leaves ovate to subobovate, subcuneiform or suboblong, (2.5–)6.5–17(–22) cm long, rounded to cuneate at base, rounded to subacute at apex, with 5–12 veins per 5 mm; inflorescences axillary, usually unbranched, (1–)3–7(–11)-flowered; flowers usually with 8 tepals; fruit spherical, 2–4 cm long, with thick, compact outer layer having air spaces near stone, greenish. *C. papuanum* is usually a canopy tree of lowland or montane forest; it sometimes grows in swampy forest and occurs up to 1850 m altitude. The wood has a density of 490–650 kg/m^3 at 15% moisture content and is pinkish-red to reddish-brown. See also the table on wood properties.

Selected sources 67, 359, 648, 702.

Calophyllum pauciflorum A.C. Smith

Journ. Arn. Arb. 22: 348 (1941).

Distribution New Guinea.

Uses The timber is probably traded as 'calophyllum'. The wood is good as a green fuel.

Observations A fairly large, possibly dioecious tree up to 36 m tall, with bole up to 50 cm in diameter, without buttresses but sometimes fluted at base; twigs 4- or 6-angled, strongly flattened, terminal bud strongly flattened, 5–11 mm long; leaves rhombiform, cuneiform, elliptical or obovate, 2.5–5.5(–9.5) cm long, cuneate at base, rounded or obtuse at apex, with 7–12 veins per 5 mm; inflorescences usually axillary, unbranched, 3–5-flowered; flowers with (7–)8 tepals; fruit spherical, 15–19 mm long, with thick, compact outer layer, greenish. *C. pauciflorum* is closely related to *C. papuanum* and grows in montane forest, often dominated by *Castanopsis* and *Nothofagus* species, at 1550–2900 m altitude.

Selected sources 648, 702.

Calophyllum peekelii Lauterb.

Bot. Jahrb. Syst. 58: 11 (1922).

Synonyms *Calophyllum kajewskii* A.C. Smith (1941).

Vernacular names Solomon Islands: baula.

Distribution Irian Jaya (northern part), Papua New Guinea including New Britain, New Ireland and Bougainville, and the Solomon Islands.

Uses The timber is used for building houses and for canoes; it is probably traded as 'calophyllum' in Papua New Guinea. The bark is used as a fuel.

Observations A medium-sized to large, possibly dioecious tree up to 40 m tall (occasionally up to 60 m), with bole up to 180 cm in diameter, often without buttresses but sometimes small buttresses present; twigs strongly 4-angled or 4-alate, terminal bud plump, 9–15 mm long; leaves obovate to oblong or subelliptical, 8.5–17.5(–21.5) cm long, acute at base, rounded or shallowly retuse at apex, with 6–9(–12) veins per 5 mm; inflorescences axillary, often branched, 7–21(–31)-flowered; flowers with 8 tepals; fruit spherical to ovoid, 45–70 mm long, with thick, compact outer layer, dull green or bluish-green. *C. peekelii* grows usually in well-drained primary lowland rain forest up to 300 m altitude. In mainland New Guinea it occurs very scattered.

Selected sources 359, 648.

Calophyllum persimile P.F. Stevens

Journ. Arn. Arb. 61: 620 (1980).

Distribution Irian Jaya and western Papua New Guinea.

Uses The timber is probably traded as 'calophyllum' in Papua New Guinea.

Observations A medium-sized tree up to 25 m tall with bole up to 40 cm in diameter, sometimes with small buttresses; twigs strongly 4-angled, terminal bud plump to conical, (4–)7–9 mm long; leaves usually elliptical to oblong, (5–)10–30 cm long, acute at base, retuse to rounded at apex, with 4–10 veins per 5 mm; inflorescences axillary, unbranched, c. 5-flowered; flowers with 4 tepals; fruit ovoid, c. 30 mm long, with thick outer layer. *C. persimile* is closely related to *C. suberosum* P.F. Stevens and grows both in well-drained rain forest and in rain forest inundated in the wet season, up to 550 m altitude.

Selected sources 648.

Calophyllum pisiferum Planchon & Triana

Ann. Sci. Nat. Bot. 4, 15: 294 (1862).

Synonyms *Calophyllum retusum* auct. non Wallich ex Choisy.

Vernacular names Thailand: kathanghan bailek (Chanthaburi, Trat), paong (Suai, Surin).

Distribution Burma, Thailand, Vietnam, Cambodia, Peninsular Malaysia, southern Sumatra, Bangka, Belitung and Borneo (Kalimantan, Sabah).

Uses The timber is probably used as bintangor. A decoction of the bark is used in Cambodia to cure diarrhoea.

Observations A shrub to medium-sized tree up to 30 m tall with bole up to 60 cm in diameter, without buttresses but sometimes with knee roots; twigs sharply 4-angled, terminal bud plump, 2–4.5 mm long; leaves ovate to oblong or (narrowly) elliptical, broadly rounded to narrowly cuneate at base, rounded to acute at apex, with 5–8(–11) veins per 5 mm; inflorescences axillary, unbranched, 5–15-flowered; flowers with 4 tepals; fruit spherical to ellipsoid, 6–9 mm long, with thin outer layer having air spaces under the skin, orange to light chestnut. In Indo-China and northern Thailand *C. pisiferum* is often a shrub or small tree growing on rocky or sandy places near streams, in Malesia it is often a medium-sized tree growing in swampy or riverine forest below 50 m altitude. This species occurs scattered over its large area of distribution.

Selected sources 648, 779.

Calophyllum pulcherrimum Wallich ex Choisy

Mém. Guttif. Inde: 41 (1849).

Vernacular names Indonesia: bintangur onjem (Sumatra), mentangur perit (Bangka). Malaysia: bintangor gasing (Peninsular).

Distribution Peninsular Malaysia, southern Sumatra, Bangka, Belitung and Borneo (Kalimantan, Sarawak).

Uses The timber is used as bintangor, particularly for poles, fishing stakes, masts and keels of boats. The fruit is edible but sour.

Observations A medium-sized tree up to 30 m tall with bole up to 45 cm in diameter, usually without buttresses but rarely buttresses present; twigs strongly 4-angled, terminal bud usually conical, about 1 mm long and usually not functional; leaves elliptical to suboblong, (3–)4–8(–11) cm long, acute to attenuate at base, bluntly acuminate at apex, with 7–13(–17) veins per 5 mm; inflorescences axillary, unbranched, 7–11(–17)-flowered; flowers with 4 (rarely 8) tepals; fruit ovoid to spherical, 15–17 mm long, with fairly thick, compact outer layer, dull green. *C. pulcherrimum* has often been confused with *C. tetrapterum*. Records of *C. pulcherrimum* from Thailand and Indo-China probably refer to *C. tetrapterum*. *C. pulcherrimum* usually grows in mixed dipterocarp forest up to 300 m altitude. The timber is fairly heavy with density of 590–900 kg/m^3 at 15% moisture content. It is not durable and not resistant to dry-wood termites. See also the table on wood properties.

Selected sources 1, 33, 44, 102, 318, 461, 648, 779.

Calophyllum rigidum Miq.

Fl. Ind. Bat., Suppl. 1(3): 497 (1861).

Synonyms *Calophyllum kunstleri* King (1890).

Distribution Peninsular Malaysia, Sumatra, Bangka, Belitung and south-western Borneo (Kalimantan, Sarawak).

Uses The timber is used as bintangor; it is used in ship building and for general construction.

Observations A medium-sized tree up to 25 m tall, but occasionally up to 35 m, with bole up to 45 cm in diameter, without buttresses but loop roots sometimes present; twigs at first 4-angled but soon becoming rounded, terminal bud plump to narrowly conical, (3–)5–10(–13) mm long; leaves usually ovate, (4–)7–17.5 cm long, cuneate or attenuate at base, acuminate at apex, with (7–) 10–17 veins per 5 mm; inflorescences axillary, usually unbranched, 3–11-flowered; flowers with 4 tepals; fruit spherical, 12–16 mm long, with fairly thick, compact outer layer, whitish. *C. rigidum* is not common and occurs scattered. It grows in well-drained dipterocarp forest, but also in swamps (e.g. in Peninsular Malaysia, Sumatra) and heath forest-like vegetation (e.g. in Sarawak), up to 600 m altitude. The density of the timber is 470–670 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 102, 190, 648, 779.

Calophyllum rubiginosum M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 308 (1956).

Synonyms *Calophyllum muscigerum* Boerl. & Koord. ex K. Heyne (1927).

Vernacular names Indonesia: lancar (Sumatra). Malaysia: bintangor daun karat (Peninsular).

Distribution Southern Peninsular Malaysia, Singapore, Sumatra and Borneo (Sarawak, Brunei, Sabah, East Kalimantan).

Uses The timber is used as bintangor. The poisonous latex is used to exterminate rats and to stupefy fish; it is also used in local medicine.

Observations A medium-sized to fairly large tree up to 40 m tall, with bole up to 75 cm in diameter, without buttresses but sometimes with small spurs; twigs strongly 2- or 4-angled, terminal bud plump, 4–8 mm long; leaves elliptical to suboblong or ovate, (4.5–)7–16 cm long, acute at base, acute or acuminate at apex, with 8–14 veins per 5 mm, finely rusty tomentose beneath; inflorescences terminal and from adjacent leaf axils, unbranched, 7–15-flowered; flowers with 8 tepals (rarely 4); fruit ovoid-ellipsoid, 20–22 mm long, with fairly thin, compact outer layer, brownish-green. *C. rubiginosum* has been confused with *C. molle* and *C. wallichianum*. It grows in lowland forest up to 500 m altitude. In some places it is abundant, e.g. in Selangor (Peninsular Malaysia).

Selected sources 33, 102, 648, 779.

Calophyllum rufigemmatum M.R. Henderson & Wyatt-Smith ex P.F. Stevens

Journ. Arn. Arb. 61: 350 (1980).

Synonyms *Calophyllum wallichianum* auct. non Planchon & Triana.

Distribution South-eastern Peninsular Malaysia, Sumatra (central) and the Riau Archipelago.

Uses *C. rufigemmatum* is an important source of bintangor timber.

Observations A large tree up to 48 m tall with bole up to 240 cm in diameter, usually without buttresses; twigs obscurely 4-angled, terminal bud plump to narrowly conical, (8–)12–18 mm long; leaves ovate to subelliptical, 7–14 cm long, cuneate to broadly rounded at base, retuse to acuminate at apex, with (11–)13–18 veins per 5 mm; inflorescences axillary, unbranched, 5(–7)-

flowered; flowers with 4(–8) tepals; fruit usually ellipsoid, (25–)30–45 mm long, with thick, compact outer layer, pale green or brownish-green. *C. rufigemmatum* has been confused with *C. wallichianum*. It grows in well-drained habitats in mixed dipterocarp forest, particularly on ridges and slopes, up to 300 m altitude.

Selected sources 648.

Calophyllum sclerophyllum Vesque

Epharmosis 2: pl. 33 (1889).

Synonyms *Calophyllum rhizophorum* Boerl. & Koord. (1910).

Vernacular names Indonesia: nangui (Sumatra), bunut jankar (Bangka), penaga janka (Kalimantan). Malaysia: bintangor jangkang (Peninsular, Sarawak).

Distribution Peninsular Malaysia, Sumatra, the Riau Archipelago, Bangka, Belitung and Borneo.

Uses The timber is used as bintangor. It is used in general construction.

Observations A large tree up to 36(–45) m tall with bole up to 80(–95) cm in diameter, having numerous branching stilt roots and sometimes also knee roots; twigs rounded to sharply 4-angled, terminal bud plump, 3–9 mm long; leaves obovate to elliptical or oblong, 6–21 cm long, stiff and leathery, cuneate at base, rounded to retuse at apex, with (5–)6–10 veins per 5 mm; inflorescences axillary, unbranched, 7–11-flowered; flowers with 8 tepals; fruit ovoid, ellipsoid or spherical, 24–30 mm long, with fairly thick, hard and compact outer layer. *C. sclerophyllum* usually grows in freshwater peat swamps or in seasonally inundated forest in the lowland and is common. The wood is fairly heavy with density of 510–830 kg/m^3 at 15% moisture content. It is reported as fairly hard and durable and not attacked by insects.

Selected sources 1, 33, 44, 100, 318, 648, 779.

Calophyllum scriblitifolium M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 326 (1956).

Vernacular names Malaysia: bintangor kelim (Peninsular).

Distribution Malaysia (Peninsular, Sarawak), Sumatra.

Uses The timber is probably used as bintangor.

Observations A large tree up to 45 m tall with bole up to 95 cm in diameter, without buttresses but sometimes with knee roots; twigs 4- or 8-angled when young, terminal bud plump, 12–22(–29) mm long; leaves oblong to elliptical, 8–19 cm long, leathery, cuneate at base, rounded to retuse at apex, with 9–16 veins per 5 mm; inflorescences axillary, unbranched, 9–11-flowered; flowers with 4 tepals; fruit ellipsoid, 30–60 mm long, with fairly thick, compact outer layer. *C. scriblitifolium* occurs in peat swamps at low altitudes, rarely in heath forest and is apparently not a common tree.

Selected sources 33, 648, 779.

Calophyllum sil Lauterb.

Bot. Jahrb. Syst. 58: 14 (1922).

Distribution The Moluccas, New Guinea and northern Australia.

Uses The wood is used for canoes in Papua New Guinea.

Observations A medium-sized tree up to 30 m tall with bole up to 140 cm in diameter, without buttresses but sometimes with spurs; twigs usually strongly 4-angled, terminal bud plump, 5–10 (–13) mm long; leaves obovate to elliptical, (3–)5–12.5 cm long, broadly rounded to cuneate at base, rounded to acute at apex, with (5–)7–13 veins per 5 mm; inflorescences axillary, usually unbranched, 3–13-flowered; flowers with 4(–6) tepals; fruit spherical to ovoid, 13–20 mm long, with fairly thin, compact outer layer, bluish to purplish-black. *C. sil* grows in savanna woodland and riverine gallery forest, rarely in secondary forest, up to 200 m altitude. Slightly different forms from the Moluccas and northern New Guinea occur in rain forest up to 650 m altitude.

Selected sources 648.

Calophyllum soulattri Burm.f.

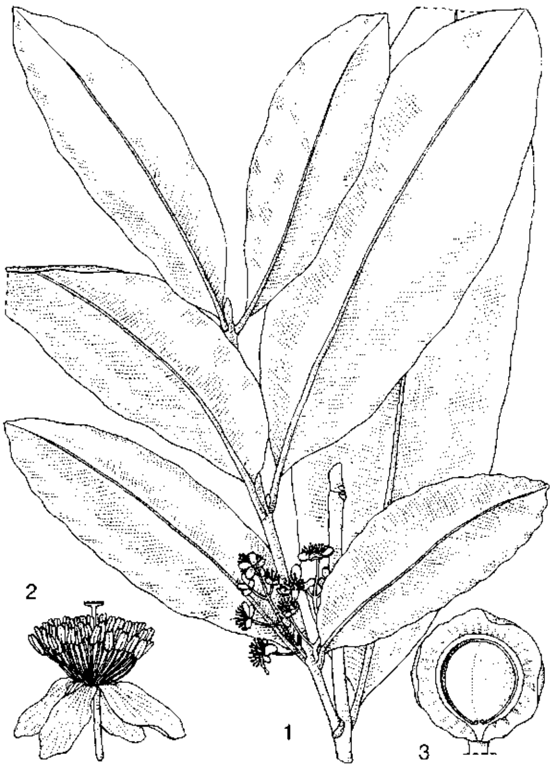
Fl. Indica: 121 (1768).

Synonyms *Calophyllum lancifolium* Elmer (1915), *Calophyllum zschokkei* Elmer (1915), *Calophyllum solomonense* A.C. Smith (1941), *Calophyllum spectabile* auct. non Willd.

Vernacular names Indonesia: sulatri (Sundanese, Java), slatri (Javanese, Java), malang-malang (Bangka). Malaysia: bintangor labu, bintangor lanchar, mintak (Peninsular). Philippines: bitanghol-sibat (general), pamintaogon (Samar-Leyte Bisaya), gigabi (Panay Bisaya). Thailand: tanghon baiyai (Surat Thani). Vietnam: c[oof]ng tr[aws]ng.

Distribution Vietnam, Cambodia, the Andaman Islands, Thailand, throughout Malesia towards the Solomon Islands and northern Australia.

Uses The timber is used for masts and spars and in house construction throughout the area of distribution. In many places it is considered as



Calophyllum soulattri Burm.f. – 1, flowering twig; 2, flower; 3, sectioned fruit.

one of the best bintangors. The latex may be used to poison dogs. The bark, roots and latex are used in local medicine. The fruits are edible but sour. The tree is sometimes planted as a shade tree or ornamental.

Observations A small to medium-sized tree up to 30 m tall with bole up to 70 cm in diameter, rarely buttressed, spurs or knee roots sometimes present; twigs usually 4-angled, terminal bud conical, 4–20 mm long; leaves ovate to elliptical or suboblong, (3.5–)6.5–29(–36) cm long, usually cuneate at base, acute or acuminate at apex, with (6–)12–18(–21) veins per 5 mm; inflorescences axillary, usually flabellate and branched, (3–)7–21-flowered; flowers with 4 tepals; fruit spherical, 9–16(–22) mm long, with fairly thick, compact outer layer, purplish-black. *C. soulattri* is a widespread but in many places rather uncommon tree of fairly small dimensions, growing in lowland or lower montane rain forest or sometimes in swamp forest, up to 1700 m altitude. The wood has a density of 400–700 kg/m^3 at 15% moisture content and is not very durable.

Selected sources 1, 33, 35, 100, 102, 318, 461, 648, 779.

Calophyllum suberosum P.F. Stevens

Austr. Journ. Bot. 22: 403 (1974).

Distribution Southern New Guinea.

Uses The timber is possibly traded as 'calophyllum' in Papua New Guinea.

Observations A medium-sized to fairly large tree up to 35 m tall with bole up to 60 cm in diameter, with stilt roots to 2 m tall; twigs 4- or 6-angled, terminal bud narrowly conical, 8–13 mm long; leaves ovate to elliptical, 16–35 cm long, broadly rounded at base, rounded to acute at apex, with 5–8(–9) veins per 5 mm; inflorescences axillary, unbranched, 3–5-flowered; flowers unknown; fruit spherical to ovoid, 80–95 mm long, with very thick, compact outer layer, green. *C. suberosum* grows in swampy and seasonally inundated forest below 50 m altitude.

Selected sources 648.

Calophyllum sundaicum P.F. Stevens

Journ. Arn. Arb. 61: 467 (1980).

Synonyms *Calophyllum retusum* auct. non Wallich ex Choisy.

Vernacular names Malaysia: bintangor gambut.

Distribution Southern Peninsular Malaysia, Singapore, Sumatra and western Borneo (West Kalimantan, Sarawak).

Uses The timber is probably used as bintangor.

Observations A medium-sized tree up to 28 m tall (perhaps sometimes very large, up to 50 m), with bole up to 65 cm in diameter, without buttresses but loop roots sometimes present; twigs 4-angled, terminal bud plump, 5–10 mm long; leaves elliptical to oblong, (3–)4.5–10(–14.5) cm long, rounded to cuneate at base, usually retuse at apex, with 11–18 veins per 5 mm; inflorescences usually axillary, unbranched, 7–11-flowered; flowers with 4 tepals; fruit ellipsoid, 15–21 mm long, with fairly thin, compact outer layer, greenish. *C. sundaicum* is locally common in peat swamps in the lowland and is rarely found in heath forest in Sarawak.

Selected sources 648, 779.

Calophyllum symingtonianum M.R. Henderson & Wyatt-Smith

Gard. Bull. Sing. 15: 338 (1956).

Vernacular names Malaysia: bintangor bukit (Peninsular). Thailand: tanghon (Trang).

Distribution Peninsular Malaysia; possibly also Thailand.

Uses The timber is used as bintangor and applied in house building.

Observations A large tree up to 40 m tall with bole up to 95 cm in diameter, sometimes with low, thick spurs or small buttresses; twigs at first slightly 4-angled but soon becoming rounded, terminal bud plump, 3–7 mm long; leaves ovate to subelliptical, 5–9 cm long, cuneate at base, acuminate at apex, with (6–)8–11 veins per 5 mm; inflorescences terminal and from adjacent leaf axils, unbranched or branched, 11–many-flowered; flowers unknown; fruit ellipsoid to ovoid, 17–20 mm long, with thin, compact outer layer. *C. symingtonianum* grows in lowland and lower montane forest at 150–1200 m altitude, and is locally abundant. The timber is reported as hard.

Selected sources 648, 779.

Calophyllum tetrapterum Miq.

Pl. Jungh.: 291 (1854).

Vernacular names Malaysia: bintangor kuning (Peninsular). Thailand: tanghon (Narathiwat, Surat Thani). Vietnam: c[oof]ng v[aar]y [oos]c.

Distribution The Andaman Islands, Cambodia, Vietnam, Thailand, Peninsular Malaysia, Singapore, Sumatra, the Riau Archipelago, Bangka, Belitung, Bawean Island, Karimoendjawa and Borneo.

Uses The timber is used as bintangor. The fruit is edible.

Observations A shrub to medium-sized tree up to 20 m tall (perhaps sometimes very large, up to 40 m), with bole up to 40 cm in diameter, without buttresses but occasionally having stilt roots; twigs usually strongly 4-angled, terminal bud plump, 1.5–4 mm long; leaves elliptical to obovate, (2–)3.5–14 cm long, cuneate at base, rounded, acute or acuminate at apex, with (4–)5–14(–17) veins per 5 mm; inflorescences usually axillary, unbranched, 3–11-flowered; flowers with 4 or 8 tepals (rarely 5–7 or 10); fruit ellipsoid to spherical, 6.5–16 mm long, with thin outer layer having large air spaces under the skin, yellowish, reddish-yellow or bluish-green. Var. *tetrapterum* (synonyms: *C. floribundum* Hook.f. p.p., *C. praineanum* King, *C. venustum* King) occurs throughout the range, usually in well-drained mixed dipterocarp forest up to 1000 m altitude, and var. *obovale* (Miq.) P.F. Stevens (synonyms: *C. obovale* Miq., *C. griffithii* T. Anderson) occurs scattered in Peninsular Malaysia, Sumatra and Borneo, in the same habitats.

Selected sources 33, 44, 102, 648, 779.

Calophyllum teysmannii Miq.

Fl. Ind. Bat., Suppl. 1(3): 499 (1861).

Vernacular names Malaysia: bintangor batu (Peninsular). Thailand: yakang (Nara).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, the Riau Archipelago and Borneo.

Uses The timber is used as bintangor, e.g. in construction.

Observations A medium-sized to large tree up to 40 m tall with bole up to 95 cm in diameter, often with spurs or small buttresses; twigs 2-, 4-, or 6-angled or rounded, terminal bud plump to conical, (2–)3.5–9.5(–12.5) mm long; leaves usually obovate, (2–)3–14 cm long, usually cuneate at base, retuse at apex, with (4–)6–12(–21) veins per 5 mm; inflorescences axillary, usually unbranched, 3–11-flowered; flowers with 4–8 tepals; fruit spherical to ellipsoid, 17–37 mm long, with fairly thick, compact and hard outer layer, greenish. Two varieties occur throughout the range of the species: var. *teysmannii* (synonym: *C. inophylloide* King var. *singapurense* M.R. Henderson & Wyatt-Smith) growing in peat swamps, mixed dipterocarp forest, kerangas forest and on ridges in lower montane forest up to 1200 m altitude, and var. *inophylloide* (King) P.F. Stevens (synonym: *C. inophylloide* King) usually growing in well-drained lowland to lower montane mixed dipterocarp forest up to 1400 m altitude. The wood is rather heavy and hard. The bark often resembles mengkulang (*Heritiera* spp.).

Selected sources 33, 102, 648, 779.

Calophyllum venulosum Zoll.

Syst. Verz. 2: 149 (1854).

Synonyms *Calophyllum javanicum* Miq. (1854).

Vernacular names Indonesia: ki sapilan (Sundanese, Java).

Distribution Peninsular Malaysia, Sumatra, West Java, Borneo and the Philippines (Mindanao, Basilan).

Uses The timber is used as bintangor. It is used for oars.

Observations A small to large tree up to 45 m tall with bole up to 80 cm in diameter, without buttresses, but sometimes shortly spurred; twigs usually 6-angled, terminal bud plump, 3–13 mm long; leaves elliptical, ovate, suboblong or obovate, 4–23.5 cm long, auriculate, cordate or rounded at base, acute to rounded at apex, with 4–10 veins per 5 mm; inflorescences usually axillary, unbranched, (1–)5(–11)-flowered; flowers with 4 tepals; fruit usually spherical, 12–20 mm long, with thick, compact outer layer, yellowish to brownish. *C. venulosum* usually grows in well-drained mixed dipterocarp forest up to 600(–1500) m altitude, but also frequently along streams. The density of the wood is 570–660 kg/m³ at 15% moisture content.

Selected sources 35, 100, 318, 648, 779.

Calophyllum vexans P.F. Stevens

Austr. Journ. Bot. 22: 407 (1974).

Vernacular names Solomon Islands: kaumanu.

Distribution The Moluccas (Seram), New Guinea, the Bismarck Archipelago, Bougainville and the Solomon Islands.

Uses The timber is traded as 'calophyllum' in Papua New Guinea. The wood is good for veneer, hardboard and paper.

Observations A fairly large, possibly dioecious tree up to 35 m tall with bole up to 60 cm in diameter, sometimes with buttresses or stilt roots; twigs 4-angled, terminal bud strongly flattened to conical, (4–)6–12 mm long; leaves elliptical, trapeziform, oblong, subovate or subobovate, 3.5–12.5 cm long, usually cuneate at base, acute at apex, with (6–)8–11(–16) veins per 5 mm; inflorescences usually axillary, unbranched, 3–5-flowered; flowers with 4–8 tepals; fruit spherical to ovoid-ellipsoid, 18–27 mm long, with fairly thick, compact outer layer, greenish. *C. vexans* usually occurs in well-drained or sometimes swampy forest up to 900(–1450) m altitude.

Selected sources 648.

Calophyllum wallichianum Planchon & Triana

Ann. Sci. Nat. Bot. 4, 15: 277 (1862).

Vernacular names Malaysia: bintangor lilin (Peninsular).

Distribution Peninsular Malaysia, Singapore, the Riau Archipelago, Sumatra and northern Borneo (Sarawak, Sabah, East Kalimantan); possibly also in North Sulawesi.

Uses The timber is used as bintangor.

Observations A medium-sized to fairly large tree up to 36 m tall with bole up to 160 cm in diameter, usually without buttresses; twigs obscurely to strongly 4-angled, terminal bud plump to conical, (12–)16–30 mm long; leaves oblong to ovate, (5–)8–25(–32.5) cm long, rounded to cuneate at base, usually acute at apex, with (8–)10–17 veins per 5 mm; inflorescences axillary, usually unbranched, 7–15(–19)-flowered; flowers with 4 tepals (rarely 6); fruit ellipsoid, (ob)ovoid or spherical, 20–30(–35) mm long, with fairly thick, compact outer layer, orange or dull yellow-green. Two varieties are distinguished: var. *wallichianum* occurs in north-western Peninsular Malaysia up to 900 m altitude, and var. *incrassatum* (M.R. Henderson & Wyatt-Smith) P.F. Stevens (synonym: *C. incrassatum* M.R. Henderson & Wyatt-Smith) occurs in eastern Peninsular Malaysia to Sumatra and Borneo. Much of the information in the literature under *C. wallichianum* refers to *C. rufigemmatum*.

Selected sources 33, 648, 779.

Calophyllum woodii P.F. Stevens

Journ. Arn. Arb. 61: 378 (1980).

Distribution Borneo.

Uses The timber is possibly used as bintangor.

Observations A medium-sized tree up to 30 m tall with bole up to 80 cm in diameter, without buttresses; twigs rounded or 4-angled, terminal bud plump to subconical, 6–12(–17) mm long; leaves elliptical to oblong, 9–22.5 cm long, cuneate to rounded at base, subrounded to acuminate at apex, with (6–)8–16(–20) veins per 5 mm; inflorescences axillary, unbranched, 7–11-flowered; flowers with 4(–5) tepals; fruit subspherical to ellipsoid, 13–20 mm long, with thick outer layer, compact but having air spaces under the skin, greenish to pale cream. *C. woodii* usually grows in well-drained mixed dipterocarp forest, sometimes in swamps, up to 850 m altitude.

Selected sources 648.

S.C. Lim (general part, properties, wood anatomy),
R.H.M.J. Lemmens (selection of species)

Campnosperma Thwaites

Hooker's Journ. Bot. Kew Gard. Misc. 6: 65 (1854).

ANACARDIACEAE

x = unknown

Trade groups Terentang: lightweight timbers, *Campnosperma auriculatum* (Blume) Hook.f., *C. brevipetiolatum* Volkens, *C. coriaceum* (Jack) Hallier f. ex v. Steenis, *C. montanum* Lauterb. and *C. squamatum* Ridley.

Vernacular names Terentang: oreywood, cedrol (En). Indonesia: pauh lebi, tumbus (Sumatra). Malaysia: kelinting, melumut, serentang. Papua New Guinea: campnosperma. Thailand: nangpron (peninsular), huasum (Trang), sangtrang (Nakhon Si Thammarat).

Origin and geographic distribution *Campnosperma*, comprising about 10 species, is distributed over a very large area including South and Central America, Madagascar (1 species), the Seychelles (1 species), Sri Lanka, the whole of South-East Asia, Micronesia and Melanesia. In South-East Asia 5 species occur; *Campnosperma* species are found in Thailand (1 species), Peninsular Malaysia (3 species), Sumatra (2 species), Borneo (3 species), Sulawesi (1 species), the Moluccas (2 species) and New Guinea (3 species). Some species show a western Malesian area of distribution (*C. auriculatum*, *C. squamatum*), others occur in eastern Malesia (*C. brevipetiolatum*, *C. montanum*) or throughout Malesia (*C. coriaceum*). *Campnosperma* is absent from Java and the Lesser Sunda Islands, and also from the Philippines.

Uses Terentang supplies a soft and lightweight timber useful for several purposes for which heavier timbers are unsuitable. It is not durable and thus suitable only for making short-lived items. Terentang timbers are commonly used for making matchboxes and splints; they are easily peeled to make veneer and can be easily folded. The timber is also used for making coffins, cigar and instrument boxes, blackboards, drawing boards, and drawers. In some sawmills the timber is converted into boards for packing crates and other low-grade uses. It provides raw material for the manufacture of chipboard and pulp. The timber is useful for light general purposes such as siding and sheathing, shelving, furniture, turnery and moulding. It can also be used for making artificial limbs and ladies' sandals. It is a substitute for jelutong (*Dyera costulata* (Miq.) Hook.f.) in pencil manufacture but is of inferior quality for this purpose. It is used in plywood manufacture as core material rather than as surface veneers, but in the Solomon Islands it is sometimes applied as fancy veneer. The wood is used commercially in Australia for TV cabinets, paint-grade face veneer and construction veneer in plywood. The timbers exported to Japan are mainly used for making drawers, alcove posts, laminated wood, plywood and packing cases. In Korea, the timbers are found to be suitable for cores of furniture and plywood, packing materials, pulp and particle board. The timber is locally used for making canoes.

It is reported that in Papua New Guinea an oil, called 'tigaso oil', is extracted from the wood. This oil is rubbed on the skin as an antiparasiticum and it is used to alleviate harness sores on horses. It also serves as a body oil for decoration, and as a hair oil. The leaves are sometimes used to pack sago, meat and fish for cooking. The seeds of *C. auriculatum* contain oil which is extracted in Sumatra and used for culinary purposes and as lamp oil.

Production and international trade In Peninsular Malaysia terentang timber is mostly used locally. Only a small volume of graded and ungraded terentang sawn timber was exported from 1980 to 1983, totalling about 475 m^3. The export of terentang sawlogs from Peninsular Malaysia was banned in 1979 (exports of sawlogs of various commercial timbers were banned between 1972 and 1983). The log production in Peninsular Malaysia increased from 12 000 m^3 in 1986 to about 25 000 m^3 in 1989 by an average of 19 000 m^3/year. In this period there was an increase in the consumption of terentang logs by plywood/veneer mills: about 6400 m^3 in 1986 and 10 700 m^3 in 1989. In 1992 9000 m^3 of terentang logs was exported from Sabah with a value of US$ 600 000.

In Papua New Guinea the timber is ranked in MEP (Minimum Export Price) group 4 and fetched a minimum export price of about US$ 43/m^3 for saw logs in 1992. Japan imports terentang timber from Sabah, Sarawak, New Guinea and sometimes in large quantities from the Solomon Islands.

Properties Terentang is a lightweight and soft timber. The heartwood is pink when fresh, becoming grey-pink on exposure, and not distinctly differentiated from the sapwood. The density is (310–)350–500(–600) kg/m^3 (average 435 kg/m^3) at 15% moisture content. The grain is shallowly to deeply interlocked, texture very fine and even.

At 15% moisture content the modulus of rupture is 42–52 N/mm^2, modulus of elasticity 6500–9000 N/mm^2, compression parallel to grain 20–26 N/mm^2, compression perpendicular to grain 2–3 N/mm^2, shear 6–9 N/mm^2, cleavage 18–38 N/mm radial and 18–39 N/mm tangential, and Janka side hardness 1470–1540 N.

The rates of shrinkage of terentang are moderately high; from green to 15% moisture content 1.6–2.1% radial and 3.2–5.5% tangential. Terentang is somewhat liable to stain and should be seasoned as rapidly as possible in well ventilated sheds. Although the timber does not normally split and is not particularly liable to surface checking, stacks of thin boards must be weighted down to prevent splitting and bowing. The timber of *C. auriculatum* dries very fast. Green timber of 25 mm and 30 mm thick (average 85% moisture content) can be air dried in 1 and 2 months respectively. However, the timber of *C. coriaceum* dries much slower and 40 mm thick boards take about 5 months to air dry. Based on its low density and air drying properties, terentang timber can be kiln-dried using red meranti (Malaysian schedule F) or jelutong (schedule H) kiln drying schedules. Terentang shrinks slightly more than the other timbers with similar density such as jelutong (*Dyera costulata*), sesendok (*Endospermum* spp.) and pulai (*Alstonia* spp.).

Despite its lightness, the timber is not particularly easy to saw because of the fibrous nature of the wood and the presence of interlocked grain. It does not severely blunt sawteeth, but they become gummed up with a fine resinous sawdust. Surfaces normally become woolly. However, *C. coriaceum* and *C. brevipetiolatum* are described as easy to saw, cross cut and plane, although the quality of finish is rough to woolly. Suitable clearance and hook angles are required to reduce this problem. Less difficulty is encountered if the timber is green. Extra care is necessary when chiselling because of the soft nature of the wood, but there are no problems in boring. Some difficulty may be encountered in turning and sanding because of the fibrous nature of the wood and the tendency for raised grain. Sometimes, there is a slight though not readily apparent gum exudation from the wood which interferes with sanding. Usually there are no problems in gluing, screwing, painting or varnishing. The timber does not split when nailed and has good nail-holding properties. It can readily be peeled to various thicknesses without pretreatment. Veneer handling is easy, but veneer surfaces may be hairy or fuzzy. Good, smooth veneer can be obtained with a well sharpened knife using a bevel angle of 20°. Gluability of veneer is good.

Terentang is rated as non-durable; stake tests show an average service life in contact with the ground of only 5–6 months under tropical conditions. Under temperate conditions a longer service life is probably possible with proper drying. The timber is susceptible to sap-stain fungal infection. Though quite immune to powder-post beetle, a slight attack to the sapwood may occur. Fresh logs are reportedly susceptible to pinhole borer attack in the Solomon Islands. Terentang is not resistant to termites. It can be easily treated with preservatives and its absorption varies due to the presence of non-distinguishable sapwood.

The main constituent of 'tigaso oil' is campnospermonol. The wood of *C. auriculatum* also contains an oil called 'terentang oil'; it principally contains cyclohexenon derivates, and may be harmful to the human skin. The resin from the wood produces severe skin irritation in some people, similar to the exudate from rengas (*Gluta* and *Melanorrhoea* spp.).

Description Small to large dioecious or polygamous trees (rarely shrubs), up to 50 m tall, but usually less, with bole up to 120(–220) cm in diameter, having small or no buttresses, sometimes with stilt roots, loop roots or pneumatophores when growing in swamps; outer bark smooth, shallowly irregularly fissured, scaly or papery flaky, usually cream, grey or yellowish-brown coloured, sometimes brown to almost black, inner bark usually red or reddish-brown, fibrous; main branches in tiers, with tendency to divide the bole into several large ascending limbs and to flat-topped crowns, twigs usually stout. Leaves arranged spirally, clustered at ends of twigs, leathery, simple and entire, usually with minute scales on both surfaces, petioled or subsessile; stipules absent. Inflorescences axillary, paniculate, sometimes seemingly racemose. Flowers unisexual, rarely bisexual, small and yellowish; calyx (3–)4(–5)-lobed; petals (3–)4(–5), free, imbricate, glabrous but sometimes with scales on outer surface; stamens twice the number of petals, inserted near the margin of a disk, epipetalous ones shorter than episepalous ones, with subulate and glabrous filaments and dorso-basifixed anthers; pistil 1, with a subglobose, 1-celled and scurfy ovary, a short or obscure style and a discoid stigma. Fruit an ovoid or subglobose drupe, incompletely 2-celled by a vertical septum, ripening red to black. Seed 1 per fruit, with testa free from endocarp, curved embryo and rather flat or slightly plano-convex cotyledons.

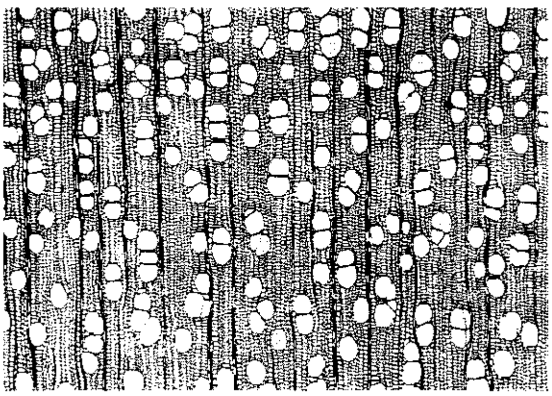
Wood anatomy

– Macroscopic characters:

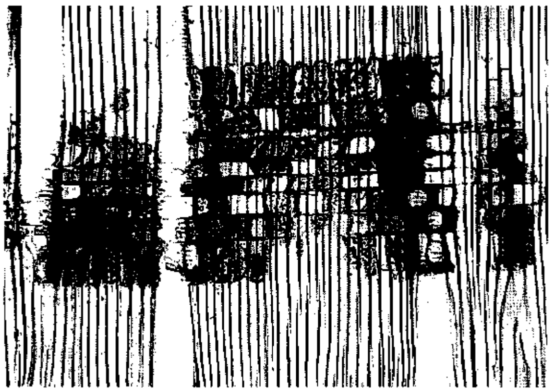
Heartwood grey-pink or mauve-grey, not distinctly differentiated from the sapwood. Sapwood becoming darker grey after long-term exposure. Grain shallowly or deeply interlocked. Texture very fine and even; planed surface without lustre or figure, but longitudinal surface mildly speckled by darker coloured rays. Growth rings absent; vessels small, moderately numerous, tyloses and deposits absent; wood parenchyma not visible with a hand lens; rays very fine or fine, sometimes just visible to the naked eye, comparatively prominent on the radial surface. Ripple marks absent. Large horizontal intercellular canals clearly visible with a hand lens or to the naked eye.

– Microscopic characters:

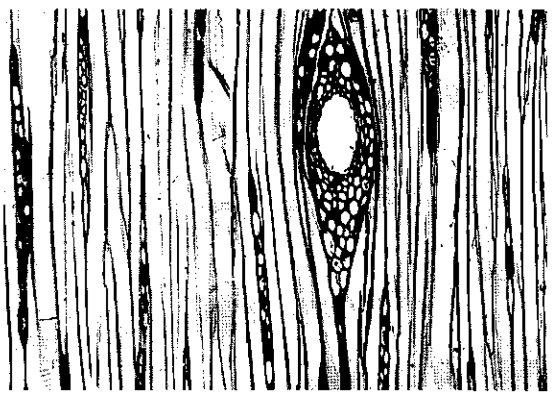
Growth rings absent. Vessels diffuse, 20–36(–40)/



transverse section (×25)



radial section (×75)



tangential section (×75)

Campnosperma auriculatum

mm^2, solitary or in radial pairs and multiples of 3–4, rarely in tangential or oblique pairs or clusters, proportion of solitary vessels very variable, round to oval or slightly angular, average tangential diameter 60–125 μm; perforations mixed simple and scalariform, multiple perforations with 6–36(–48) bars; intervessel pits alternate to opposite, locally sometimes scalariform, polygonal to elongate, 4–6(–10) μm; vessel-ray pits large and simple, horizontally to vertically elongate; tyloses absent or thin-walled and sporadic; deposits absent. Fibres c. 1040–1480 μm long, non-septate and septate, thin-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma extremely rare or absent. Rays 4–11/mm, usually 1–3-seriate, but fusiform rays with radial canals wider, up to 1.0 mm high, heterocellular with 1–2 rows of square to upright marginal cells (Kribs type heterogeneous II to III) or homocellular. Crystals and silica bodies absent. Radial canals present.

Growth and development The trees in the centre of pure stands on peat attain a mean bole diameter of only 25 cm and almost never exceed 40 cm, but towards the margin of the stands trees may attain 80 cm in diameter. Flowering and fruiting of trees are quite regular and frequent, and in many areas terentang has been found flowering throughout the year. The flowers, with their disks producing nectar, are evidently entomophilous. The fruits are eaten by birds, especially pigeons, which disperse the seeds. The fruits of trees growing in swampy forests or near rivers are also dispersed by water.

Other botanical information The genus *Campnosperma* is often placed in the tribe *Rhoeae*, together with the genera *Euroschinus*, *Parishia*, *Pentaspadon*, *Pistacia* and *Rhus*. The leaves on vegetative shoots are usually much larger than those on fertile shoots. The smaller limbs and branchlets of terentang trees have a branching pattern which is very similar to *Terminalia* species. Terentang is sometimes associated with *Terminalia* species (e.g. *Terminalia copelandii* Elmer and *T. brassii* Exell) and these trees look very similar.
In Sri Lanka the timber of *Campnosperma zeylanicum* Thwaites is sometimes used for boxes.

Ecology Terentang is often found in swampy lowland forests where it may form pure stands or be dominant or co-dominant. Sometimes open *Campnosperma* forest, often consisting of trees with sparse crowns and light bark, gives the impression of a forest of dead trees from the air.

Throughout the humid tropical lowland of New Guinea terentang forest grows in permanent, stagnant and non-tidal freshwater swamps with undergrowth of sago (*Metroxylon sagu* Rottb.), pandans (*Pandanus* spp.), *Thoracostachyum* spp., *Scleria* spp. and *Nepenthes* spp., but in areas with lower annual rainfall terentang is replaced by *Melaleuca* spp. as the dominant trees. In terentang forest in New Guinea the soil is inundated up to 1.5 m for at least 5 months per year and at the end of the dry season the water table is nearly at soil level; peat formation occurs regularly. *C. brevipetiolatum* occurs up to 500 m altitude in areas with a uniform rainfall regime (mean annual rainfall 2000–5000 mm) and a mean annual temperature of 23–28°C (mean minimum temperature of coldest month: 20–24°C, mean maximum temperature of hottest month: 28–34°C). It grows on acid, preferably deep soils. It is a strongly light-demanding species.

In western Malesia terentang may also be co-dominant in freshwater swamps, sometimes even forming pure stands (e.g. in Peninsular Malaysia and Sumatra). In addition, terentang occurs in forests on well-drained soil, in primary as well as secondary forest, sometimes up to 1600 m altitude, particularly near streams and in valleys, and usually in low numbers.

Propagation and planting The seeds show a short viability and need no pretreatment for germination. The weight of 1000 seeds of *C. brevipetiolatum* is approximately 400 g. The seedlings reach plantable size in 4 months.

Silviculture and management Terentang demands strong light and regeneration is often abundant in regrowth forests where it has sufficient regeneration to maintain its present abundance.

C. brevipetiolatum has been one of the major species planted in the Solomon Islands, and as such is an important element of the reforestation and afforestation programmes.

Diseases and pests *Ambleypelta cocophaga* causes death or dieback in young trees of *C. brevipetiolatum*.

Harvesting A common defect of the timber is caused by small areas of spongy heart in some logs; sometimes minute compression failures or cross-breaks occur. The logs are liable to split through the pith but other forms of splits or checks and natural defects are uncommon.

Yield The annual production of *C. brevipetiolatum* timber in planted forest in the Solomon Islands is 10–20 m^3/ha.

Genetic resources Outside swampy forests, terentang is not abundant in the forest and averages about one tree of commercial size per 12 ha. More than 2 trees per ha may occur in narrow belts near streams, but terentang might be liable to genetic erosion in these habitats. However, terentang is very common locally in freshwater and peat-swamp forest, and natural regeneration may be plentiful. Here genetic erosion seems to be much less likely.

Prospects Terentang is a useful timber for light utility purposes because of its light weight. It is also a popular timber for peeling in Japan, and it is of interest to the Australian market because it is amenable to preservative treatment and is of low density. Terentang timber is regularly exported from Papua New Guinea and the Solomon Islands. In other countries like Malaysia, the supply is irregular and largely consumed by local industries. However, it may be assumed that in these countries, unlike other lightweight hardwoods such as meranti (from *Shorea* spp.), mersawa (from *Anisoptera* spp.), sepetir (from *Sindora* spp.), nyatoh (from *Madhuca*, *Palaquium*, *Payena* and *Pouteria* spp.) and jelutong (from *Dyera costulata*), terentang is exported under mixed light hardwood, which fetches a much lower price, comparatively. Unless sufficient research is done on, for instance, growth and yield of this timber, the role of terentang on the world market is not expected to increase.

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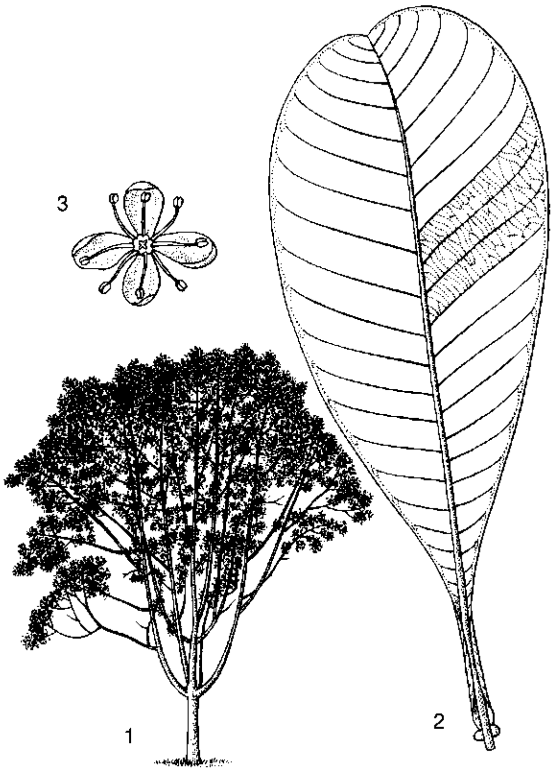
Selection of species

Campnosperma auriculatum (Blume) Hook.f.

Fl. Brit. India 2: 41 (1876).

Synonyms *Campnosperma oxyrhachis* Engl. (1883).

Vernacular names Indonesia: antumbus, madang rimueng (Sumatra), hamtangen (Sampit, Kalimantan). Malaysia: terentang daun besar, napan, serentang (Peninsular). Thailand: nangpron (peninsular), yaang re (Surat Thani), huasum (Trang).



Campnosperma auriculatum (Blume) Hook.f. – 1, habit of young tree; 2, leaf; 3, male flower.

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, Bangka and Borneo.

Uses The timber is used as terentang. The oil extracted from seeds may be used for cooking and as lamp oil.

Observations A medium-sized to fairly large tree up to 38 m tall, with bole up to 80(–135) cm in diameter; leaves obovate to oblanceolate, large (up to 20 cm wide), at base narrowly decurrent and with distinct ear-like lobes, glabrous beneath; flowers in large, profusely branched panicles; fruit with solid septum, dull reddish-purple. *C. auriculatum* is locally co-dominant in freshwater swamps and common to rare in mixed primary and secondary forests up to 1000(–1600) m altitude. In swamp forest this species prefers places inundated regularly by eutrophic water. The density of the wood is about 370 kg/m^3 at 17% moisture content. See also the table on wood properties.

Selected sources 102, 315, 318, 578, 633, 748, 779, 807.

Campnosperma brevipetiolatum Volkens

Bot. Jahrb. Syst. 31: 466 (1902).

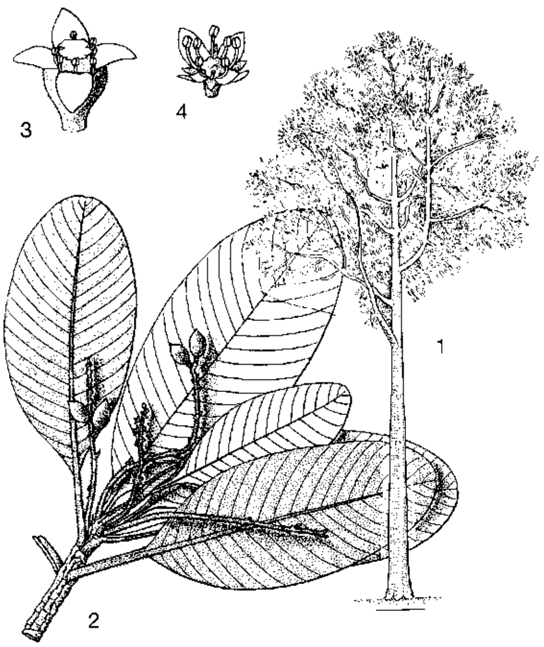
Vernacular names Indonesia: lakuoeng, taniruana (Moluccas), dalipo (Sulawesi).

Distribution Sulawesi, the Moluccas, New Guinea, Melanesia and Micronesia.

Uses The timber is traded as 'campnosperma' for uses similar to terentang from western Malesia; *C. brevipetiolatum* is the most important *Campnosperma* species for timber production in New Guinea.

Observations A large tree up to 50 m tall, with bole up to 120(–220) cm in diameter; leaves oblanceolate, large (up to 17.5 cm wide), at base broadly and gradually decurrent and with ear-like lobes, glabrous beneath except at base; flowers in large, profusely branched panicles; fruit with hollow septum, red to black when ripe. *C. brevipetiolatum* is often dominant in peat and sago swamps, scattered to rare elsewhere except in the Solomon Islands where it may be co-dominant on well-drained soils. It is also planted in the Solomon Islands for reforestation. The density of the wood is 310–420 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 67, 241, 315, 359, 545, 735, 748, 764.



Campnosperma coriaceum (Jack) Hallier f. ex v. Steenis – 1, tree habit; 2, fruiting twig; 3, female flower; 4, male flower.

Campnosperma coriaceum (Jack) Hallier f. ex v. Steenis

Fl. Mal. Bull. No 3: 74 (1948).

Synonyms *Campnosperma griffithii* Marchand (1869), *Campnosperma macrophyllum* (Blume) Hook.f. (1876).

Vernacular names Indonesia: ambacang rawang, meranti lebar daun (Sumatra), terentang malung (Bangka). Malaysia: terentang simpoh, terentang kelintang (Peninsular).

Distribution Peninsular Malaysia, Sumatra, Lingga, Bangka, Borneo and New Guinea.

Uses The timber is used as terentang; it is traded in New Guinea as 'campnosperma'.

Observations A medium-sized to large tree up to 40 m tall, with bole up to 90 cm in diameter, but usually much less, when growing in swamps often with prop roots, loop roots or pneumatophores; leaves elliptical or oblong, rarely obovate, large (up to 19 cm wide), at base acute to cuneate and without ear-like lobes, densely pubescent beneath, rarely glabrescent; flowers in fairly large, profusely branched panicles; fruit with hollow septum, black when ripe. *C. coriaceum* occurs gregariously in peat swamps with oligotrophic water and scattered or rare in mixed forest up to 500(–1000) m altitude.

Selected sources 318, 633, 735, 748, 779, 807.

Campnosperma montanum Lauterb.

Bot. Jahrb. Syst. 56: 359 (1920).

Vernacular names Indonesia: hotong otan (Moluccas), kaauwe (Irian Jaya).

Distribution The Moluccas and New Guinea including the Bismarck Archipelago.

Uses The timber is traded as 'campnosperma' in New Guinea.

Observations A shrub or small to medium-sized tree up to 30 m tall, with bole up to 60 cm in diameter; leaves elliptical-lanceolate or obovate-oblong, comparatively small (up to 9 cm wide on fertile twigs, but much larger on vegetative twigs), at base gradually decurrent and without ear-like lobes (but these rarely (obscurely) present on vegetative twigs), initially pubescent beneath but glabrescent; flowers in small, scantly branched panicles; fruit with solid septum, red to black when ripe. *C. montanum* occurs in freshwater swamps as well as in well-drained lowland and submontane forest up to 1500 m altitude. In New Guinea it is found in mixed forest together with *Lithocarpus*, *Nothofagus* and *Agathis* spp. Locally *C. montanum* is fairly common.

Selected sources 735, 748.

Campnosperma squamatum Ridley

Kew Bull.: 197 (1933).

Synonyms *Campnosperma minor* Corner (1939).

Vernacular names Malaysia: terentang daun kecil (Peninsular), terentang puteh, kayu mansan (Sarawak).

Distribution Peninsular Malaysia, Singapore and Borneo.

Uses The timber is used as terentang.

Observations A medium-sized tree up to 30 m tall, with bole up to 60 cm in diameter, rarely stilt roots present; leaves elliptical, obovate, oblanceolate or spatulate, comparatively small (up to 8(–11) cm wide), at base decurrent but ending abruptly and slightly increasing in size but without distinct ear-like lobes, usually glabrous on both sides; flowers in small to fairly large, scantly branched panicles; fruit with hollow septum, green speckled white to dark green. *C. squamatum* occurs in swamp forest in the lowland, mixed primary forest on well-drained soil, and in submontane forests up to 1200 m altitude. Locally it is common.

Selected sources 633, 748, 779.

Ani Sulaiman (general part, properties, wood anatomy, selection of species)

Cotylelobium Pierre

Fl. forest. Cochinch. fasc. 15, text accomp. pl. 235 (1890).

DIPTEROCARPACEAE

x = unknown

Trade groups Resak: heavy hardwood, e.g. *Cotylelobium burckii* (Heim) Heim, *C. lanceolatum* Craib and *C. melanoxylon* (Hook.f.) Pierre ex Heim. Resak often includes timber of the genus *Vatica* and sometimes also that of *Upuna*. Timber of *Cotylelobium* spp. is traded in Indonesia under the name 'giam', which may cause confusion because this is the trade name for the heavy wood of *Hopea* spp.

Vernacular names Resak. Brunei: resak batu. Indonesia: giam, resak bukit. Thailand: khiam (general).

Origin and geographic distribution *Cotylelobium* comprises 5 species and occurs in Sri Lanka (2 species), peninsular Thailand (2 species), Peninsular Malaysia (2 species), Sumatra (1 species) and Borneo (3 species). Within Malesia 3 species are recognized.

Uses Resak is used for piling (also in contact with the ground or water), construction of houses (beams, posts, rafters, boards, door and window frames), bridges and ships (keels and ribs), for heavy-duty flooring, turnery, cabinet work and railway sleepers. Less heavy resak timber is also used for furniture, package, pallets and as a substitute for keruing (*Dipterocarpus* spp.), e.g. in Japan. Resak timber of *Cotylelobium* spp. has a high silica content (timber of *Vatica* spp. lacks any silica) which makes it especially suitable for salt-water piling and shipbuilding.

The resin may occasionally be used for caulking boats and for illumination but is of no commercial importance. An extract from the bark is used locally to prevent frothing during the boiling of sap of the sugar palm for sugar manufacture, and to arrest fermentation of toddy and local wine.

Production and international trade The timber is traded together with timber of *Vatica* spp. as resak, particularly on local markets. As *Cotylelobium* trees are often larger, they are considered more valuable for their timber than *Vatica* trees. The export of resak logs from Sabah was 13 000 m^3 in 1992, and of sawn timber 5700 m^3; the total value was US$ 2.4 million.

Properties Resak is a heavy and hard timber. The heartwood is yellowish-brown to reddish-brown when fresh, darkening to dark brown on exposure. When the wood is fresh, the sapwood is clearly differentiated from the heartwood and is light yellowish-brown; when dry it can be less sharply defined. The density is 810–1160 kg/m^3 at 15% moisture content. The grain is straight or only slightly interlocked, texture fine and even.

At 15% moisture content, the modulus of rupture for *C. melanoxylon* from Indonesia is 133–135 N/mm^2, modulus of elasticity 17 700–18 630 N/mm^2, compression parallel to grain 68–69 N/mm^2, compression perpendicular to grain c. 6 N/mm^2, shear 7–8 N/mm^2, cleavage c. 77 N/mm radial and 82 N/mm tangential, Janka side hardness 8860 N and Janka end hardness 10 200 N.

The rates of shrinkage are high, for *C. melanoxylon* from green to oven dry 6.1% radial and 10.4% tangential. The wood is moderately slow in drying, and there is a slight risk of checking and deformation. Boards of 25 mm thick take about 2.5 months to dry from 35% to 15% moisture content.

Working qualities are rated as moderately easy to moderately difficult. Sawing is usually rather easy, although silica is present. Planing and boring is easy and has a smooth finish; turning is slightly difficult.

The wood is very durable and is resistant to termites and teredos. It is very difficult to treat with preservatives, but for most applications treatment is not required.

Wood of *C. burckii* contains 52% cellulose, 31.5% lignin, 7% pentosan, 0.3% ash and 0.1–0.2% silica; wood of *C. melanoxylon* contains up to 0.4% silica. The solubility of *C. burckii* wood is 3.4% in alcohol-benzene, 2.8% in cold water and 3.7% in hot water. Charcoal made from *Cotylelobium* wood has an energy value of over 29 000 kJ/kg.

Description Small, medium-sized or large trees, up to 50 m tall, bole frequently twisted, sometimes cylindrical and straight, branchless for up to 30 m but often forked at lower height and up to 160(–200) cm in diameter, buttresses small and rounded; outer bark thin, brittle, smooth at first and hoop-marked, greyish, becoming irregularly flaky, leaving a dippled or scroll-marked surface, inner bark about 1.5 cm thick, often separated from the outer by a red line, pinkish to pale yellow, with prominent bast fibres, resinous; crown hemispherical, rather small; twigs often densely stellate hairy or with short tufted hairs. Leaves alternate, simple and entire, leathery, margin revolute, lower surface scaly; midrib sunken or not prominent above, slightly prominent beneath, secondary veins parallel, bifurcating and anastomosing towards the margin to form a looped intramarginal vein; tertiary venation reticulate; petiole comparatively short, straight; stipules often early caducous. Inflorescence axillary or terminal, racemose, usually short. Flowers bisexual, actinomorphic, 5-merous, lanceolate in bud, sweet smelling; sepals imbricate, free, subequal, densely hairy; petals free, elliptical-oblong, cream to pink; stamens 15, subequal, in 3 whorls, filaments short, more or less triangular, anthers 4-celled, the inner cells smaller than the outer, oblong, setose along the margins, with a short, subulate appendage; ovary superior, free from the calyx, globose, without a stylopodium, densely tomentose, style 1, slender, more than 3 times as long as the ovary, tomentose towards the base, stigma small, trifid. Fruit a 1-seeded, globose nut; fruit calyx lobes free almost to the base, all distinctly enlarged, 2 of them obtuse and larger than the other 3 acute ones. Seedlings with the first pair of leaves opposite, succeeding leaves arranged spirally.

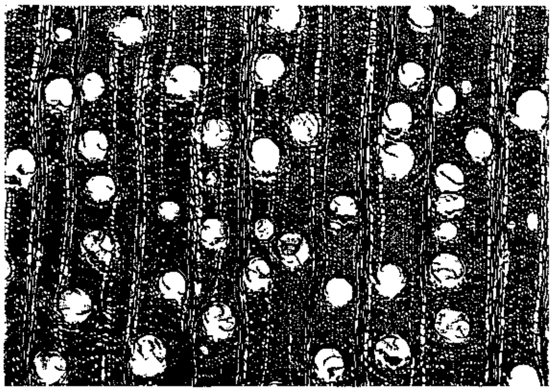
Wood anatomy

- Macroscopic characters:

Heartwood red-brown, darkening on exposure to darker brown, clearly demarcated from the pale yellow-brown sapwood. Grain straight to shallowly interlocked, producing a ribbon or silver figure. Texture fine and even. Growth rings indistinct; vessels just visible to the naked eye, vessel lines conspicuous on longitudinal surfaces; parenchyma moderately abundant, rather indistinct with a hand lens; rays of two sizes, fine- and larger-sized ones, individually distinct to the naked eye on the end grain, not conspicuous on longitudinal surfaces; ripple marks absent. Axial intercellular canals approximately half the size of larger vessels, scattered singly or in pairs, rarely in tangential series, empty or filled with chalky white deposits of dammar.

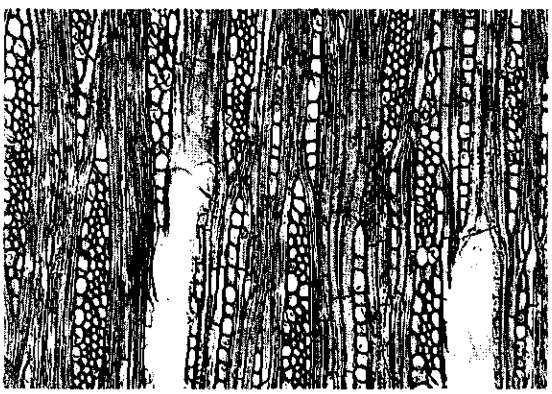
- Microscopic characters:

Growth rings indistinct. Vessels diffuse, 8–10/mm^2 (but c. 20/mm^2 in *C. burckii*), predominantly solitary (95–98%), pairs rare, uniformly distributed and moderately numerous, mostly round, average tangential diameter 120–140 μm; perforation plates simple; intervessel pits rare, loosely alternate when present, vestured, 4–5 μm; vessel-ray pits simple, rounded, with large apertures of c. 20 μm; tyloses abundant. Fibres 1–1.5 mm long, non-septate, thick- to very thick-walled, bordered pits moderately conspicuous, most prominent in *C. melanoxylon*. Parenchyma partially surrounding pores, to aliform with short wings, diffuse, diffuse-in-aggregates, occasionally forming short lines spanning several cells, also surrounding axial intercellular canals. Rays 6–8/mm, uniseriate



transverse section (×25)

radial section (×75)



tangential section (×75)

Cotylelobium melanoxylon

and multiseriate 2–6(–8) cells wide, up to 1(–2) mm high, weakly heterocellular with 1–3 rows of square to upright marginal cells (Kribs type heterogeneous III and II, type heterogeneous I present in *C. burckii*), uniseriates few, short, sheath cells present, prominent in *C. melanoxylon*. Silica grains in ray cells of all species, prismatic crystals in addition to silica in upright cells of *C. melanoxylon*. Horizontal intercellular canals absent. Axial gum canals diffuse, sometimes in pairs, rarely in short tangential arcs, average diameter 50–60 μm, commonly occluded with chalky white deposits.

Species studied: *C. burckii, C. lanceolatum, C. melanoxylon*.

The diffuse axial gum canals distinguish resak (*Cotylelobium* and *Vatica*) from *Dipterocarpus, Dryobalanops, Hopea* and *Shorea*. *Anisoptera* can be distinguished from *Cotylelobium* by larger pores (and by the lower density and distinctive yellowish colour of the wood). *Cotylelobium* is readily separated from *Upuna* and *Vatica* by the presence of silica in ray cells.

Growth and development Resak trees tend to flower periodically and synchronously over wide areas. In seasonal climates, they flower generally in the dry season, e.g. from January to March in Thailand. Fruiting is often prolific and fruits mature about 2 months after flowering. In Thailand mature fruits, which are brown, are present at the beginning of the rainy season (March – June). There, germination of the seeds usually starts with the first rains, either on the ground or already on the mother trees. During the first 3–5 years, the seedlings are stunted and hardly growing in height; they actually increase the girth of the stem. They normally produce shoots during the wet season, but these often die back in the dry season. After about 5 years (or more), when the stem and root system are strong enough, the seedlings will start to grow in height. The trees grow slowly, and it takes a long time to achieve commercial size. In Sarawak *C. melanoxylon* showed an annual diameter increment of 0.2 cm.

Other botanical information The genus *Cotylelobium* is very closely related to *Vatica* especially to its section *Sunaptea* (Griffith) Burck. This close relationship is expressed in characters of the perianth, fruit and wood anatomy. The two taxa differ in their gynoecium, androecium and leaf venation. In *Cotylelobium* the secondary veins of the leaf anastomose to form a distinct intramarginal vein (which is absent in *Vatica*), the anthers are narrower and more hairy, and the style is longer than in *Vatica*. It has been proposed to divide the genus *Vatica* into three different genera and at the same time merge *Cotylelobium* with one of these (*Sunaptea*). *Cotylelobium* belongs to the tribe *Dipterocarpeae* and, although no chromosome counts have been performed, the expected basal number (x) is 11. The Malesian species of *Cotylelobium* differ only in the indumentum, shape and venation of the leaves. They are sometimes difficult to identify because of the occurrence of more or less intermediate specimens.

Ecology *Cotylelobium* species belong to the main and often dominant canopy trees of vegetations on dry acid soils with a pH of 3.7–4.5, especially on coastal hills up to 400 m altitude. They usually occur scattered but are sometimes semi-gregarious in primary dipterocarp forest. They grow on sandy loam soils, giant or regular podzols, peaty soils overlying limestone or sandstone ridges up to 1500 m altitude. In peninsular Thailand they occur in an area with a mean annual rainfall of about 2400 mm, 175 rainy days and a very short or no dry period. The average minimum temperature is 22.2°C, the average maximum temperature 33.7°C.

Propagation and planting Mature fruits should be collected from mother trees. Fruits lying on the ground are mostly damaged by insects. They should be treated with fungicides, bactericides and insecticides. The nuts are soaked in water for one day before being sown in nursery beds. Using this method, a germination rate of 80–95% may be reached. When seeds are kept for more than 3 weeks, the germination rate decreases to 30–40% or less. The nursery beds should be shaded to about 50% of full sunlight. After about 2 weeks seeds will start to germinate. The seedlings are transferred to containers filled with a mixture of 25% black ash and 75% sandy loam and some organic fertilizer when they have reached a height of about 10 cm. Like all dipterocarps the seedlings need mycorrhizal infection for optimal growth. They are ready for planting into the field when they are 1.5–2 years old and have attained a height of about 50 cm and a stem diameter at soil level of about 30 mm. Spacing is 3 m × 3 m or 4 m × 4 m.

Silviculture and management Management systems applied to lowland dipterocarp forest used to have a 30-year rotation. At present the 'selection cum improvement felling system' is applied in peninsular Thailand; the minimum girth for which cutting is allowed under this system is 200 cm at breast height. Since *Cotylelobium* trees

are slow growers, cutting cycles should be long. In the Bako forest, Sarawak, on average 83 saplings and 623 seedlings of *C. melanoxylon* were counted per ha.
Resak trees should be planted under quick growing nurse trees to protect them from strong sunlight and to achieve better growth.

Genetic resources *Cotylelobium* species usually occur scattered in the forest, and although regeneration may be plentiful, it takes a very long time for trees to reach a commercially interesting size. When large-scale logging operations and comparatively short cutting cycles are employed, resak may easily become endangered, except when forest reserves of sufficient size are maintained.

Prospects *Cotylelobium* timber is most valuable, but the very slow growth of the trees and their scattered occurrence in natural forest hampers commercial management and means that the survival of the species is at risk under indiscriminate exploitation without good management. Further research on silvicultural aspects is urgently needed.

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Selection of species

Cotylelobium burckii (Heim) Heim

Rech. Dipt.: 122 (1892).

Synonyms *Cotylelobium flavum* Pierre (1891), *Cotylelobium asperum* v. Slooten (1929), *Sunaptea burckii* (Heim) Kosterm. (1987).

Vernacular names Brunei: resak durian. Indonesia: giam durian, resak bukit tembaga, resak babalok (Kalimantan). Malaysia: resak badang, resak durian, resak penyau (Sarawak).

Distribution Borneo (Kalimantan, Sarawak and Brunei).

Uses The wood is used as resak and is especially suitable for making boats.

Observations A medium-sized to fairly large tree up to 40 m tall, bole frequently crooked, up to 65 cm in diameter; leaves oblong-lanceolate, 8–15 cm × 3–5 cm, margin prominently revolute, lower surface evenly densely ochrous tomentose, the intramarginal vein just within the margin; 2 larger fruit calyx lobes up to 6.5 cm × 1.8 cm. *C. burckii* is locally common on giant podzols or poor sandy soils, often near the coast, and in heath forest at low altitudes. The density of the wood is 865–1160 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 102, 258, 382, 739, 748.

Cotylelobium lanceolatum Craib

Kew Bull.: 113 (1913).

Synonyms *Cotylelobium malayanum* v. Slooten (1932), *Sunaptea lanceolata* (Craib) Kosterm. (1987).

Vernacular names Brunei: resak bukit. Indonesia: giam padi (general), resak gagil, resak daun kecil (East Kalimantan). Malaysia: resak batu, resak bukit (Peninsular), resak kelabu (Sabah, Sarawak). Thailand: mai khiam.

Distribution Peninsular Thailand, Peninsular Malaysia, the Anambas Islands and Borneo.

Uses The timber is used as resak. The bark is used locally to prevent frothing in sweet palm juice and to arrest fermentation of toddy and local wine.

Observations A medium-sized to large tree up to 45 m tall, bole usually short and bent or twisted, up to 125 cm in diameter; leaves narrowly ovate-lanceolate, 6–8 cm × 2.5–3 cm, the margin revolute, the lower surface densely dark grey tomentose, the intramarginal vein at about 2 mm from the margin; 2 larger fruit calyx lobes up to 6.5 cm × 1.8 cm. *C. lanceolatum* is locally abundant on podzolic and sandstone soils or on peat overlying limestone, often in heath forest up to 1500 m altitude. The density of the wood is 810–1160 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 102, 253, 258, 382, 677, 739, 748.

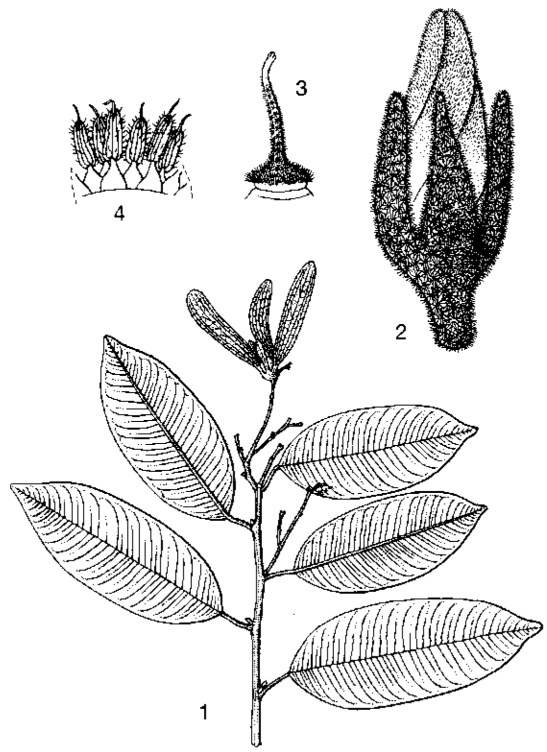
Cotylelobium melanoxylon (Hook.f.) Pierre ex Heim

Rech. Dipt.: 120 (1892).

Synonyms *Cotylelobium beccarii* Pierre (1891), *Cotylelobium harmandii* Heim (1892), *Vatica leucocarpa* Foxw. ex den Berger & Endert (1925).

Vernacular names Brunei: resak hitam. Indonesia: giam tembaga, resak tembaga (general), resak daun lebar (Sumatra). Malaysia: resak (Peninsular), resak hitam (Sarawak), resak tempurong (Sabah). Thailand: khiam daeng, khiam dam, khiam khaao (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and Borneo.



Cotylelobium melanoxylon (Hook.f.) Pierre ex Heim – 1, fruiting twig; 2, flower bud; 3, ovary; 4, stamens.

Uses The timber is used as resak, especially for construction, house posts and boats. The bark is used locally to prevent frothing in sweet palm juice and to arrest fermentation of toddy and local wine.

Observations A medium-sized to large tree up to 50 m tall, bole frequently twisted, branchless for up to 30 m and up to 160 cm in diameter; leaves ovate-lanceolate, 5–10 cm × 2–6 cm, the margin slightly revolute, lower surface glabrescent, the intramarginal vein at about 2 mm from the margin; 2 larger fruit calyx lobes up to 4.5 cm × 1.5 cm. *C. melanoxylon* prefers dry, often sandy or loamy soils and moist podzols, and often occurs near the coast, up to 300 m altitude. The density of the wood is 830–1155 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 258, 382, 425, 450, 462, 578, 628, 677, 739, 748.

C. Niyomdham (general part, selection of species),
W.C. Wong (properties),
J. Ilic (wood anatomy)

Cratoxylum Blume

Verh. Batav. Genootsch. Kunsten 9: 172, 174 (1823).

GUTTIFERAE

x = probably 7; *C. cochinchinense*: $n = 11$, *C. formosum*: $2n = 14$

Trade groups

- Geronggang: lightweight hardwood, e.g. *Cratoxylum arborescens* (Vahl) Blume.
- Derum: medium-weight hardwood, e.g. *C. cochinchinense* (Lour.) Blume, *C. formosum* (Jack) Dyer.

Vernacular names

- Geronggang. Brunei: serungan. Indonesia: gerunggang (general), madang baro (Sumatra), adat (Kalimantan). Malaysia: gonggang (Peninsular, Sarawak), serungan (Sabah). Thailand: kalong-ngae, ngong-ngang (Narathiwat).
- Derum. Brunei: pelawan. Indonesia: mampat (Sumatra), butun (Kalimantan). Malaysia: mempat (Peninsular), entemu (Sarawak), serungan batu (Sabah). Philippines: salinggogon (Pilipino). Laos: tiou-tiou. Thailand: tiu-kliang (northern), tiu-khao (Bangkok). Vietnam: th[af]nh ng[aj]nh.

Origin and geographic distribution *Cratoxylum* comprises 6 species and occurs from eastern India through mainland South-East Asia towards the Malesian area. In Malesia it is encountered in Peninsular Malaysia, Sumatra, Borneo, Java, the Lesser Sunda Islands, Sulawesi and the Philippines.

Uses Geronggang is a non-durable, general-utility timber used for light construction under cover. It is suitable for boards, cladding, shelving, cheap and light flooring and furniture, interior joinery, shelving, shuttering, panelling, mouldings, concrete forms and interior parts of ships. Being light, the wood is especially suited for boxes and other light packing cases. On a local scale geronggang is used for posts, beams, joists and agricultural implements. When impregnated, geronggang wood makes good roofing shingles. It is sometimes used as a substitute for red meranti except for purposes where strength is required and has also been traded mixed with light red meranti. Good-quality particle board, wood-wool cement board and standard-quality hardboard can be manufactured from geronggang. The wood is suitable for the production of pulp.

Derum timber is not commercially exploited due to its scarcity. There is a local demand for the timber for purposes such as poles and local house construction. The wood is sometimes handsomely figured and suitable for turnery, carving and furniture.

Both geronggang and derum wood are favourites for firewood and charcoal manufacture. Sometimes the bark and base of the trunk produces a resinous exudate which is used as a remedy for scabies and leg wounds. A decoction of the bark, roots and leaves has been used against stomachache and fever. The leaves have been chewed as being salutary. Several species are favoured as ornamental trees.

Production and international trade Geronggang is traded in comparatively small amounts. Peninsular Malaysia exports sawn timber, particularly to Singapore. In 1983 5700 m^3 of saw logs was exported, with a value of US$ 260 000, and in 1984 1700 m^3 with a value of US$ 72 000. Sabah exported only 185 m^3 (worth US$ 15 500, US$ 84/m^3) in 1987, but in 1992 the export had increased to 8500 m^3 of logs and 5000 m^3 of sawn timber with a total value of US$ 1.5 million. No export statistics are available from other countries.

Properties Geronggang is a lightweight hardwood. The heartwood is light brick-red to deep pink, gradually darkening on exposure to reddish-brown, distinctly demarcated from the yellow, sometimes pink or orange sapwood. The density is 350–610(–710) kg/m^3 at 15% moisture content. The grain is straight to interlocked, texture moderately coarse but even. Planed surfaces are lustrous, lacking a distinct figure.

At 15% moisture content the modulus of rupture is c. 60 N/mm^2, modulus of elasticity 10 100 N/mm^2, compression parallel to grain 29 N/mm^2, compression perpendicular to grain 3 N/mm^2, shear 4–6 N/mm^2, cleavage 44 N/mm radial and 51 N/mm tangential, Janka side hardness 1750 N and Janka end hardness 2400 N.

The rates of shrinkage are moderate, from green to 15% moisture content 2.2–2.6% radial and 4.2–4.7% tangential. The timber seasons rapidly without significant defects; end checks are the main ones. Boards of 2.5 cm thick take about 2 months to air dry, boards of 4 cm thick slightly longer. In Malaysia kiln schedule E is recommended.

Geronggang is easily sawn in green as well as in air-dry condition. The wood usually contains silica and saws are blunted fairly rapidly. It can be planed to a smooth surface, except on radial surfaces of green wood. The wood is easy to bore and turn, but the quality of finish is rough. Tests on machining properties showed poor results in mortising, shaping and sanding. The wood is easy to nail without splitting and, after some filling, it takes an attractive and smooth polish. Geronggang can be peeled at a 90° peeling angle to produce good veneer, without pretreatment. Gluing with urea-formaldehyde with the addition of 20% wheat flour gives good plywood.

Geronggang is rated as non-durable. Untreated stakes have a service life in contact with the ground of less than one year to 2 years. The wood is susceptible to termite and ambrosia beetle attack. It is easily treated with preservatives using the open tank process. It absorbs 320–480 kg/m^3 of creosote. Laboratory tests indicate, however, that it is difficult to treat with CCA preservative by the full-cell process. Treated wood can be very durable.

Wood of *C. arborescens* contains 53% cellulose, 22% lignin, 18.5% pentosan, 1.0% ash and 0.1% silica. The solubility is 4.1% in alcohol-benzene, 0.7% in cold water, 5.1% in hot water and 14.2% in a 1% NaOH solution. The energy value is 19 900 kJ/kg.

Derum is a moderately heavy hardwood. The heartwood is brown with a purple tinge and is not clearly differentiated from the sapwood. The density is (580–)700–950(–1050) kg/m^3 at 15% moisture content. The grain is straight or interlocked, texture moderately fine and even.

At 15% moisture content, compression parallel to grain is 48 N/mm², compression perpendicular to grain 9.5 N/mm², and shear 14.5 N/mm².

The rates of shrinkage are moderate, from green to 15% moisture content 2.3% radial and 4.6% tangential. Derum seasons fairly slowly but without serious defects. Boards of 15 mm thick take about 3 months to air dry, boards of 40 mm thick 6 months.

Derum is moderately difficult to difficult to resaw; cross cutting is rated as easy to difficult. Planing is fairly easy, producing smooth surfaces.

Logs of *C. formosum* were peeled successfully into 1.6 mm thick veneer in experiments in Malaysia, but with slight difficulty into 3.2 mm thick veneer. The veneer dries at a moderate rate with only slight defects. It was glued with urea-formaldehyde adhesive to produce good-quality plywood; phenol-formaldehyde adhesive is not suitable. The wood is moderately durable in contact with the ground or when exposed to the weather.

Description Deciduous or evergreen trees or shrubs of up to 35(–50) m tall; bole straight or of rather poor shape, branchless for up to 27 m, up to 60(–100) cm in diameter, without buttresses, sometimes slightly fluted at base; bark surface smooth or papery-scaly to fissured, at the base of the stem exuding a yellow or orange to red resinous translucent sap hardening black; crown rather compact and dark; branches compressed, ridged. Leaves simple, opposite or rarely subopposite, decussate, sessile or shortly petioled, often with minute translucent glandular dots; stipules absent. Inflorescence a terminal panicle or axillary raceme or cyme, sometimes flowers single. Flowers bisexual, actinomorphic, 5-merous, sometimes heterodistylous, scented; sepals coriaceous, persistent in fruit, with longitudinal pale or black glandular lines or dots; petals caducous to subpersistent, obovate, deep crimson to pink or white, with red or black glandular dots or lines, sometimes with a scale-like, nectariferous appendage at the base; stamens in 3 bundles, with numerous, dorsifixed, crimson to white anthers and alternating with 3 staminodial scales, filaments slender, united for over half their length; ovary superior, incompletely 3-celled, styles 3, free, slender, glabrous, with small, capitate stigmas; ovules 4 or more on the basal half of each placenta. Fruit a more or less woody, 3-valved, dehiscent capsule, the columella-like placenta persistent at base and becoming woody, septa attached to the columella at base, free in the distal part. Seed imbricate, cylindrical to ovoid, winged unilaterally or all around. Seedling with epigeal germination.

Wood anatomy

– Macroscopic characters:

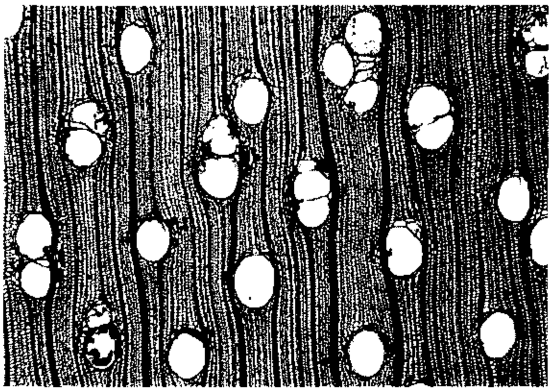
Geronggang: heartwood light brick-red to dark pink when fresh, darkening on exposure to medium brown with a reddish tinge, generally distinct from the yellowish sapwood. Grain generally straight, sometimes interlocked. Texture moderately coarse but uniform. Growth rings indistinct or absent; vessels visible to the naked eye, tyloses common to infrequent, visible with hand lens; parenchyma not visible with hand lens; rays not visible to the naked eye, barely distinct with hand lens. Ripple marks absent.

Derum: heartwood light brown to medium brown, sometimes with a purple tinge, but rarely with red or pink highlights, not distinct from the sapwood. Grain generally straight, sometimes interlocked. Texture moderately fine and uniform. Growth rings indistinct or absent; vessels not visible to the naked eye, tyloses generally absent; apotracheal banded parenchyma abundant and distinct with hand lens; rays not visible to the naked eye, barely distinct with hand lens. Ripple marks absent.

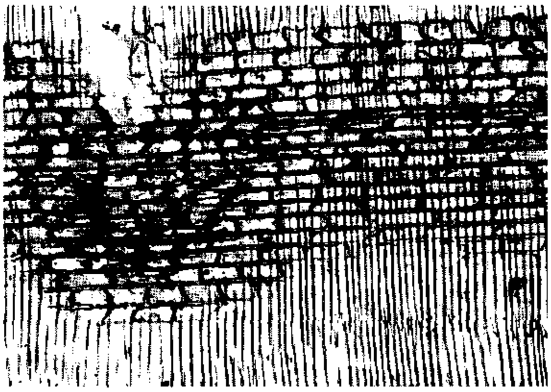
– Microscopic characters:

Geronggang: growth rings indistinct or absent. Vessels diffuse, 7–10/mm², occasionally in diagonal pattern, but mostly in short radial multiples (sometimes in radial multiples of 4 or more and then a large vessel is aligned with several abnormally small vessels), 100–200 μm in diameter; perforation plates simple; intervessel pits alternate, circular to oval, non-vestured, 4–6(–8) μm; vessel-ray pits similar but half-bordered; tyloses common to infrequent. Vasicentric or vascular tracheids absent or rare. Fibres 1–1.4 mm long, non-septate, thin- to thick-walled, pits simple to minutely bordered. Axial parenchyma scanty, paratracheal to vasicentric, locally aliform, in some specimens continuous tangential bands sporadically present; mostly 8 cells per parenchyma strand. Rays 6–10/mm, 300–600 μm in height, homocellular to heterocellular, with one row of upright and/or square marginal cells, (1–)2–3(–4) cells wide; storied structure absent. Crystals absent. Silica bodies present in procumbent and upright ray cells.

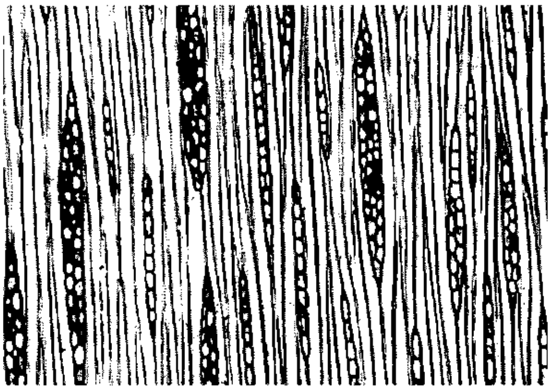
Derum: growth rings indistinct or absent. Vessels diffuse, 15–35/mm², mostly in short radial multiples, 90–120 μm in diameter; perforation plates simple; intervessel pits alternate, circular to oval, non-vestured, 4–6 μm in diameter; vessel-ray pits similar to intervessel pits but half-bordered; tyloses, if present, not common. Vasicentric or vascular tracheids absent or rare. Fibres 1–1.4 mm long,



transverse section (×25)

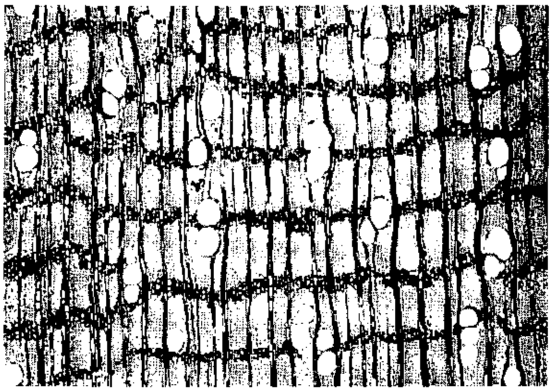


radial section (×75)



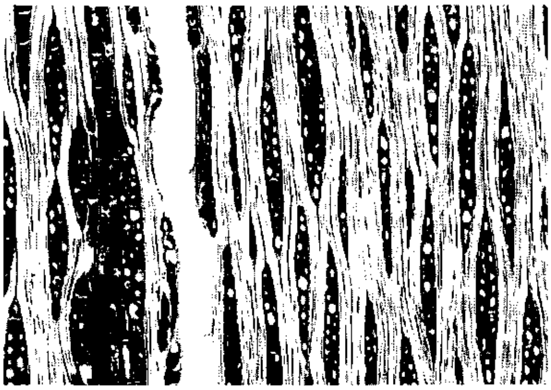
tangential section (×75)

Cratoxylum arborescens (geronggang)



transverse section (×25)

radial section (×75)



tangential section (×75)

Cratoxylum formosum (derum)

non-septate, thin- to thick-walled, pits simple to minutely bordered. Axial parenchyma banded in wide to narrow bands (generally 2–5 cells wide), bands sometimes interconnecting and forming a slightly wavy or irregular pattern; mostly 8 cells per parenchyma strand. Rays 11–15/mm, 300–600 μm in height, homocellular to heterocellular, with one row of upright and/or square marginal cells, mostly 2–3 cells wide (1–2 cells wide in some samples of *C. sumatranum*); storied structure absent. Crystals absent. Silica bodies present in procumbent and upright ray cells.
Species studied: geronggang: *C. arborescens*; derum: *C. cochinchinense*, *C. formosum*, *C. sumatranum*.

Growth and development Little information is available on growth rates, but geronggang trees are fast growers. Mean annual diameter increments of 1.3 cm are reported in young trees. Trees are believed to reach timber size in about 60 years.
C. formosum can be easily recognized when in blossom, because the crown is then more or less leafless and the twigs appear to flush red as the buds open and subsequently carry pink flowers. Most species are heterodistylous: long-styled plants with long stamens and small pollen grains, and short-styled plants with long stamens and large pollen grains. Stamens seem not to be heteromorphic but those of the long-styled flower type curve when the flowers open, which brings the anthers to the same height as the styles of the short-styled flowers. Stigmas of long-styled plants receive much more pollen than stigmas of short-styled plants. Nectariferous petal appendages are present in heterodistylous species and the flowers are pollinated by bees (e.g. *Apis* spp.); these species show a trend towards specialized insect pollination. The wing-like expansion of the testa of the seed may promote dispersal by wind.

Other botanical information The genus *Cratoxylum* belongs to the tribe *Cratoxyleae* together with two other genera from Madagascar and North America. It is most closely related to the Madagascan genus *Eliea*, as evidenced by features of the wood anatomy. *Cratoxylum* is divided into three sections. This botanical subdivision coincides with the two trade groups recognized. Geronggang wood originates from the two species of the section *Isopterygium* Engler which is characterized by the presence of a wing all around the seed. The two other sections (*Cratoxylum* and *Tridesmos* (Choisy) Dyer) with unilaterally winged seeds, provide derum wood.

Ecology Geronggang characteristically occurs in freshwater or peat-swamp forest on sandy or sandy-loamy soils, and sometimes in coastal dipterocarp swamp forest. It generally appears scattered but is sometimes locally abundant and can even become dominant. Geronggang is found in areas without a pronounced dry season (A and B rainfall types) from sea-level up to 900 m, in Sabah up to 1800 m altitude. It is often found in areas with shifting cultivation or other more secondary habitats. In Sabah it is found associated with palawan (*Tristania* spp.) and *Weinmannia blumei* Planchon. In Sumatra the main associated species are pulai (*Alstonia scholaris* (L.) R.Br.), terentang (*Campnosperma* spp.) and perupok (*Lophopetalum* spp.).
Derum is generally found in drier sites than geronggang, such as open woodland or well-drained sites on a wide variety of soils. It occurs in both primary and secondary forests and sometimes in thickets or grassland. Derum has been encountered in heath forest and on limestone hills as well as along rivers and in hill forest from sea-level up to 1200 m altitude.

Silviculture and management Natural regeneration of geronggang is usually scarce but is often abundant in gaps in the forest. Enrichment planting with nursery-raised seedlings on an experimental scale in Indonesia showed good results in swamp forests. Planting strips are usually spaced 6 m apart and the spacing within the strips is 2 m. Fellings may result in an increase of geronggang in swampy areas.

Harvesting In swamp forest in Indonesia geronggang trees of over 40 cm in diameter are harvested. It is advisable to remove geronggang logs from the felling area as soon as possible; they should be sawn quickly. The logs are susceptible to fungal and insect attack and they tend to split. Geronggang logs float in water and can be transported by river. Geronggang is easy to treat with preservatives.

Genetic resources Most geronggang and derum species occur commonly and widespread and are not readily liable to genetic erosion, but some of them (e.g. *C. maingayi*) are rare and may become endangered.

Prospects Geronggang trees often occur abundantly in secondary forest (after felling), they grow rapidly, and the wood is comparatively easy to impregnate. These features extend the possibilities for this tree's application and may prove profitable in the future. However, more research is needed on growth, propagation and silviculture.

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Selection of species

Cratoxylum arborescens (Vahl) Blume

Mus. Bot. Lugd.-Bat. 2: 17 (1852).

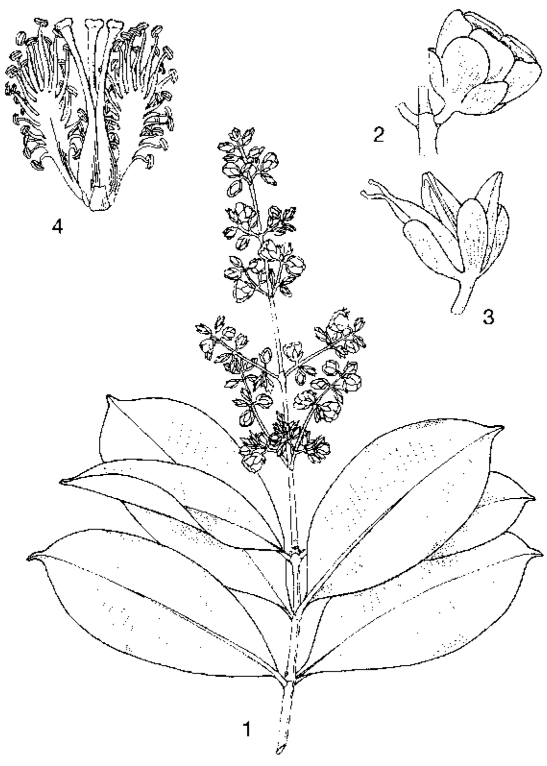
Synonyms *Cratoxylum cuneatum* Miq. (1859), *Cratoxylum arborescens* (Vahl) Blume var. *miquelii* King (1890).

Vernacular names Brunei: gerunggang. Indonesia: geronggang (general), lede (northern Sumatra), gerunggang (Kalimantan). Malaysia: geronggang (general), serungan (Sabah).

Distribution Southern Burma, Peninsular Malaysia, Sumatra and Borneo.

Uses *C. arborescens* is the most important source of geronggang timber.

Observations A medium-sized to large, evergreen tree of up to 50 m tall, bole up to 65(–85) cm in diameter, bark surface fissured or fissured and papery scaly, brown to grey-brown or yellow-brown, inner bark laminated, pink to orange; leaves 2–4 times as long as broad, 5–16 cm × 2–6 cm, with an acute to cuspidate apex, sometimes scarcely glaucous beneath, secondary veins united at the margin to form an intramarginal vein; inflorescence terminal; flowers homostylous, petals red or rarely orange or white, with a fimbriate nectary appendage; seeds 10–18 per locule, winged all around. *C. arborescens* occurs scattered but is sometimes dominant and gregarious in coastal swamp forest up to 900(–1800) m altitude. The density of the wood is 350–610(–710) kg/m^3 at 15% moisture content. See also the table on wood properties.



Cratoxylum arborescens (Vahl) Blume – 1, flowering twig; 2, flower; 3, dehisced fruit; 4, pistil and two staminodial fascicles.

Selected sources 24, 33, 89, 100, 144, 146, 159, 276, 359, 461, 690, 692, 696, 748, 779, 807.

Cratoxylum cochinchinense (Lour.) Blume

Mus. Bot. Lugd.-Bat. 2: 17 (1852).

Synonyms *Cratoxylum polyanthum* Korth. (1842), *Cratoxylum ligustrinum* (Spach) Blume (1852), *Cratoxylum hypoleuca* Elmer (1913).

Vernacular names Brunei: baduk-baduk, mogizon, pelawan-pelawan. Indonesia: kayu lulus, lelulus (Sumatra), mara jalang (West Kalimantan). Malaysia: derum selunchor (Peninsular), geronggang bogoi (Sabah), patok tilan (Iban, Sarawak). Laos: tiou-tiou 'luang. Thailand: kui-chongbaang (Lampang), tiu kliang, tiu bai lueam (northern). Vietnam: th[af]nh ng[aj]nh nam.

Distribution From Burma and southern China towards Peninsular Malaysia, Sumatra, Borneo and Palawan (the Philippines); the presence in southern India is probably due to an introduction.

Uses The timber is used as derum if trees of sufficient size can be found. Sometimes grown as an ornamental.

Observations A small to medium-sized, deciduous tree of up to 33 m tall, bole often of poor shape, sometimes fluted at the base, up to 55 cm in diameter, bark surface smooth, peeling off in angular pieces or long strips with age, light brown to yellowish-brown, inner bark light green to greenish-yellow; leaves elliptical to ovate-lanceolate or lanceolate, 3–10.5 cm × 1–4 cm, with an obtuse to acutely acuminate apex, glaucous beneath; inflorescence consisting of small 1–5-flowered terminal or axillary cymes; flowers heterodistylous, petals dark red to pink or orange, without a nectary scale; seeds (5–)6–8 per locule, unilaterally winged. *C. cochinchinense* is locally common in both primary and secondary forest, as well as in open woodland and grassland. It is often found along water courses and sometimes in peat swamps up to 750 m altitude (up to 1200 m in China). The correctness of the inclusion of *C. ligustrinum* (Spach) Blume in the present taxon is sometimes questioned. The density of the wood is 790–1000 kg/m^3 at 15% moisture content.

Selected sources 33, 89, 100, 146, 153, 276, 430, 571, 748, 779, 807.

Cratoxylum formosum (Jack) Dyer

Hook.f., Fl. Brit. India 1: 258 (1874).

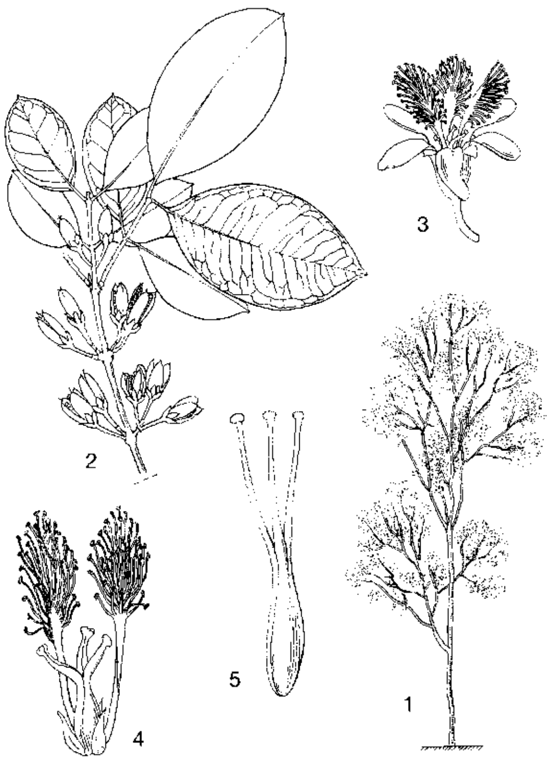
Synonyms *Tridesmis ochnoides* Spach (1836), *Tridesmis formosa* (Jack) Korth. (1843), *Cratoxylum pentadelphum* Turcz. (1863).

Vernacular names Brunei: pelawan. Indonesia: kemutul (Sumatra), mulun, kasat baku (Kalimantan). Malaysia: derum (Peninsular), geronggang biabas (Sabah), entemu (Sarawak). Philippines: salinggogon (general, Pilipino), mangogong, marangguub (Palawan). Laos: tiou-tiou 'som-som. Thailand: tiu khao (Bangkok), tiu som (Nakhon Ratchasima), muu-to (peninsular). Vietnam: th[af]nh ng[aj]nh d[ej]p.

Distribution Burma, southern China, southern Vietnam, Cambodia, southern Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi and the Philippines.

Uses The timber is used as derum; the wood is also used for firewood and charcoal. *C. formosum* is sometimes planted as an ornamental.

Observations A medium-sized to large tree of up to 45 m tall, bole slightly fluted and spiny at base, up to 65 cm in diameter, bark surface papery scaly, grey-brown to red-brown or purplish, inner bark yellow to yellow-brown; leaves elliptical or lanceolate to ovate or obovate, 3–17 cm × 1–8 cm, with an acute or shortly acuminate to rounded apex, sometimes glaucous beneath; inflorescence consisting of small 1–6-flowered cymes in the lower axils of shoots or apparently axillary on older branches; flowers heterodistylous, petals white or pink to red or rarely purplish, with an entire nectary scale at base; seeds (7–)12–17 per locule, unilaterally winged. *C. formosum* occurs in primary to old secondary forest and sometimes in savanna, along streams, along mangrove swamps, in peat-swamp forest and on hill slopes on sand or clay



Cratoxylum formosum (Jack) Dyer – 1, habit of young tree; 2, fruiting twig; 3, flower; 4, pistil of short-styled flower and two staminodial fascicles; 5, pistil of long-styled flower.

soils up to 600(–1200) m altitude. It is divided into two subspecies: subsp. *pruniflorum* (Kurz) Gogelein (synonym: *C. pruniflorum* Kurz) occurs in mainland South-East Asia and differs from subsp. *formosum* in having pubescent twigs, pedicels and calyces. The density of the wood is 700–1050 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 33, 61, 89, 100, 146, 175, 276, 422, 430, 512, 748, 779, 789, 807.

Cratoxylum glaucum Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 176 (1842).

Synonyms *Cratoxylum microphyllum* Miq. (1861), *Cratoxylum polystachyum* Turcz. (1863), *Cratoxylum procerum* Diels (1926).

Vernacular names Brunei: serongan. Indonesia: edat (Bangka, West Kalimantan), kayu longgang (West Kalimantan), geronggang (East Kalimantan). Malaysia: geronggang puteh (Sarawak).

Distribution Southern Peninsular Malaysia, the eastern Sumatran islands and Borneo.

Uses The timber is used as geronggang.

Observations A shrub or small tree of up to 25 m tall, bole up to 50 cm in diameter; leaves elliptical, 2–10 cm × 1–5 cm, with an acute or obtuse or sometimes rounded apex having a black mucro, densely greyish to orange-yellow papillose glaucous beneath; inflorescence a terminal, few- to many-flowered, cylindrical panicle; flowers homostylous, petals deep red to crimson, with a small, shallowly denticulate nectary scale at the base; seeds (4–)6–8 per locule, winged all around. *C. glaucum* occurs generally on acid soils, in freshwater or peat-swamp forest, in heath forest on podzolized soils. It occurs scattered but locally dominant and sometimes in almost pure stands, from sea-level up to 200(–1000) m altitude.

Selected sources 24, 89, 276, 354, 748, 779.

Cratoxylum maingayi Dyer

Hook.f., Fl. Brit. India 1: 258 (1874).

Synonyms *Cratoxylum acuminatum* Merr. (1938), *Cratoxylum subglaucum* Merr. (1938), *Cratoxylum thorelii* Pierre ex Gagnep. (1943).

Vernacular names Indonesia: semapat (western Sumatra), pematang (Palembang), kayu bonbon (Asahan). Malaysia: derum, derum bukit (Peninsular), entemu (Sarawak). Thailand: taeo (Nakhon Si Thammarat), taeo kha (Yala).

Distribution Scattered in Burma, Cambodia, Thailand, central Vietnam, Peninsular Malaysia, Sumatra and Borneo (Sarawak).

Uses The timber is used as derum.

Observations A small to medium-sized deciduous tree of up to 20(–35) m tall, bole often of poor shape, up to 55 cm in diameter, bark surface smooth to narrowly fissured with small scales, pale grey to yellow-brown; leaves elliptical to oblong or obovate, 2–9 cm × 1–4.5 cm, with a shortly acuminate to rounded apex, not glaucous beneath; inflorescence consisting of small 1–4-flowered axillary cymes; petals white to pink, with a truncate, undulate-denticulate nectary scale at the base; seeds 4–6 per locule, unilaterally winged. In general *C. maingayi* is rather uncommon, occurring in lowland forest on hillsides and ridges, sometimes on limestone up to 800 m altitude.

Selected sources 33, 89, 276, 430, 748, 779, 807.

Cratoxylum sumatranum (Jack) Blume

Mus. Bot. Lugd.-Bat. 2: 16 (1852).

Synonyms *Cratoxylum celebicum* Blume (1852), *Cratoxylum clandestinum* Blume (1852), *Cratoxylum racemosum* Blume (1852), *Cratoxylum hypericinum* (Blume) Merr. (1921).

Vernacular names Brunei: laka-laka, serungan-mampat. Indonesia: renjung gede (Sundanese), wuluan (central Java), lingan (Kalimantan). Malaysia: derum (Peninsular), geronggang (Sarawak, Sabah), patok tilan (Iban, Sarawak). Thailand: khee tiu (Chiang Mai), tiu dam (northern), saliu (central).

Distribution From western India through Burma and Thailand towards Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi and the Philippines.

Uses The timber is used as derum.

Observations A small to medium-sized, deciduous tree of up to 35 m tall, bole up to 40 cm in diameter, bark surface fissured, peeling off in thin, long strips, dark brown to rust brown, inner bark pink or red to orange-brown; leaves elliptical to ovate-oblong, 4–18 cm × 2–7 cm, with a rounded to cuspidate apex, sometimes glaucous beneath; inflorescence many-flowered, often a large, foliate panicle; flowers homostylous, petals dark red to brick or brownish-red; seeds 3–10 per locule, unilaterally winged. *C. sumatranum* is divided into 3 subspecies: subsp. *neriifolium* (Kurz) Gogelein occurring on the Asian mainland, subsp. *sumatranum* distributed in the western Malesian area including the Philippines, and subsp. *blancoi* (Blume) Gogelein (synonym: *C. blancoi* Blume) only found in the Philippines. *C. sumatranum* occurs scattered in primary forest, secondary forest, open woodland, thickets and grassland on a variety of well-drained soils up to 800(–1200) m altitude. The density of the wood is 580–820 kg/m³ at 15% moisture content.

Selected sources 33, 100, 146, 175, 276, 748, 779.

J. Kartasubrata (general part),
A. Martawijaya (properties),
R.B. Miller (wood anatomy),
G. dos Santos (wood anatomy),
M.S.M. Sosef (selection of species)

Cynometra L.

Sp. pl.: 382 (1753); Gen. pl. (Ed. 5): 179 (1754).
LEGUMINOSAE
$2n$ = unknown

Trade groups Kekatong: heavy hardwood, e.g. *Cynometra malaccensis* Knaap-v. Meeuwen, *C. ramiflora* L.

Vernacular names Kekatong. Indonesia: kateng, kepel (Java). Malaysia: belangan (Peninsular), katong, katong-katong (Sabah, Sarawak). Philippines: oringen, balitbitan (Tagalog). Cambodia: chôm'prinh. Thailand: mangkhak (Phuket), katong (Narathiwat).

Origin and geographic distribution *Cynometra* is pantropical and consists of about 150 species, most of which occur in South America. Within Malesia some 20 species are currently recognized, but several more might be present in New Guinea.

Uses The wood of kekatong, being not durable or only moderately so, is suitable for interior construction, door and window frames, heavy-duty flooring and interior trim. When treated with preservative it is also suitable for heavy outdoor construction, poles, posts, beams, railway sleepers, fenders, and for boat and ship building. Kekatong is also suitable for tool handles, toys and novelties. The hardness of the wood makes it generally unsuitable for plywood and veneer. Some species have attractive corewood, especially several species from India, Indo-China and Peninsular Malaysia, and are used for decorative panelling, parquet flooring and turnery. The wood yields good-quality charcoal.
The fruits of *Cynometra cauliflora* L. (namnam) are edible and used for various purposes such as compote, sambal and in salads. The same species is sometimes planted as an ornamental.

Production and international trade Kekatong is not an important export timber, and only very small amounts are exported. No figures are available, except for the export of round logs from Sabah in 1987, which amounted to only 200 m³ with a value of US$ 16 000 (price: US$ 80/m³).

Properties Kekatong is a heavy hardwood. The heartwood is golden-brown, deep pinkish-brown to red when freshly cut, darkening to dark red on exposure, corewood often brown-black or chocolate brown. The heartwood is not sharply demarcated from the pale pinkish-brown sapwood. Planed surfaces are generally not lustrous; the wood is attractively streaked on radial surfaces and mottled on tangential surfaces. The density is (720–)850–1065(–1155) kg/m³ at 15% moisture content. The grain is straight to slightly or deeply interlocked, occasionally spiral, texture moderately fine, often uneven.
At 19% moisture content the modulus of rupture is 135–163 N/mm², modulus of elasticity 18 400–18 900 N/mm², compression parallel to grain 67–87 N/mm², compression perpendicular to grain 11.5–13.5 N/mm², shear 15.5–20 N/mm², cleavage c. 61 N/mm radial and 74 N/mm tangential, Janka side hardness 12 370–13 820 N and Janka end hardness c. 12 600 N.
The rates of shrinkage from green to air dry (19% moisture content) are 1.6% radial and 2.7% tangential. Kekatong air dries moderately fast for a heavy hardwood. Boards of 40 mm thick take about 5 months to air dry, 15 mm thick boards take about 3 months. Cupping, bowing, twisting and springing do not usually occur during drying, but end checking and splitting may cause problems. Kekatong can be kiln dried easily; 25 mm thick boards take approximately 8 days to dry. Kiln schedule B (Malaysia) is recommended. It is advised to use end coating.
In green condition, the wood is easy to resaw but difficult to cross cut; in air dry condition it is difficult to saw with ordinary saws but chromium-plated teeth give good results. The wood planes to a smooth finish; it polishes well, but pre-boring is necessary for nailing. It peels satisfactorily, but the often irregular shape of the logs and their high density make the timber unsuitable for plywood. It is also considered too dense for chipboard.
Kekatong is moderately durable in contact with the ground under tropical conditions. Graveyard tests in Malaysia show an average service life of 4.2 years. Wood of *C. inaequifolia* and *C. ramiflora* is said to be not durable. It is resistant to termites, but the sapwood is often attacked by pow-

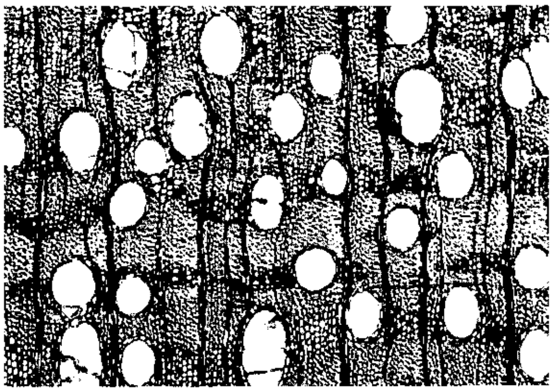
der-post beetles, and the wood of *C. ramiflora* by longhorn beetles. Kekatong is not resistant to marine borers. It is durable for both interior and exterior work under temperate conditions. The wood is usually very difficult to treat with preservatives, but there are also reports of kekatong wood which absorbs preservatives fairly well.

Description Shrubs or small to fairly large evergreen trees of up to 40 m tall; bole sometimes of poor shape, up to 80 cm in diameter, with or without buttresses; bark surface smooth, lenticellate, grey to brown, sometimes with an exudate, sapwood not well-defined; buds small, with numerous brown scales in two rows; new leaves developing in bright pink tassels. Leaves alternate, paripinnate, with 1–3(–6) pairs of opposite leaflets, young leaves often in white, pendulous tassels; petiole short, with stipules falling immediately after the unfolding of the bud, leaving no scar; leaflets sessile or shortly petiolate, asymmetrical, entire, leathery, often abruptly tipped, base very unequal, cuneate on the distal side, variously rounded on the basal side, usually glabrous. Inflorescence usually a dense, sessile, axillary raceme with 1(–2) racemes per axil, exceptionally cauliflorous and then 3–5 racemes together; bracts scale-like, bracteoles caducous after anthesis. Flowers bisexual, more or less irregular, small; receptacle short, campanulate, circumscissile under the ripening fruit; calyx with 4(–5) free, imbricate sepals reflexed at anthesis; corolla with 5, narrow, free, glabrous petals, the lateral petals covering the standard in the bud; disk absent; stamens (8–)10(–15), free, of equal length or alternately shorter and longer, sometimes 1 stamen sterile, anthers medi-dorsifix, lengthwise dehiscent, introrse, c. 1 mm long, the connective very often cleft below the insertion of the filament, mostly apiculate at the apex; ovary superior, 1-celled, with 1(–2) ovules, stipe central or excentric, rarely merged with the receptacle. Fruit a fleshy to woody pod, 1(–2)-seeded, indehiscent, oblong, flat to globose, smooth or rugose, sometimes warty, often brown with a thickened stipe. Seed circular, compressed, with a large embryo and little or no endosperm. Seedling with epigeal or hypogeal germination; the cotyledons equal, being massive foodstoring organs.

Wood anatomy

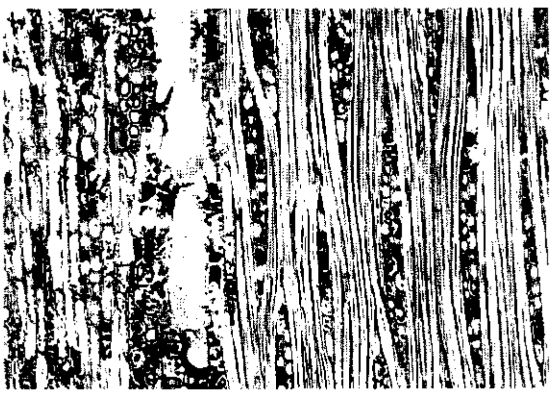
– Macroscopic characters:

Sapwood up to 90 mm wide, pale pinkish-brown, gradual transition to darker coloured heartwood but clearly demarcated from deep pinkish grey-brown to dark brown inner heartwood. Grain straight to slightly or deeply interlocked, occasion-



transverse section (×25)

radial section (×75)



tangential section (×75)

Cynometra ramiflora

ally spiral. Texture medium to fine, uneven. Figure with attractive streaks on quartersawn faces, with slight lustre or not lustrous. Growth rings not evident although zones of fibres without parenchyma and vessels may give an impression of growth rings; vessels medium to small, not readily discernible to the naked eye, with white or pinkish chalk-like deposits; parenchyma abundant, paratracheal, wide bands visible to the naked eye often forming attractive zig-zag patterns on backsawn surfaces; rays fine, individual rays barely discernible to the naked eye, ripple marks absent.

– Microscopic characters:

Growth rings inconspicuous. Vessels diffuse, 2–5(–10)/mm^2, solitary and in radial multiples of 2–3(–4), clusters rare, mostly circular to oval, average tangential diameter 120–140(–220) μm; perforations simple; intervessel pits loosely alternate, rounded, 3–4(–5) μm, vestured; vessel-ray and vessel-parenchyma pits similar but half-bordered; helical thickenings absent; tyloses absent. Fibres 1.5–2.5 mm long, non-septate, moderately thick- to thick-walled, with simple pits mainly in radial walls. Parenchyma abundant, aliform to confluent, forming more or less continuous or wavy, regularly spaced bands, 6–7 cells wide; occasionally in marginal bands 1–2 cells wide; in 2–4, mostly 4-celled strands. Rays 8–10/mm, narrow, (1–)2–3(–4)-seriate, c. 0.6 mm high, highest rays up to 1.5 mm, weakly heterocellular (Kribs type heterogeneous III and II). Prismatic crystals in chambered vertical parenchyma cells and mainly in procumbent ray cells, occasionally in chambered upright cells; extraneous brownish coloured materials abundant in parenchyma and ray cells.

Superficially *Dialium* and *Koompassia* resemble *Cynometra* but differ by having ripple marks (storied structure). Anatomically, *Maniltoa* wood is almost identical to *Cynometra* but differs by being paler in colour, usually more dense, having chambered crystals confined to upright ray cells, somewhat more heterocellular rays, and having some radial multiples with up to 6 vessels.

Species studied: *C. cauliflora, C. inaequifolia, C. malaccensis, C. ramiflora*.

Growth and development Kekatong grows in distinct flushes. The trees are slow growers; the maximum diameter for trees of *C. malaccensis* is reported to be only 37.5 cm at an age of 40 years.

Other botanical information The genus *Cynometra* belongs to the tribe *Cynometreae* together with five other closely related genera. It differs from the other genera by floral characters only. It is doubtful whether *Cynometra* is truly distinct from *Maniltoa*, because *Maniltoa polyandra* (Roxb.) Harms occupies an intermediate position. The delimitation of *Cynometra* from the other genera within the tribe is less controversial.

Ecology *Cynometra* species occur in lowland forest and some are associated with waterlogged conditions or grow along rivers. Several species characteristically occur in mangrove forest. Kekatong generally occurs in primary forest but sometimes also in secondary forest, usually up to 900 m, though in New Guinea it is found up to 1300 m.

Silviculture and management Kekatong is never planted; trees are felled in natural forest, and to date there has been no replanting or enrichment planting.

Harvesting The logs cannot be transported by river because they sink in water; they must be transported over land.

Genetic resources Some species are considered locally endangered and should be protected there, e.g. *C. ramiflora* in the Philippines.

Prospects The prospects for exploitation of kekatong are limited because the wood has restricted utility. The trees grow slowly and the boles are often of poor form and small dimension.

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Selection of species

Cynometra elmeri Merr.

Pl. elmer. born.: 98 (1929).

Synonyms *Cynometra inaequifolia* auct. non A. Gray.

Distribution Sabah and the Philippines.

Uses The wood is used as kekatong.

Observations A small to medium-sized tree of up to 25 m tall, bole up to 75 cm in diameter; leaves with 1 pair of acuminate leaflets; pod smooth, flat but thickened along the sutures, 4–6 cm × 2.5–3.5 cm. *C. elmeri* occurs in the inner fringes of mangroves and in swamp forests up to 300 m altitude.

Selected sources 100, 146, 366.

Cynometra inaequifolia A. Gray

Wilkes, U.S. Expl. Exped. 1: 473 (1854).

Vernacular names Philippines: dila-dila.

Distribution The Philippines.

Uses The wood is used as kekatong.

Observations A small tree of up to 20 m tall; leaves with 2 pairs of obtuse or sometimes emarginate leaflets, the lower pair much smaller than the upper one; pod with rough surface, but not rugose, flat, 4–4.5 cm × 2–2.5 cm. *C. inaequifolia* grows in forests at low and medium altitudes. The name *C. inaequifolia* has been commonly used for other species outside the Philippines, e.g. for *C. malaccensis* in Peninsular Malaysia and *C. elmeri* in Sabah.

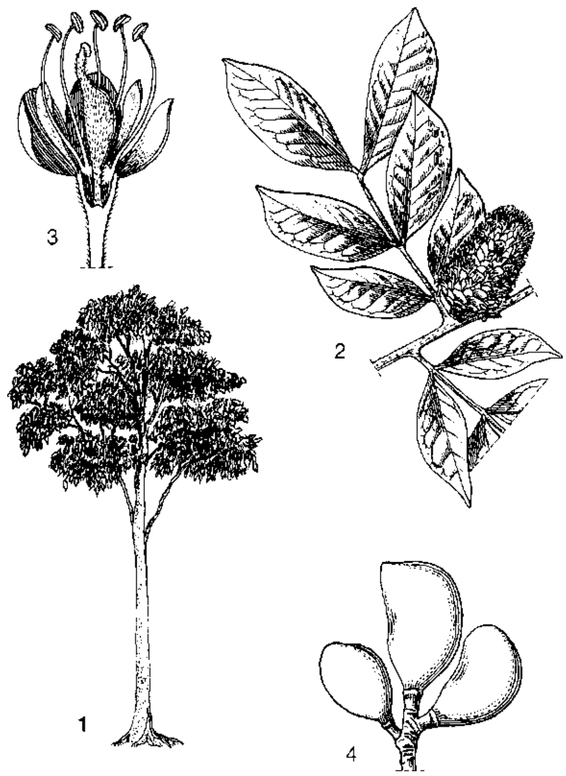
Selected sources 366, 579.

Cynometra malaccensis Knaap-v. Meeuwen

Blumea 18: 18 (1970).

Synonyms *Cynometra inaequifolia* auct. non A. Gray.

Vernacular names Malaysia: kekatong, katong, belangkan (Peninsular Malaysia). Thailand: klee (Narathiwat), mang khak (Phuket), roi de (Pattani).



Cynometra malaccensis Knaap-v. Meeuwen – 1, tree habit; 2, flowering twig; 3, sectioned flower; 4, fruits.

Distribution India (Assam), peninsular Thailand and Peninsular Malaysia.

Uses The wood is used as kekatong and is suitable for house building and tool handles.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole straight, columnar, up to 115 cm in diameter, occasionally fluted, usually with steep and tall plank-like buttresses of up to 3 m high, outer bark grey, smooth, hooped, rarely shallowly dimpled, inner bark granular, hard, pale brown to pinkish, often flecked; leaves with (2–)3 pairs of equally sized and acuminate leaflets; pod smooth, flat, 4–5 cm × 4 cm. *C. malaccensis* is locally abundant and grows in lowland and hill forest up to 1300 m altitude. The density of the wood is 910–1065 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 102, 153, 159, 183, 190, 366, 493, 578, 626, 779.

Cynometra mirabilis Knaap-v. Meeuwen

Blumea 18: 25 (1970).

Vernacular names Malaysia: katong-katong (Sabah).

Distribution Sabah and the Philippines.

Uses The wood is used as kekatong.

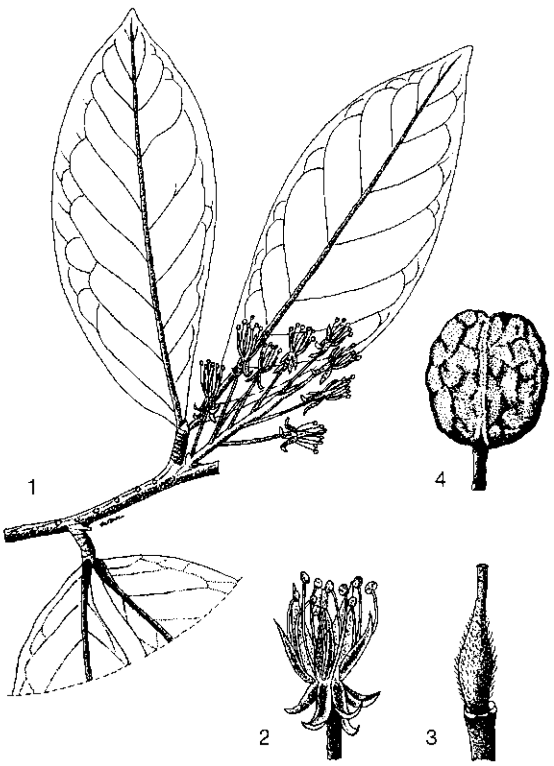
Observations A small to medium-sized tree of up to 35 m tall, bole sometimes of a poor shape, up to 80 cm in diameter, outer bark pale yellow-grey, smooth or lenticellate in old specimens, inner bark thin, pink-brown; leaves with 1–2 pairs of equally sized, acuminate leaflets; stipe of the ovary fused laterally with the receptacle; pod rugose, flat, 2.7–3 cm × 1.6–1.7 cm. *C. mirabilis* occurs on hills near the sea or along rivers, up to 200 m altitude.

Selected sources 146, 366.

Cynometra ramiflora L.

Sp. pl.: 382 (1753).

Synonyms *Cynometra bijuga* Spanoghe ex Miq. (1855), *Cynometra hosinoi* Kaneh. (1935), *Cynometra neo-caledonica* Guillaumin (1936).



Cynometra ramiflora L. – 1, flowering twig; 2, flower; 3, ovary; 4, fruit.

Vernacular names Indonesia: kateng, kepel, wunut (Java). Malaysia: katong laut (general). Philippines: balitbitan, oringen (general). Cambodia: chôm'prinh. Thailand: phang kha (central), ma khak (peninsular), maeng kha (Trat). Vietnam: c[aa]y tr[aa]m ngh[eej], c[aa]y m[os]t.

Distribution India, Indo-China, Thailand, throughout Malesia to the Pacific; often erroneously reported from Australia.

Uses The wood is used as kekatong; it is suitable for house building, tool handles, woodcraft and ornamental purposes.

Observations A small to medium-sized tree of up to 30 m tall, bole up to 60 cm in diameter and sometimes with buttresses of up to 90 cm high, outer bark smooth but with numerous lenticels, dark grey to brown, inner bark whitish or light brown to red, sapwood pale pinkish-brown, heartwood cream to reddish-brown; leaves with 1–2 pairs of rounded to acuminate leaflets, the lower pair usually smaller than the upper one; pod distinctly rugose, globose or slightly flattened, woody, 2.2–5 cm × 1.3–4 cm. *C. ramiflora* is a characteristic constituent of the inner fringe of mangrove forest but is also found inland in riverine and even savanna vegetation up to 525 m altitude. The density of the wood is 720–1155 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 35, 89, 100, 102, 146, 153, 175, 183, 235, 318, 366, 381, 493, 579, 625, 626, 779.

I. Soerianegara (general part),
A. Martawijaya (properties),
J. Ilic (wood anatomy),
M.H.A. Hoffman (selection of species)

Dalbergia L.f.

Suppl. pl. : 52 (1782).

LEGUMINOSAE

$x = 10$; *D. latifolia*, *D. sissoo*: $2n = 20$

Trade groups

- Sonokeling: medium-weight to heavy hardwood, *D. latifolia* Roxb.
- Sonosissoo: medium-weight to heavy hardwood, *D. sissoo* Roxb. ex DC.

Vernacular names

- Sonokeling: (East) Indian rosewood, Bombay blackwood (En). Palissandre de l'Inde, Palissandre Asie (Fr). Indonesia: sonobrits, sonosungu (Java).

– Sonosissoo: Indonesia: sonowaseso (Java). Thailand: pradu-khaek (Lampang).

Origin and geographic distribution *Dalbergia* includes about 100 species and is found in tropical and subtropical regions of all continents. Most species are found in Asia (70) from northern Pakistan to China, with the centre of diversity in the Himalayas. Most are shrubs or woody climbers. Some 18 species are trees with valuable timber. Only one tree species is indigenous to the Malesian region. Within Asia at least 7 species are valuable timber trees, most of them occurring in Assam and Burma. Both sonokeling and sonosissoo are amongst the most widely distributed species and are widely planted within and outside Asia.

Uses Sonokeling is well known for its application in high-class furniture, cabinets and as a decorative timber used, for example, in passenger ships and for instrument cases. It is suitable for marine and aircraft grade plywood and, owing to its beautiful colour and figure, for decorative veneer. Because of its strength and durability it is suitable for all kinds of constructional work, for doors, window frames and wagon building. It is also used for heavy-duty striking tools such as hammers, felling axes and agricultural implements such as ploughs, harrows, rollers, etc. In cart and carriage building, it is used for felloes, spokes, poles, shafts, rims, etc.

Sonokeling is one of the most popular woods for carving and engraving. It is suitable for turnery and is an excellent timber for high-class bentwood furniture, walking-sticks, umbrella handles and other bentwood articles. It is also used for making musical instruments and sports equipment.

Sonosissoo is used for the same purposes, but it is a less decorative wood because it is lighter coloured than sonokeling and lacks the dark streaks. It is suitable for shoe lasts as a substitute for imported beech or maple wood. The root wood of sonosissoo has been used for tobacco pipes.

Both species are used as a shade tree in agroforestry systems in India (sonokeling is also used for this purpose in Java). Leaves of sonosissoo are used in India as fodder and the wood as firewood. They are both recommended for afforestation of eroded soils in Java.

Production and international trade Sonokeling and sonosissoo are highly valued timbers for local processing in the furniture industry and for carving. The export of non-processed and semi-processed *Dalbergia* timber is not important in South-East Asia, and figures on production and trade are scanty. In 1990 a total of 16 750 m^3 of *Dalbergia* timber was harvested in Java, the larger part of which was sonosissoo. The price of sonokeling wood from Java is comparable with that of teak wood.

Properties Sonokeling is a medium-weight to heavy hardwood. The heartwood is dark purplish-brown with very dark brown to black streaks and is clearly demarcated from the 3–5 cm thick whitish to yellowish sapwood. The heartwood of sonosissoo is golden brown to deep brown with darker streaks, which are much less prominent than in sonokeling wood. The density of sonokeling wood is 770–860 kg/m^3 at 15% moisture content. The grain is straight, sometimes wavy, texture moderately fine.

A test of sonokeling wood from Java gave the following results for mechanical properties (density at test 790 kg/m^3, moisture content 12.5%): modulus of rupture 114 N/mm^2, modulus of elasticity 270 N/mm^2, compression parallel to grain 61 N/mm^2, shear 8–9 N/mm^2, cleavage 85 N/mm radial and 91 N/mm tangential, Janka side hardness 6970 N and Janka end hardness 8015 N.

The rate of shrinkage from green to oven dry is 2.9% radial and 6.4% tangential. Sonokeling splits easily at the end during drying, especially when green wood is kiln dried too fast. Pre-drying is recommended. The temperature during kiln drying should be 43–71°C and the corresponding relative humidity should decrease from 84% to 38%. Once dry, the wood is exceptionally stable in service.

Sonokeling is rather difficult to work with hand tools but it is quite easy to machine. It can be planed to a smooth surface. Turning, screwing, polishing and gluing give good results, and the wood can be peeled or sliced to make decorative veneer that can be glued satisfactorily to make plywood.

Sonokeling wood is durable; graveyard tests showed an average life in contact with the ground of 7.3 years under tropical conditions. Laboratory tests indicate that the wood is resistant to dry-wood termites and very resistant to wood-rotting fungi. It is difficult to treat with preservatives using the vacuum-pressure method.

Sonokeling wood contains 54% cellulose, 27% lignin, 10% pentosan, 1% ash and 0.6% silica. The solubility is 4.5% in alcohol-benzene, 1.8% in cold water, 5.2% in hot water and 15.9% in a 1% NaOH solution. The energy value is 19 180 kJ/kg.

Description Small to large trees, shrubs or woody climbers, trees up to 43 m tall, with a straight or more crooked bole of up to 150(–180) cm in diameter and often only branchless for 3–10(–12) m; buttresses absent to prominent; root a taproot; outer bark whitish or grey. Leaves alternate, imparipinnate; leaflets alternate, reticulately veined, without stipels. Inflorescence a terminal or axillary cyme or panicle; bracts and bracteoles usually small and subpersistent. Flowers bisexual, papilionoid, small; calyx 5-merous, the teeth prominent with the upper 2 broader than the lower 3; standard glabrous, keel connate at the apex; disk absent; anthers small, globular, non-versatile, dehiscing with small, transverse slits; ovary stipitate, style short, incurved, glabrous, with a small stigma, ovules few or 1. Fruit an indehiscent pod, thin-walled, with 1 or rarely few central seeds, not winged. Seed reniform, compressed. Seedling with hypogeal germination.

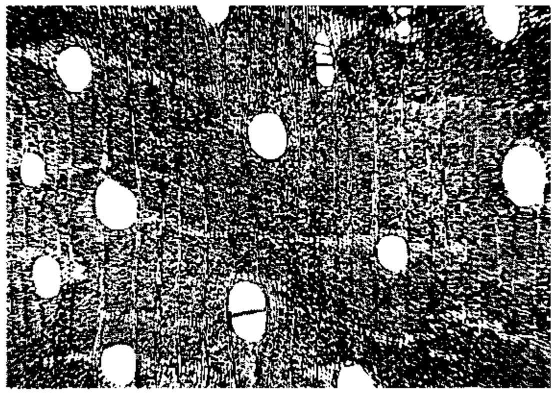
Wood anatomy

– Macroscopic characters:

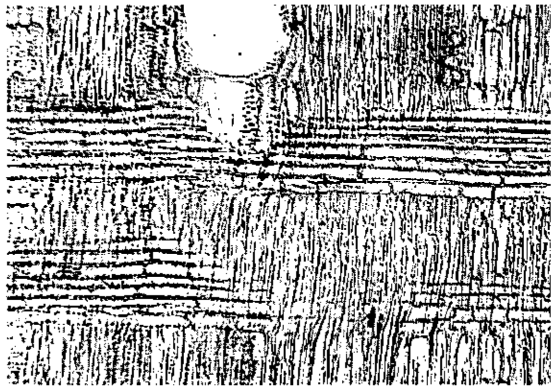
Heartwood deep red-brown, often with purplish streaks, distinctly demarcated from the whitish sapwood. Grain straight. Texture moderately fine. Growth rings usually distinct; in the inner, wider part of the growth ring, vessels more numerous and wider than in the outer, smaller part, in heartwood the latter dark brown, almost black; vessels just visible to the naked eye, in heartwood often filled with dark brown gum; rays and axial parenchyma not distinct without a lens; ripple marks distinct.

– Microscopic characters:

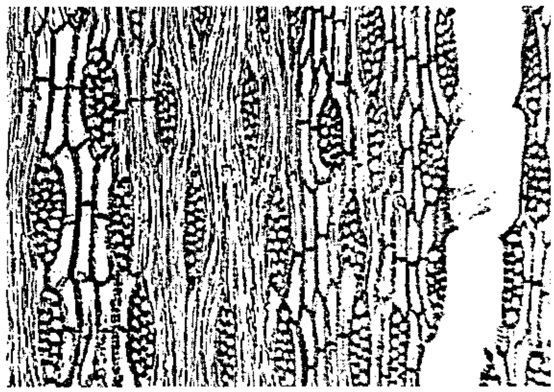
Growth ring boundaries marked by marginal parenchyma bands; within a growth ring, the diameter of libriform fibres slightly decreases while the fibre wall thickness increases somewhat and the vessel frequency decreases towards the latewood. Vessels diffuse, where numerous about 10/mm^2, solitary or occasionally mutually flattened in multiples, in radial multiples of usually 2(–3) vessels, usually completely surrounded by parenchyma, round to oval, average tangential diameter of solitary vessels 80–175 μm, of vessels in multiples 100–155 μm; perforations simple; intervessel pits alternate, distinctly vestured, hexagonal, 7 μm, sometimes with coalescent apertures; vessel-ray and vessel-parenchyma pits similar but half-bordered. Fibres 600–800 μm long, non-septate, thick-walled, with simple to minutely bordered pits almost entirely confined to the radial walls; gelatinous layers regularly present. Axial parenchyma rather abundant, paratracheal, banded and apotracheal diffuse; paratracheal parenchyma vasicentric to winged-aliform, vasicentric parenchyma one to several cell layers thick; band-



transverse section (×25)



radial section (×75)



tangential section (×75)

Dalbergia latifolia

ed parenchyma somewhat undulating, very variable in tangential length, 1–4 cells wide, also marginal, the tangentially longer bands less wide than the tangentially shorter ones, usually enclosing one, sometimes more vessels; apotracheal diffuse parenchyma scarce, usually near paratracheal and banded parenchyma; parenchyma strands not immediately bordering upon vessels, usually 2-celled, parenchyma rarely fusiform, when bordering upon vessels 3–4-celled. Rays 8–12/mm, 1–3(–4)-seriate (usually 2–3-seriate), up to 7–8(–17) cells high, mostly homocellular, almost entirely composed of procumbent parenchyma cells, only one row of marginal cells usually shorter in radial direction or sometimes even composed of upright parenchyma cells. Crystals prismatic, in chambered axial parenchyma cells, rarely in short procumbent or upright marginal ray cells. Deposits dark reddish-brown, rather often present in vessels, libriform fibres and procumbent ray parenchyma cells, sometimes in axial parenchyma. Vessel elements, axial parenchyma strands, fusiform parenchyma cells, rays and probably also libriform fibres distinctly storied.
Species studied: *D. latifolia*.

Growth and development Seedlings of sonokeling have a strong taproot and are practically devoid of any secondary roots when young. Initial growth of seedlings is slow. Nodules which are the result of symbiotic nitrogen-fixing bacteria are already found on the roots of seedlings. Young trees are also relatively slow growing; reported growth rates differ considerably. In Java an annual height growth of 2 m and an annual volume increment of 15 m^3/ha have been recorded for young plantations on favourable sites, but in India 10-year-old stands have an average height of 6 m with a trunk diameter of 4–5 cm. In India the average age of reaching a diameter of 60 cm has been estimated at no less than 240 years! Trees of over 200 years have also been recorded from Java.

Sonokeling seldom flowers in Java; the flowering periods are September – November and February – March. Pods are mature in December and May – June.

Sonosissoo trees grow fast; under exceptional conditions, they may reach 3.7 m in 1 year, 11 m in 5 years, and 15 m in 10 years.

Other botanical information The genus *Dalbergia* belongs to the tribe *Dalbergieae* and is closely related to the mainly neotropical genus *Machaerium*. The genus is usually subdivided into 5 sections or subgenera. *D. latifolia* and *D. sissoo* both belong to the section *Sissoa* Benth. Some other tree species of the genus *Dalbergia* are used for timber, e.g. *D. bariensis* Pierre (in Indo-China and Thailand), *D. cambodiana* Pierre (Indo-China), *D. cochinchinensis* Pierre (Indo-China, Thailand), *D. cultrata* Graham ex Benth. (Burma, Indo-China, Thailand), *D. oliveri* Gamble (Indo-China, Thailand), *D. melanoxylon* Guillaumin & Perrottet (Africa), *D. nigra* Allemão ex Benth. (South America) and *D. retusa* Hemsl. (Central and South America).

Ecology Sonokeling occurs in Java in deciduous forest in periodically very dry localities. Older trees are very drought-resistant. Sonokeling thrives well in areas with up to 6 dry months with mean monthly rainfall of less than 40 mm. It tolerates maximum temperatures of 35–48°C and minimum temperatures of 0–6°C; it is only marginally frost hardy. It grows well on deep, permanently moist but well-drained soils and also attains large dimensions on vertisols. Growth is retarded on nutrient poor, dry and stony soils. In Java sonokeling grows naturally up to 600 m altitude, but it is successfully cultivated as high as 1000 m altitude.

Sonosissoo grows in its natural area of distribution on well-drained, colluvial and alluvial soils of pH 5.0–8.5, in areas with 750–2000 mm annual rainfall. In Java plantations of sonosissoo are successfully established on red-yellow grumusols and regosols in areas with annual rainfall of about 1900 mm and at about 250 m altitude.

Propagation and planting Usually sonokeling is propagated from root suckers of 1–2.5 cm diameter (the tree is often surrounded by numerous suckers). Root and stem cuttings can also be used. The buds of root suckers and stem cuttings start to sprout about 9 days after planting, and those of root cuttings about 15 days after planting, but after 2 months all young plants are more or less the same height. Seeds have no dormancy, and the germination rate is often low (30–40%). The weight of 1000 seeds of sonokeling is approximately 50 g, that of sonosissooo approximately 30 g.

Sonosissoo is propagated successfully by air layering in India; application of growth regulators (auxins) enhances rooting and callus formation. In Nepal and India successful methods of tissue culture have been developed for both sonokeling and sonosissoo. In vitro mass multiplication of sonokeling is carried out in India from callus of shoot tips and shoot segments of over 50-year-old trees on a Murashige and Skoog medium containing naphthalene acetic acid and benzylaminopurine.

For rooting, regenerated shoots from the calli are excised and first treated with a half-strength Murashige and Skoog medium, supplemented with indole-3-acetic acid, indole-3-butyric acid and naphthalene acetic acid for 48–72 hours. Then the plantlets are transferred to a hormone-free half-strength Murashige and Skoog medium. Rooted plantlets are transferred to pots and grown in the greenhouse.

Sonosissoo has been successfully propagated in Nepal by culturing cotyledons excised from seedlings on a Murashige and Skoog medium with the addition of benzylaminopurine (1.0 mg/l), naphthalene acetic acid (0.1 mg/l) and casein hydrolysate (1000 mg/l). Under these conditions 2–5 shoots developed from the nodal region of the cotyledon after 7 days. Multiple shoot formation was obtained by transferring these shoots to a medium supplemented with 0.25 mg/l benzylaminopurine and 1000 mg/l casein hydrolysate. The shoots continued to proliferate at a sustained rate of 10–15 microshoots per explant after 4 weeks of culture. They were subcultured for 2 years without any loss of multiplication potential. The microshoots root easily in non-sterile sand beds. Young plants are planted into the field at a spacing varying from 1 m × 2 m to 3 m × 3 m. Sonosissoo is planted in agroforestry systems in India with a spacing of 4.5 m × 4.5 m, and wheat is cultivated under the trees.

Silviculture and management In Java sonokeling is only planted on sites which are not sufficiently productive for teak (*Tectona grandis* L.f.). It is generally grown in pure stands, but sometimes mixed with mahogany (*Swietenia* sp.). Pruning and thinning are recommended 5–10 years after planting.

Diseases and pests In East Java *Fusarium solani* caused widespread damage to sonokeling plantations over 15 years old. The symptoms are inward rolling of young leaves, dieback and discoloration of other leaves, and red streaks formed on outer layers of the sapwood. Root suckers of affected trees should not be used for propagation. Wilt disease caused by *Fusarium* spp. is a common and serious problem of sonosissoo. Greenhouse experiments in India showed that compared with non-inoculated plants, plants pre-inoculated with vesicular-arbuscular mycorrhizae (VAM, *Glomus fasciculatus* and *G. tenuis*) showed better growth and were less susceptible to wilt disease. Physiological stress caused by inferior site conditions increases the susceptibility of the trees to this disease.

Sonokeling seedlings often suffer seriously from damping-off; the mortality rate may be up to 60%. Up to 12 years old, sonokeling is susceptible to fungi of the genus *Phytophthora*. In nurseries leaf rusts (*Uredo sissoo* and *Maravalia achroa*) may be pathogenic to sonosissoo. In Java the trees are attacked by various insects such as leafminers, defoliators and stem-borers, but this causes no real problems for trees grown under favourable conditions. Phanerogamous parasites are widely found on trees in Java, e.g. *Dendrophthoe falcata* (L.f.) Ettingsh. and *Scurrula philippensis* (Cham. & Schlecht.) G. Don (both *Loranthaceae*).

Genetic resources Stands of *Dalbergia* trees have been depleted considerably all over the world. The decorative wood has been imported in Europe for several centuries for furniture and interior finishing. In many areas, large *Dalbergia* trees have become rare. In Java, for instance, it is now difficult to find an old and large sonokeling tree. However, sonokeling and sonosissoo are planted on a considerable scale in agroforestry systems in India, and, on a much smaller scale, in Java.

Prospects In general, rosewood (wood of a dark red or purplish colour streaked and variegated with black, particularly but not exclusively obtained from *Dalbergia* species) is one of the most expensive woods. Natural stands of *Dalbergia*, however, need urgent protection. Loggers should take full account of the fact that the trees are usually slow growers, and that therefore cutting cycles should be very long. Sonokeling and sonosissoo are suitable for incorporation in agroforestry systems, but to obtain straight boles, close spacing is desirable and this means establishing monoculture plantations. Sonokeling seems to offer good prospects for timber production in plantations in Java, but more research is needed on silvicultural aspects. Comparison of Javanese provenances of sonokeling with those from India appears to be useful, particularly concerning botany, growth and propagation.

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Selection of species

Dalbergia latifolia Roxb.

Pl. Corom. 2: 7, t. 113 (1799).

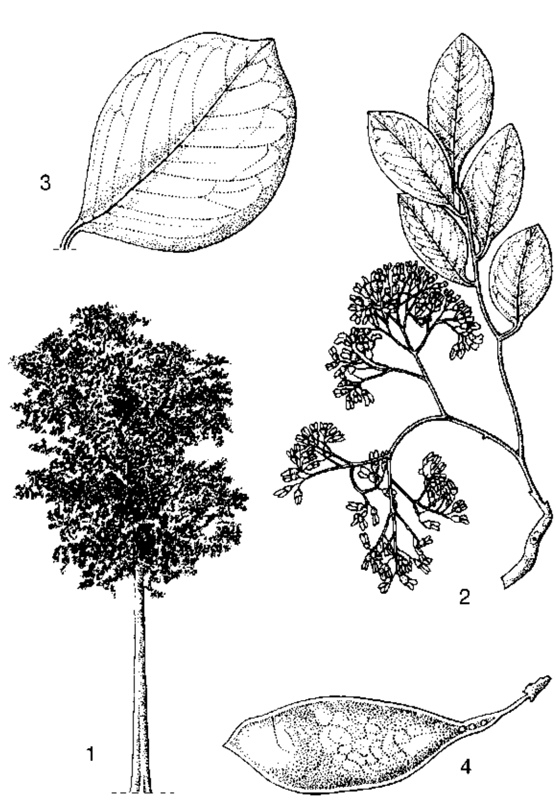
Vernacular names Indian rosewood, Bombay blackwood (En). Palisandre de l'Inde (Fr). Indonesia: sonokeling, sonobrits, sonosungu (Java). Vietnam: tr[aws]c.

Distribution Nepal, western and north-eastern India and Java; planted in mainland South-East Asia, Java and Africa.

Uses The timber is used as sonokeling. The species is planted as shade tree.

Observations A medium-sized to large tree of up to 43 m tall, bole straight or slightly twisted and usually branchless for 3–12 m with a diameter of up to 180 cm, buttresses prominent; leaves with 3–7 leaflets and a straight rachis, leaflets obtuse to emarginate with or without a small cusp; flowers distinctly pedicellate, corolla white or pale pink, stamens 9, style 1.7–2.5 mm long; pod 4–9 cm × 1.5–2 cm, with 1–3(–4) seeds. *D. latifolia* occurs in evergreen or deciduous forest on deep, well-drained, moist soils up to 600 m altitude in Java, in India much higher. The disjunct distribution is remarkable. The density of the wood is 770–860 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 35, 54, 102, 160, 217, 234, 281, 328, 373, 461, 570, 576, 634, 662, 712, 762.



Dalbergia latifolia Roxb. – 1, tree habit; 2, flowering twig; 3, lateral leaflet; 4, fruit.

Dalbergia sissoo Roxb. ex DC.

Prodr. 2: 416 (1825).

Vernacular names Sonosissoo (general). Indonesia: sonowaseso (Java). Thailand: pradu-khaek, du-khaek (Lampang).

Distribution Iraq, Iran, Afghanistan, Pakistan and India; planted in mainland South-East Asia, Java and Africa.

Uses The timber is used as sonosissoo. The tree is planted in agroforestry systems, the leaves are used as forage, the wood is used as firewood.

Observations A small to medium-sized tree of up to 30 m tall, bole often crooked and branchless for 3–8 m, with a diameter of up to 100 cm, buttresses absent; leaves with 3–5 leaflets and a zig-zag rachis, leaflets abruptly acuminate; flowers sessile or subsessile, corolla yellowish-white, stamens 9–10, style 0.3–0.5 mm long; pod 3–8 cm × 1–1.3 cm, with 1–2(–3) seeds. *D. sissoo* grows on well-drained colluvial and alluvial soils, often near rivers and streams up to 1500 m altitude.

Selected sources 35, 102, 120, 160, 217, 234, 281, 328, 461, 563, 672, 712, 766.

S. Prawirohatmodjo (general part),
J. Suranto (general part),
A. Martawijaya (properties),
R.W. den Outer (wood anatomy),
M.S.M. Sosef (selection of species)

Dialium L.

Mant. pl. (Syst. Nat. ed. 12, Vol. 2): 3 (1767).
LEGUMINOSAE
x = probably 14 ($2n$ = 28 counted for three African species)

Trade groups Keranji: heavy hardwood, e.g. *Dialium indum* L., *D. platysepalum* Baker, *D. procerum* (v. Steenis) Stey.

Vernacular names Keranji: velvet tamarind, tamarind plum (En). Indonesia: kranji (Sumatra). Burma: taung-kaye. Cambodia: krâlanh, krâlanh lomië. Laos: kheng. Thailand: kayi-khao (peninsular), yi-thongbung (Nakhon Si Thammarat). Vietnam: xoay, x[aa]y, nh[ooj]i.

Origin and geographic distribution *Dialium* has a pantropical distribution and consists of about 30 species. Of these, 7 species occur within the Indo-Malesian area whereas some 20 are present in Africa and Madagascar and only 1 in Central and South America. Within Malesia the genus is confined to the western half (Peninsular Malaysia, Sumatra, Java and Borneo) and does not cross Wallace's line, an important biogeographical barrier which lies between Borneo and Sulawesi. The absence from eastern Malesia and areas further east and south implies that the Malesian species have a western origin.

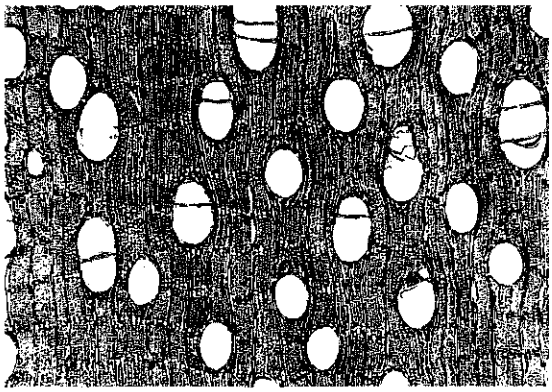
Uses Keranji is a good general-purpose timber. Because of its moderate natural durability and strength it has a limited suitability for purposes in contact with the ground such as poles and piles, fences, railway sleepers, telegraph and power transmission posts and cross-pieces, bridges, and sledges used in logging. Locally the timber is used for ship and boat building and for vehicle bodies (framework and floor boards). Keranji is chiefly used in construction, e.g. as mine timber, for joinery, beams, door and window frames, sills, posts, joists, rafters, fender supports, columns, and various parts of staircases. Keranji is also very suitable for purposes where toughness and resilience is required, such as gymnasium equipment, agricultural implements, tool handles (heavy impact), mallets, oil presses and industrial flooring. Due to the attractive sheen which is usually dark red or brown, keranji is suitable for decorative panelling, cabinet and furniture making, toys and novelty items. Due to the hardness of the timber it is not recommended for veneer and plywood production, neither is it suitable for particle board or pulp production.
The pulpy fruits of some species are edible and are generally sold dry. The bark is rich in tannins but has been used for tanning on a very limited scale. The bark has also been used as a substitute for betel nut and medicinally against diarrhoea and herpes.

Production and international trade Keranji is especially exported from Sabah and Sarawak to Japan, but in fairly small amounts. The export of round logs from Sabah in 1987 was 63 500 m^3 with a value of US$ 4 million (US$ 63/m^3), but in 1992 it was only 17 000 m^3 (logs) and 13 500 m^3 (sawn timber) with a total value of US$ 3.5 million. Export of keranji is not significant elsewhere. During the late 19th Century and the beginning of the 20th Century, logs were exported from Peninsular Malaysia to China, but when the number of large trees diminished, keranji timber lost its importance.

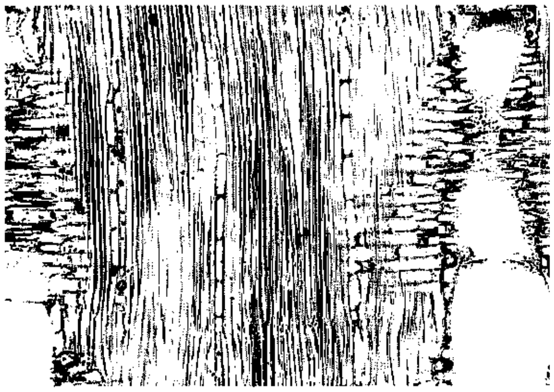
Properties Keranji is a heavy, hard and fairly strong timber. The heartwood is generally golden brown to reddish-brown, becoming darker upon exposure, and clearly distinct from the lighter (white to yellowish-white) sapwood. The planed surface is usually lustrous; the radial surface often shows a stripe figure, the tangential surface a faint zig-zag design. The density is 750–1100 (–1250) kg/m^3 at 15% moisture content. The grain is generally interlocked or wavy, sometimes straight, texture fine to moderately coarse and even.
At 15% moisture content the modulus of rupture is 134–166 N/mm^2, modulus of elasticity 19 400–20 100 N/mm^2, compression parallel to grain 72–91 N/mm^2, shear 16–23 N/mm^2, cleavage c. 56 N/mm radial and 67 N/mm tangential, and Janka side hardness 10 600–11 300 N.
The rates of shrinkage are usually high, from green to 15% moisture content (1.0–)3.7% radial and (1.7–)6.6% tangential. Keranji dries moderately slowly. During drying the wood is liable to split, and there is a tendency to moderate surface and end checking, and to slight warping. Warping and checking can be prevented by quarter-cut sawing and slow and careful seasoning techniques. Boards 15 mm and 40 mm thick take re-

spectively 2 and 6 months to air dry. In Malaysia kiln schedule E is recommended. Seasoned wood is stable in service.
Keranji is difficult to saw, especially when seasoned. The wood blunts sawteeth and cutter edges rapidly, and chromium-plated teeth are recommended. It produces a moderately smooth finish in planing, but it has tendency to grain pick-up on radial faces; a 20° cutting angle is recommended. The wood turns well. Pre-boring is needed for nailing and screwing.
The wood is usually rated as moderately durable in contact with the ground under tropical conditions. Graveyard tests with stakes in Malaysia showed a maximum service life in contact with the ground of 5.5 years. Logs, particularly the sapwood, may be attacked by pinhole borers, marine borers and termites. Under temperate conditions keranji is durable in exposed situations or in contact with the ground. The heartwood is very difficult to impregnate.

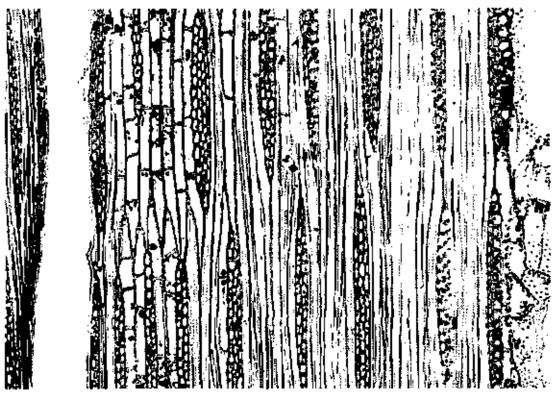
Description Evergreen or more rarely deciduous, unarmed, small to large trees of up to 45 m tall or occasionally large shrubs; bole columnar but often slightly twisted above, branchless for up to 21 m, up to 120 cm in diameter and usually prominently buttressed with plank-like forked buttresses; bark surface generally smooth, often rugose or rugulose and occasionally flaking with small, thick scales, rarely lenticelled and hoop-marked, inner bark hard, brown, finely mottled, producing a little clear exudate soon turning red, sapwood hard, cream to yellowish-brown, ripple-marked; twigs terete, lenticellate, generally hairy when young and glabrescent; indumentum consisting of simple, patent or adpressed hairs. Leaves alternate, either unifoliolate or simply imparipinnate; stipules small, linear-triangular, very early caducous; leaflets alternate or sometimes opposite to subopposite, entire, subleathery, hairy above when young, indumentum beneath generally persistent. Inflorescences axillary or terminal, consisting of many-branched and many-flowered panicles; bracteoles very early caducous. Flowers bisexual, irregular; sepals (in Asiatic species) 3 or 5; petals (in Asiatic species) 0 (5 in *D. modestum*), when present not conspicuous, clawed; disk present or absent; stamens (in Asiatic species) 2 or 6 (5 in *D. modestum*), anthers basifixed, dehiscing by longitudinal slits; ovary sessile or sometimes shortly stipitate, with (1–)2 ovules, densely adpressed hairy, style solitary, excentric or central, with a punctiform stigma. Fruit an indehiscent, ellipsoid or ovoid to subglobose or



transverse section (×25)



radial section (×75)



tangential section (×75)

Dialium platysepalum

slightly compressed berry-like pod, hard, brittle and glabrescent outside, sometimes glaucous, the 1–2 seeds entirely embedded in a dry mealy reddish-brown pulp. Seed usually reniform with a smooth testa, usually dark brown when dry, areoles absent, endosperm present. Seedling with epigeal germination; hypocotyl elongated; cotyledons large, succulent; first two leaves opposite.

Wood anatomy

– Macroscopic characters:

Heartwood generally uniformly brown or reddish-brown when freshly cut, often darkening on exposure, sometimes becoming almost black with age, distinctly demarcated from the creamy white or yellowish sapwood. Grain generally interlocked or wavy, sometimes straight. Texture fine to moderately coarse. The radial surface usually displays a ribbon figure, tangential surface with dark markings or ripple marks caused by storied elements, especially rays and parenchyma. Vessels not visible to the naked eye.

– Microscopic characters:

Growth rings absent. Vessels diffuse, 3–7(–11)/mm^2, 50–70% solitary and in radial multiples of 2–3 (sometimes more), round to oval, average tangential diameter (75–)120–190(–390) μm; perforations simple; intervessel pits alternate, 7–11(–13) μm, usually vestured; vessel-ray pits similar to intervessel pits; helical thickenings absent; whitish, yellowish or yellowish-brown gum-like deposits usually present, tyloses usually absent. Fibres (800–)900–1100(–1500) μm long, non-septate, usually thick-walled and with very narrow lumen, with simple pits. Parenchyma abundant, basically apotracheal, banded, usually one side of the band touching the vessels, bands usually 2–3 cells wide, usually broken or discontinuous and irregularly spaced from each other, 3–5 bands per radial mm, in (3–)4(–8)-celled strands. Rays 9–11(–18)/mm, (1–)2–3(–4)-seriate, (100–)210–320(–560) μm high, storied, essentially homocellular with procumbent cells but sometimes marginal cells twice as high as body cells. Prismatic crystals present in chambered axial parenchyma cells. Silica bodies sometimes present in axial parenchyma cells (e.g. *D. kunstleri*).

Species studied: *D. indum*, *D. kunstleri*, *D. platysepalum*.

Growth and development During germination, the testa breaks at soil level, exposing the creamy white, thick cotyledons. As the seedling grows, the hypocotyl elongates and lifts the cotyledons above the soil level, leaving the testa behind on (or sometimes partly in) the soil. The clasping cotyledons then spread and do not change colour immediately but remain creamy white for some time until the first leaves start to develop. Then the cotyledons turn green and remain attached to the hypocotyl until the first leaves are fully developed.

Keranji trees are moderately slow growers. A tree of *D. platysepalum* in Malaysia reached a bole diameter of 49 cm after 40 years.

The fruits are dispersed by animals (e.g. monkeys) which like to eat the pulp embedding the seeds. However, the fruits are also capable of being transported by water, since they float. Transport by sea currents may lead to long-distance dispersal.

Other botanical information The genus *Dialium* belongs to the subtribe *Dialiinae* together with 12 other genera, among which is *Koompassia* (kempas and tualang). The genus is very heteromorphic in the number of floral parts, but can be accurately defined by its characteristic fruit. The genera *Arouna*, *Dansera* and *Uittienia* have been merged with *Dialium* and recognized as separate subgenera. This resulted in 4 subgenera: *Dialium*, *Arouna* (Aublet) Stey., *Dansera* (v. Steenis) Stey. and *Uittienia* (v. Steenis) Stey., respectively. *Dialium* subgenus *Arouna* is confined to tropical Africa and Madagascar. This subdivision is confirmed by anatomical characters as well as pollen morphology. The merging of *Uittienia* (comprising only one species: *U. modesta* v. Steenis) with *Dialium* is, however, debatable because of its unique fruit characters.

Ecology Most species of keranji inhabit primary rain forest. Because of the hardness of the wood, specimens are often left by loggers or in shifting cultivation and they become relicts in secondary forest. Keranji occurs scattered, not gregarious as do many other related species, sometimes along river banks and in low-lying swampy areas and peat swamps but also on well-drained land. Keranji is generally found in the lowlands, but occasionally up to 1150 m altitude.

Propagation and planting Germination of untreated seeds of *D. platysepalum* is staggered over a period of about 17 months; 75% of the seeds have germinated after 50 weeks. Mechanical scarification (cutting with secateurs on one side of the seed) is the best treatment to promote germination. About 70% of the scarified seeds germinate within a month. Treatment with concentrated sulphuric acid (H_2SO_4) is much less effective.

The seeds can be sown in beds containing a mixture of equal parts of forest topsoil and river sand.

They are buried just below the soil surface and a layer of sawdust is spread on top. The beds should be shaded and watered regularly (twice a day).
There are no records of the establishment of plantations, except for *D. cochinchinense*, which is reported to be planted in villages in northern Peninsular Malaysia for its edible fruits.

Harvesting Keranji trees are difficult to cut because of the dense wood. They often have tall buttresses, and these have to be slashed before cutting as much wood would be wasted if the trunk were cut above the buttresses. This, and its scattered occurrence, make keranji timber not very valuable commercially.
The logs cannot be transported by river because they sink in water; they are therefore transported over land.

Genetic resources Keranji trees are found scattered in the forest. Large-scale logging may endanger the individual species.

Prospects Two facts discourage exploitation of keranji trees: they occur scattered in primary forest, and are difficult to cut because of their hardness. Moreover, when keranji trees are found near villages, people prefer gathering the fruits above cutting the trees. However, timber is becoming more and more valuable, and there is a tendency to view any timber species left in the forest as worth harvesting. In addition, keranji wood is very suitable for special uses such as tool handles, cross ties and flooring. Therefore, research is desirable, especially on silvicultural and management aspects.

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Selection of species

Recently the genus was fully revised by Rojo but his results have not been published to date. He has merged many of the formerly recognized taxa, because they lack distinctive characters. The treatment of the species below follows Rojo's revision and hence many names are treated here as synonyms of others for the first time.

Dialium cochinchinense Pierre

Fl. forest. Cochinch. fasc. 24: pl. 384A (1898).

Vernacular names Velvet tamarind (En). Malaysia: keranji kertas kechil (Peninsular). Cambodia: krâlanh lomië. Laos: kheng. Thailand: khleng (general), i-dang (northern), kayi (peninsular). Vietnam: xoay, x[aa]y, nh[ooj]i.

Distribution Peninsular Burma, Laos, Cambodia, southern Vietnam, Thailand and Peninsular Malaysia. The species is planted locally in Peninsular Malaysia.

Uses The timber is used as keranji. The sweet pulp of the fruits is edible. The tree is used locally as a shade tree.

Observations A medium-sized tree of up to 30 m tall, bole up to 50 cm in diameter; leaflets 5–9, 4–8 cm × 1.5–5 cm, glabrescent; sepals 5, petals 0, stamens 2; fruit ellipsoid to ovoid, sometimes slightly compressed, 1.5–1.8 cm × 0.8–1 cm. *D. cochinchinensis* occurs in evergreen and deciduous (dipterocarp) forest with a canopy varying from dense to open; from sea-level to 300 m altitude. The density of the wood is about 1100 kg/m^3 at 13% moisture content. See also the table on wood properties.

Selected sources 152, 235, 359, 578, 587, 626, 649, 779.

Dialium hydnocarpoides de Wit

Blumea 7: 320 (1953).

Synonyms *Dialium praetermissum* de Wit (1953).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as keranji.

Observations A medium-sized tree of up to 30 m tall, bole up to 45 cm in diameter and with prominent buttresses of up to 5 m high; leaflets (11–)15–17(–19), (2.5–)3.5–6(–8.5) cm × (1.5–)2–3 (–3.5) cm, brownish hairy beneath but glabrescent; sepals 5, petals 0, stamens 2; fruit subglobose, 1.5–2 cm in diameter. *D. hydnocarpoides* is a comparatively rare species that occurs scattered in primary forests on yellow sandy loam soils at very low altitudes.

Selected sources 102, 146, 188, 587, 779.

Dialium indum L.

Mant. pl. (Syst. Nat. ed. 12, Vol. 2): 24 (1767).

Synonyms *Dialium laurinum* Baker (1878), *Dialium patens* Baker (1878), *Dialium angustifolium* Ridley (1929), *Dialium marginatum* de Wit (1953), *Dialium turbinatum* de Wit (1953).

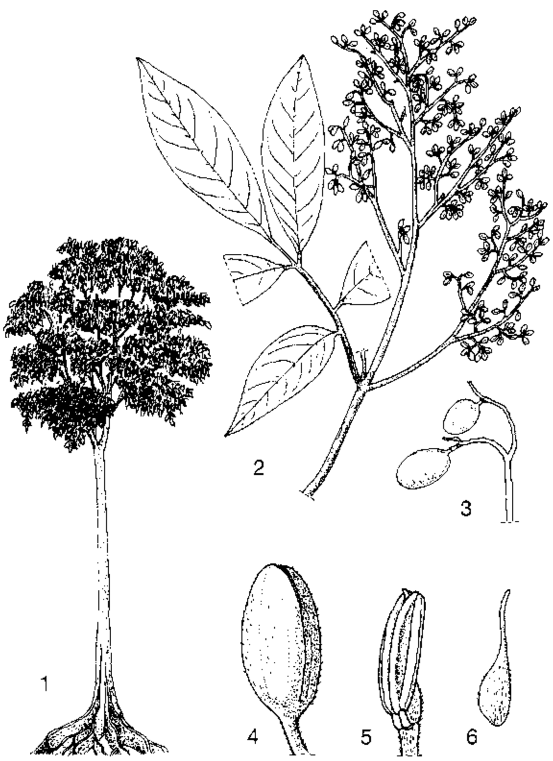
Vernacular names Indonesia: keranji (general). Malaysia: keranji kertas basar, keranji tebal besar, keranji paya (general). Thailand: yi, kayi khao (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, Java and Borneo.

Uses The timber is used as keranji. The fruits are edible. The bark can be used for tanning.

Observations A medium-sized to fairly large tree up to 40 m tall, bole columnar, branchless for up to 12 m and up to 100 cm in diameter; leaflets 5–9, 6–11 cm × 2.5–5 cm, glabrous; sepals 5, petals 0, stamens 2; fruit globose to ovoid, 1.5–3 cm × 1–2 cm. *D. indum* occurs in swamp and peat-swamp forests, on well-drained flat country and in hills up to 1150 m altitude. The density of the wood is 795–1060(–1250) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 102, 146, 153, 188, 190, 235, 359, 401, 587, 626, 779, 796.



Dialium indum L. – 1, tree habit; 2, flowering twig; 3, fruits; 4, flower bud; 5, flower with sepals removed; 6, ovary.

Dialium kunstleri Prain

Journ. As. Soc. Beng. 66: 168 (1897).

Synonyms *Dialium dewittei* v. Steenis (1948), *Dialium silvestre* de Wit (1953), *Dialium trifoliolatum* de Wit (1953).

Distribution Peninsular Malaysia (rare) and Borneo (common).

Uses The timber is used as keranji.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole up to 90 cm in diameter; leaflets 3–5(–7), (4–)5–15(–19) cm × (2–)3–6 (–7.5) cm, glabrous above, glabrescent beneath; sepals 3, petals 0, stamens 6; fruit broadly ellipsoid to ovoid, 3–4 cm × 2.5–3 cm. *D. kunstleri* is usually found on brown to yellowish silt or sandy loam soils and occurs in primary forest up to 250 m altitude.

Selected sources 100, 146, 587, 779.

Dialium modestum (v. Steenis) Stey.

Reinwardtia 2: 355 (1953).

Synonyms *Uittienia modesta* v. Steenis (1948).

Vernacular names Indonesia: nyamut, keranji, bumbun merah (Kalimantan).

Distribution Borneo.

Uses The timber is used as keranji.

Observations A small to medium-sized tree of up to 30 m tall, bole branchless for up to 18 m and up to 80 cm in diameter; leaves unifoliolate, leaflet 7–20 cm × 3.5–7.5 cm, glabrous; sepals 5, petals 5, stamens 5; fruit not brittle but with a hard pericarp, globose, 4–6 cm in diameter. *D. modestum* is a fairly common species of primary, non-inundated forests up to 600 m altitude. This species might well form a genus separate from *Dialium*; it

should then be called *Uittienia modesta* v. Steenis.
Selected sources 337, 587, 650, 747.

Dialium platysepalum Baker

Hook.f., Fl. Brit. India 2: 270 (1878).

Synonyms *Dialium maingayi* Baker (1878), *Dialium ambiguum* Prain (1897), *Dialium kingii* Prain (1897), *Dialium wallichii* (Baker) Prain (1897), *Dialium havilandii* Ridley (1929), *Dialium triste* de Wit (1953).

Vernacular names Malaysia: keranji kuning besar, keranji kuning kechil, keranji bulu (general). Thailand: yee thong bueng (peninsular).

Distribution Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as keranji. The fruit is edible.

Observations A medium-sized to large tree of up to 45 m tall, bole branchless for up to 21 m and with a diameter of up to 120 cm; leaflets (5–)7–11(–15), (5–)6–8(–15) cm × (1.5–)2–4(–7) cm, veins beneath velvety hairy; sepals 5, petals 0, stamens 2; fruit subglobose to obovoid, 1.5–2.5(–3) cm long. *D. platysepalum* usually grows on yellow sandy clay soils in lowland rain forest or freshwater swamp forest up to 1000 m altitude. The density of the wood is 810–1010 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 102, 146, 152, 190, 569, 578, 587, 591, 779, 796.

Dialium procerum (v. Steenis) Stey.

Reinwardtia 29: 355 (1953).

Synonyms *Dansera procera* v. Steenis (1948).

Vernacular names Indonesia: merbau merah, maranji, tica pinang (southern Sumatra). Malaysia: keranji tunggal.

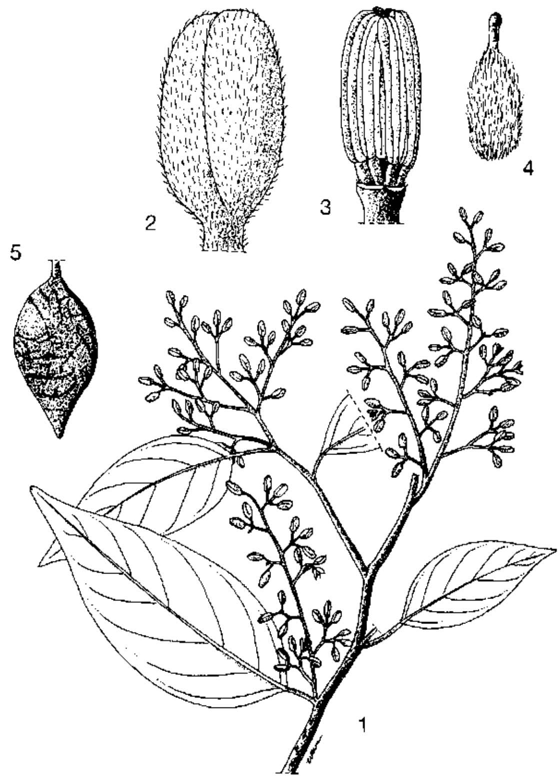
Distribution Peninsular Malaysia, southern Sumatra and north-western Borneo.

Uses The timber is used as keranji.

Observations A medium-sized to large tree of up to 45 m tall, bole up to 90 cm in diameter; leaves unifoliolate, leaflet 6.5–16 cm × 3.5–7 cm, glabrous above, glabrescent beneath; sepals 3, petals 0, stamens 6; fruit more or less ovoid, 4–5 cm × 2.5 cm. *D. procerum* is found on alluvial sandy soils, sometimes inundated, in primary and old secondary forests up to 560 m altitude.

Selected sources 100, 587, 747, 779.

J.P. Rojo (general part, wood anatomy, selection of species),
D.S. Alonzo (properties)



Dialium procerum (v. Steenis) Stey. – 1, flowering twig; 2, flower bud; 3, flower with sepals removed; 4, ovary; 5, fruit.

Dipterocarpus Gaertner f.

Fruct. 3: 50 (1805).

DIPTEROCARPACEAE

$x = 10, 11$; *D. costatus*, *D. elongatus*, *D. kunstleri*, *D. obtusifolius*: $2n = 20$, *D. baudii*, *D. cornutus*, *D. oblongifolius*: $2n = 22$, *D. alatus*: $2n = 20, 22$

Trade groups Keruing: medium-weight to heavy hardwood, e.g. *Dipterocarpus baudii* Korth., *D. cornutus* Dyer, *D. costulatus* v. Slooten, *D. crinitus* Dyer, *D. verrucosus* Foxw. ex v. Slooten. Because of the comparatively wide variation in density of the wood a subdivision into lightweight keruing, medium-weight keruing and heavy keruing is sometimes made.

Vernacular names Keruing: Indonesian gurjun (En). Keruing, kruen (Fr). Indonesia: lagan (Sumatra), tempudau, kerup (Kalimantan). Philippines: apitong, panau. Burma: kanyin, eng, in. Cambodia: thbaèng, khlông, chhe: ti:ël. Laos: nha:ng. Thailand: yang-na (general), yang-khon

(Chanthaburi), yang-pai (northern). Vietnam: d[aaf]u, l[oo]ng, d[aaf]u r[as]i, ch[of].

Origin and geographic distribution *Dipterocarpus* consists of some 70 species and is distributed from Sri Lanka, India and Burma, through Indo-China, southern China and Thailand towards western Malesia. Within Malesia the genus is found in Peninsular Malaysia, Sumatra, Java, Bali, Sumbawa, Borneo, the Philippines and intervening islands. Hence it does not cross Wallace's line (between Borneo and Sulawesi), which is regarded as an important biogeographical barrier, except between Bali and Sumbawa. The oldest fossil records are from the Miocene.

Uses Keruing is an important source of general construction timber, for medium and heavy construction. Because it is not very durable when in contact with the ground its main applications are for interior purposes such as beams, joists, staircases, stringers, door and window frames, vehicle and wagon bodies, heavy-duty furniture and flooring (except for the heaviest pedestrian traffic). A special application is in laboratories where a high impermeability for chemicals is required. When treated with a preservative the timber can be used outdoors, for example for telegraph and powerline poles, foundation piles, fences, railway sleepers, and for ship building and wharves. Other purposes are heavy-duty pallets, general-duty crates and boxes, agricultural tools and toys. Because of the resinous nature of several keruing species, their wood is generally less suitable for flooring and woodwork exposed to the sun, or to be painted. The wood is widely used for the manufacture of veneer and plywood, especially for the structural grade. Oily keruing is not suitable for the production of low-density particle board. The surfaces of such boards are rough, probably because of the stiffness of the flakes. Keruing flakes can, however, be used as core material in the manufacture of 3-layered particle board. Hardboard of good quality can be obtained from keruing, and good-quality paper can be produced from keruing pulp. Locally the wood is made into good-quality charcoal.

An oleo-resin, known as 'minyak keruing' (Malaysia) or 'apitong oil' (the Philippines), is produced by all species of keruing, but only a few produce sufficient amounts to make collecting on a commercial scale feasible. This oleo-resin is used locally as a coat for waterproofing paper, for caulking baskets and boats, as a varnish for walls and furniture, in the preparation of lithographic ink or, sometimes mixed with bark of *Melaleuca* sp., for torches. It has also been tried as a substitute for linseed oil. Medicinally the oil is applied to ulcers as well as sores and foot diseases of cattle. Contradictory results have been obtained when this oil was applied in the treatment of gonorrhoea. Destructive distillation of the wood yields a tar rich in creosote oils. In the Philippines, substituting apitong oil for diesel fuel gave positive results but needs further research.

The bark is considered to be a tonic, and a hot decoction of it is used to cure rheumatism and liver complaints. Locally it is used for house walls. Bark extracts yield a tannin-formaldehyde adhesive. Locally the nuts are boiled and eaten as a vegetable or chewed as chew-nuts (e.g. in Thailand).

Production and international trade Keruing is one of the most important export timbers of South-East Asia, second only to meranti. In Indonesia keruing is exported together with kapur (*Dryobalanops* spp.) in a combined export group. In 1987 the export of sawn kapur/keruing timber from Indonesia was 213 000 m^3 (with a value of US$ 39 million), increasing to 463 000 m^3 (with a value of US$ 99 million) in 1989. Keruing accounts for about 82% of this combined timber group. Moreover, keruing is much used in plywood production in Indonesia. In Peninsular Malaysia the export of sawn keruing timber was 475 000 m^3 (worth US$ 55 million) in 1981, decreasing gradually to 192 000 m^3 (worth US$ 19 million) in 1984. Thereafter, exports increased again, and by 1989 had almost reached the level of 1981, with 428 000 m^3 (worth US$ 65 million); exports in 1990 fell back to 363 000 m^3 (with a value of US$ 59 million) and in 1992 to 190 000 m^3 (with a value of US$ 37 million). Sabah and Sarawak export keruing in even larger amounts. In Sabah the export of round logs in 1987 was 1.1 million m^3 with a value of US$ 85 million; exports in 1992 were 234 000 m^3 of logs and 260 000 m^3 of sawn timber with a total value of US$ 87 million.

The annual export of keruing from the Philippines was in 1980 and 1981 over 100 000 m^3 (worth US$ 7–8 million); more than 90% of the exported timber volume was unprocessed. Exports fell to 6000 m^3 (worth US$ 850 000) in 1987 (entirely sawn timber), and to only 22 m^3 (worth US$ 3000) in 1990. In Thailand, keruing timber is mostly for local use. In 1986 the production was 706 000 m^3, but it fell dramatically to 203 000 m^3 in 1989 and 48 000 m^3 in 1990, illustrating the decline of the natural forest.

The annual production of keruing wood-oil in Thailand peaked in 1984 with 1.7 million l, but fell to 640 000 l in 1989 and 293 000 l in 1990.

Properties Keruing is a moderately heavy to heavy hardwood. The sapwood is yellowish to greyish-brown and usually distinctly demarcated from the heartwood, which is greyish-brown to red-brown, usually not distinctly lustrous on planed surfaces. The density is (500–)600–980(–1070) kg/m^3 at 15% moisture content. The grain is straight, sometimes interlocked, texture moderately coarse to coarse but even. The wood has a distinctive smell of resin and the surface is often sticky.

At 15% moisture content, the modulus of rupture is 76–133 N/mm^2, modulus of elasticity 12 900–22 300 N/mm^2, compression parallel to grain 43–68 N/mm^2, compression perpendicular to grain 5–9 N/mm^2, shear 6–12.5 N/mm^2, cleavage 53–76 N/mm radial and 56–93 N/mm tangential, Janka side hardness 3575–7300 N and Janka end hardness 4250–6135 N.

Keruing is a timber with high shrinkage. The rate of shrinkage from green to 15% moisture content is (1.6–)2.0–4.7% radial and (3.5–)4.0–7.0(–7.4)% tangential, from green to oven dry (3.5–)5.0–7.0% radial and (8.5–)9.6–13.0(–13.5)% tangential. The wood is rather difficult to dry because of this high shrinkage and the great difference between radial and tangential shrinkage; it is prone to cupping, bowing, springing and end checking. Usually there is little splitting, surface checking, staining and insect attack during drying. Boards of 15 mm, 20 mm, 40 mm and 50 mm thick take about 3, 4, 5 and 8 months, respectively, to air dry. For kiln drying of 25 mm thick boards, kiln schedule D is recommended in Malaysia. The kiln-drying characteristics differ between species. Wood of *D. grandiflorus* is very resinous and 25 mm thick boards may take up to 15 days to kiln dry from 50% to 10% moisture content and are prone to cupping and bowing. *D. cornutus* boards can be dried in about 7 days and show considerably less warping. Hence, when wood of various species of keruing is to be kiln dried as a mixed charge, the wood should be sticker-stacked at 450 mm spacing and a longer equalization treatment of 2–3 days is recommended. Resin exudation can be reduced, if desired, by using moderately low dry-bulb temperatures.

The working properties vary with the resin and silica content of the wood. In general, keruing is easy to cross cut but slightly difficult to resaw as the resin tends to clog the sawteeth. Wood with a high silica content quickly blunts sawteeth. Occasionally dabbing the saw with kerosene, and frequent sharpening, can overcome the problem. With a few exceptions (e.g. *D. baudii*) keruing is easy to plane and gives smooth to moderately smooth surfaces. Ease of boring ranges from easy to slightly difficult with smooth to moderately smooth surfaces. *D. cornutus* wood has a tendency to split and tear grain during boring. Turning is usually slightly difficult, giving rough surfaces. Keruing is peeled for plywood manufacture, especially for the structural grade. The resin interferes with the gluing properties and the species which are too oily are generally not used. Resin patches are usually seen on the surface of the veneer. Preheating is essential for good peeling. Keruing flakes can be used as core material in the manufacture of 3-layered particle board, while a lighter wood can be used for faces. Hardboard made from keruing was found to have similar mechanical properties but better water repellency when compared with hardboards made from Japanese oak and beech wood. In general, keruing is a technically suitable raw material for hardboard production. Heat-tempered hardboard made from *D. crinitus* wood was found to meet the requirements of the British standards.

Graveyard tests in Malaysia showed an average service-life of stakes (50 mm × 50 mm × 600 mm) in contact with the ground ranging from 0.8 years for *D. kerrii* to 4.1 years for *D. verrucosus*. Under temperate conditions, stakes may last 10–15 years. Most keruing wood is classified as moderately durable. The resistance to wood rotting fungi is quite variable, and to dry-wood termites usually poor, except wood of *D. elongatus* and *D. lowii*. In general, the sapwood is readily susceptible to fungal, borer and dry-wood termite attack and should be rejected. Keruing is fairly resistant to marine borers (mean service life of 6–7 years). Preservatives are absorbed very readily by most keruing species, with the exception of *D. crinitus* and *D. lowii*. An absorption of 100–130 kg/m^3 of an equal mixture of creosote and diesel fuel can be obtained when using the open tank method, and 300 kg/m^3 of copper-chromium-arsenic based preservatives, using the full-cell pressure treatment. Treated keruing can be very durable in exposed conditions, more than 20 years in the tropics.

Wood of *D. gracilis* contains 51% cellulose, 19% lignin, 17% pentosan, 0.9% ash and 0.6% silica. The solubility is 3.9% in alcohol-benzene, 0.3% in cold water, 3.2% in hot water and 11.7% in a 1% NaOH solution. The energy value is 20 425 kJ/kg.

The resin consists of sesquiterpenoids, and has fungicidal and termiticidal properties, as was demonstrated for *D. kerrii*.

Description Medium-sized to large, resinous trees of up to 65 m tall; bole usually branchless for as much as 35 m, straight with little taper, with a diameter often exceeding 150 cm with a maximum of 260 cm and usually with small and concave or sometimes tall and straight stout buttresses; bark surface orange-brown bleached by the sun 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 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 in dormant stage, prominent and specifically diagnostic, not much broader than the twigs. Leaves alternate, simple, leathery, rarely thin, 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; petiole geniculate at the joint with the lamina, stout or slender; stipules paired, large, hastate to lorate, obtuse, more or less succulent, caducous, characteristically carpeting the forest floor in the growing season. Inflorescence simple or branched, racemose, short, stout, zigzag, 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, or rarely all 5 short; petals large, oblong to narrowly oblong, strongly contorted, loosely cohering at base on falling, 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.

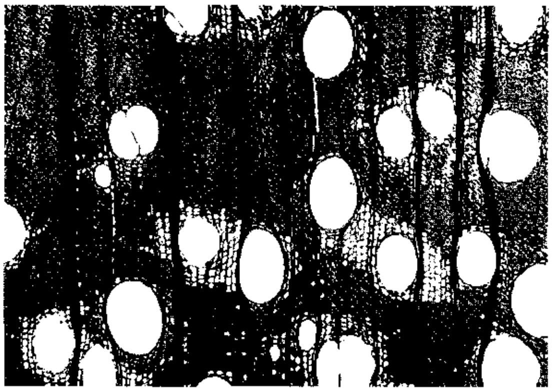
Wood anatomy

– Macroscopic characters:

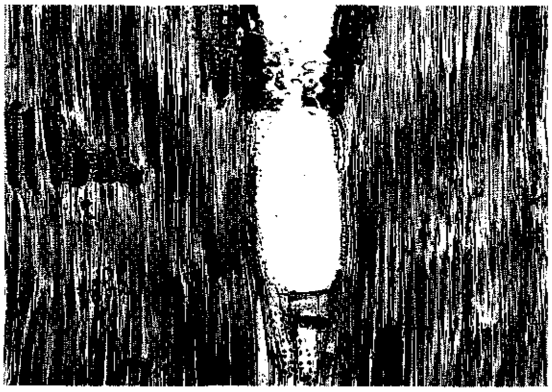
Heartwood varying from greyish-brown, pink-brown to red-brown, sometimes with a purple tinge, darkening on exposure, sapwood pale with grey tinge, 50–75 mm wide, often but not always clearly demarcated from the heartwood, some species with characteristic white blotches. Grain straight, interlocked grain rare, fissile. Texture medium to coarse, even. Growth rings indistinct; vessels medium-sized to moderately large, mostly visible to the naked eye as individual pores, vessel lines long and conspicuous on longitudinal surfaces, varying amounts of tyloses visible; parenchyma absent or sparse; rays of two sizes, fine and larger sized ones individually distinct to the naked eye; ripple marks absent. Axial intercellular canals in short tangential arcs spanning several rays, empty or filled with chalky white or black resin often producing resinous exudation on end surfaces.

– Microscopic characters:

Growth rings indistinct. Vessels diffuse, 3–10/mm^2, predominantly solitary (over 95%), a few in pairs, uniformly distributed, tending to oblique arrangement, distinctly oval, average tangential diameter (120–)180–250(–280) μm; perforation plates simple, horizontal and rounded; intervessel pits sparse, loosely alternate, rounded, tending to be horizontally elongated, vestured, pit border diameter approximately 5–7 μm; vessel-ray pits simple, rounded, with large apertures of c. 20 μm; tyloses varying from sparse to abundant. Vasicentric tracheids few to common. Fibres 1.7–2.0 mm long, non-septate, walls moderately thick to thick, pits small, distinctly bordered. Parenchyma paratracheal, partially surrounding pores, to aliform with short wings, diffuse, surrounding axial intercellular canals, in 4–5-celled strands, free from extraneous materials. Rays 6–8/mm, uniseriate and multiseriate, the latter 3–6(–8) cells wide, up to 2.0 mm high, heterocellular with 1–3 rows of square to upright marginal cells (Kribs type heterogeneous III and II, occasionally I), uniseriate rays few, short; sheath cells present. Silica bodies abundant in ray cells of all species; crystals absent; dark staining material usually abundant.



transverse section (×25)



radial section (×75)

tangential section (×75)

Dipterocarpus costatus

Horizontal intercellular canals absent; axial gum canals in short tangential series of 2–7 individual canals, (50–)80–120(–170) μm, smaller, as large as, or larger than the vessels, occasionally forming continuous tangential series in *D. confertus* and *D. elongatus*.

Species studied: *D. acutangulus*, *D. borneensis*, *D. caudatus*, *D. caudiferus*, *D. confertus*, *D. costatus*, *D. costulatus*, *D. crinitus*, *D. dyeri*, *D. elongatus*, *D. eurynchus*, *D. geniculatus*, *D. globosus*, *D. gracilis*, *D. grandiflorus*, *D. kunstleri*, *D. lowii*, *D. oblongifolius*, *D. palembanicus*, *D. rigidus*, *D. verrucosus*.

The axial gum canals arranged in typically short tangential series of 2–7 canals distinguish *Dipterocarpus* from most other *Dipterocarpaceae*. *Anisoptera* differs from *Dipterocarpus* by the wood lacking pink tints and by the lack of oblique arrangement of the vessels.

Growth and development Viable fruits start to germinate a few days to a few weeks after they have fallen on the ground. The radicle extrudes from the apex of the nut, causing the pericarp to split irregularly. The folded cotyledons remain in the nut close to the soil surface, but the plumule frees itself by elongating the petioles of the cotyledons. In some species with small nuts, the nuts may be raised from the ground. The plumule grows from between the petioles of the cotyledons, first producing a pair of opposite leaves, but with subsequent leaves arranged spirally; the leaves have large stipules. 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.

Keruing seedlings need shade for optimal growth. For *D. oblongifolius* maximum height increment after one year is obtained at about 30% of full daylight, but root weight (more important for transplanting) is maximum at about 60% of full daylight. Seedlings of *D. hasseltii* show optimal growth at 50% shading. The average annual height growth and annual diameter growth differ between species. In experiments in Java, *D. retusus* had an average height growth of 50 cm/year and an average diameter increment of 0.7 cm/year; for *D. grandiflorus* and *D. tempehes* the corresponding figures were 58 cm/year and 0.9 cm/year, and 83 cm/year and 0.9 cm/year, respectively. A comparatively large average annual height growth of 160 cm/year was reported for *D. gracilis* on Java. Several species may reach large bole diameters in a comparatively short time. The following bole diameters of 40-year-old planted trees have been reached or estimated in Malaysia: *D. oblongifolius* 79 cm, *D. kerrii* 74 cm, *D. costulatus* 73 cm, *D. baudii* 65 cm, *D. cornutus* 61 cm, *D. grandiflorus* 58 cm, *D. hasseltii* 52 cm, *D. chartaceus* 51 cm, and *D. crinitus* 48 cm. Other species appear to grow slowly, e.g. *D. kunstleri* and *D. palembanicus*, which reportedly reach maximum bole diameters after 40 years of only 24 cm and 20 cm, respectively, and *D. caudiferus* which needs over 150 years to reach a diameter of 75 cm (estimated in Sabah).

Some keruing species are reported to flower and fruit annually. Examination of flowering shoots of *D. oblongifolius* in Malaysia revealed alternating periods of flowering and vegetative growth; the tree investigated flowered and fruited annually in April – August and sometimes again in October – January. The apical reiteration of primary branches (i.e. starting new copies of its growth model) has been described for *D. kunstleri*.

Keruing trees probably need mycorrhizae for optimal growth, but data are lacking. Ectomycorrhizae have been recorded for *D. cornutus* and *D. obtusifolius*, but the identity of the fungal symbionts is unknown. Self-compatability has been demonstrated for *D. oblongifolius* in Malaysia.

Other botanical information The genus *Dipterocarpus* is characterized by its bark with warty lenticels, its generally amplexicaul stipule scars, its prominent resting 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*. *Dipterocarpus* has been divided into 5 sections on the basis of characters of the fruit calyx tube, but these do not correlate with other characters and they vary within a species. Natural hybrids between species of the genus have been observed and are mentioned in the subsequent species treatments. The hybrids are generally found in small patches together with the parent trees. *D. intricatus* Dyer, *D. tuberculatus* Roxb., and *D. turbinatus* Gaertner f. supply much of the timber used in Indo-China and Thailand, but they do not occur in Malesia.

Ecology Most species grow scattered, but some, such as *D. elongatus, D. gracilis* and *D. obtusifolius*, frequently occur gregariously. This may be due to their fire-resistance, their high germination rate or to peculiar chemical properties of the soil. Keruing species occur in evergreen forest, semi-evergreen forest or savanna woodland up to 1000(–1400) m altitude. In Thailand *D. obtusifolius* (and some other species) is frequently found in association with pines, forming the Pine-Dipterocarp association.

Propagation and planting Viability of the seeds is short. In the nursery, seeds should be sown immediately (no later than 7 days after collecting the nuts), preferably under a cover of dry hay, and kept continuously wet. Seeds of *D. humeratus* can be successfully stored for up to 8 weeks at half of their initial moisture content and at 15°C in sealed polyethylene bags filled with nitrogen gas. Seeds of *D. oblongifolius* survived at 4°C for at least 2 months. The germination rate, however, is often low. Tests in the Philippines showed a germination rate for *D. grandiflorus* of 56% and a survival percentage of seedlings of 22%; the comparable figures for *D. gracilis* are 16% and 6%, and for *D. hasseltii* are 14% and 3%, respectively. Fruits of *D. crinitus* seem to be particularly prone to insect attack and viable seeds are difficult to obtain. The weight of a nut of *D. crinitus* is approximately 1.5 g, for *D. gracilis* about 3 g. Germinated seeds are often immediately put into plastic bags and kept under shade. After one year the seedlings have reached 50 cm in height on average, and can be planted out in the field. It has been recommended to plant *Paraserianthes falcataria* (L.) Nielsen as a source of mycorrhiza and as a shade tree, before transplanting the keruing seedlings.

Experiments with vegetative propagation have had varying degrees of success, but were not successful at commercial levels. In Malaysia, stem cuttings of *D. chartaceus* showed a rooting success of 60–80%, and in the Philippines the air layering of *D. grandiflorus* resulted in only 10% of the branches developing roots. Wildlings of *D. retusus* survive much better than cuttings and are recommended as planting stock for enrichment planting.

In plantations spacing is 3 m × 3 m, 4 m × 4 m or 2 m × 4 m, to attain straight boles. In strip planting, spacing is 2–3 m in the strip, and 6–10 m between strips.

Silviculture and management Keruing 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 have been well established (about 120 cm tall) the canopy can be opened up, to speed up growth. Many species regenerate well only in primary forest, and for these species enrichment planting after selective cutting is recommended. In plantations, weeding is necessary during the first 3 years. Thinnings should be carried out after 5, 10, 15 and 25 years. In the first 2–3 years, shade trees are used such as *Acacia auriculiformis* Cunn. ex Benth. and *Paraserianthes falcataria*.

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. In Peninsular Malaysia the fungus *Cylindrocladium scoparium* is pathogenic to seedlings of *D. grandiflorus*.

Insects may damage seeds, e.g. *Alcidodes crassus (Coleoptera), Alcidodes dipterocarpi, Nanophyes shoreae (Coleoptera)* and *Cydia pulverula (Lepidoptera)*.

Harvesting Keruing timber is usually obtained from natural forests using selective cutting systems, just as for most other dipterocarp timbers. Fresh logs usually sink in water and cannot be transported by river, but the logs of species with lighter wood may float.

For firewood production, coppicing is an adequate method in Thailand to harvest trees of *D. obtusifolius* (a savanna species) with a diameter of less than 20 cm.

D. kerrii appears to be by far the most important species for tapping keruing oil in Malaysia. Other species tapped are *D. chartaceus, D. cornutus* and *D. gracilis*, and in Thailand also *D. baudii* and *D. costatus*. Usually the tap consists of an axe-cut hole in the stem, 90–120 cm from the base of the trunk, sloping down to the centre of the bole. The lower part of the notch is often hollowed out to catch the wood oil. The flow of wood oil is stimulated by firing which is spasmodic, depending on the flow of the oil. There have been no studies to test whether tapping does or does not affect timber production, but in Thailand tapping is usually done within 18 months before felling of the tree. It is reported that the maximum quantity of wood oil can be obtained when the bole is tapped on the side which bears the largest branch.

Genetic resources Although keruing is common over large areas, and is often outnumbered only by meranti (*Shorea* sp.), the trees usually occur scattered (e.g. in Thailand with an approximate density of 8 trees/ha). Indiscriminate logging of trees belonging to a genus with so many species may endanger the less common ones. The establishment of reserves of sufficient extent, located in areas with optimal species richness, seems to be the best way to protect genetic diversity.

Prospects The exploitation of keruing in Indonesia and Malaysia has gained importance towards the end of the 1980s. Keruing is now one of the valuable timbers in the development of the forest industry, particularly for the production of veneer and plywood (e.g. in Kalimantan). Keruing is only planted on a very small scale, and research on silvicultural aspects is urgently needed to enable large-scale planting to ensure supplies for the future.

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Selection of species

Dipterocarpus acutangulus Vesque

Compt. Rend. Hebd. Séances Acad. Sc. 78: 626 (1874).

Synonyms *Dipterocarpus tawaensis* v. Slooten

(1927), *Dipterocarpus helicopteryx* v. Slooten (1940), *Dipterocarpus appendiculatus* auct. non R. Scheffer.

Vernacular names Brunei: keruing beludu. Indonesia: mandurian putih, resak lebar daun, sagelam (East Kalimantan). Malaysia: keruing beludu (Sarawak, Sabah), keruing butik (Sarawak), keruing merkah (Sabah).

Distribution Peninsular Malaysia and Borneo.

Uses The timber is used as keruing.

Observations A large to very large tree of up to 60 m tall, bole cylindrical, branchless to a considerable height and with a diameter of up to 130 cm, buttresses few, short, rounded, bark surface reddish-brown to grey, inner bark reddish-brown, sapwood light ochre; buds ovoid, densely buff pubescent; leaves elliptical to ovate, or rhomboid, 7–10 cm × 3–6 cm, base obtuse or cuneate, apex with long acumen, secondary veins 7–12(–14) pairs, petiole and leaf beneath caducous densely pubescent, petiole 15–25 cm long, stipules linear, obtuse; fruit calyx tube globose or ellipsoid, with 5 ribs, surface warty, pruinose, 2 larger fruit calyx lobes about 10 cm × 2.5 cm, 3 shorter ones about 5 mm × 5 mm. *D. acutangulus* occurs in mixed dipterocarp forest, on sandy soils, on coastal hills and inland ridges up to 1000 m altitude. It is a polymorphic species; some collections have leaf characters intermediate between *D. acutangulus* and *D. globosus*. The density of the wood is 690–880 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 476, 677, 737, 746, 748.

Dipterocarpus alatus Roxb. ex G. Don

Gen. Syst. 1: 813 (1831).

Synonyms *Dipterocarpus philippinensis* Foxw. (1911).

Vernacular names Philippines: hairy-leafed apitong (general), apinau (Tagalog), ayamban (Iloko). 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.

Distribution Burma, Thailand, Laos, Cambodia, Vietnam and the Philippines (Luzon).

Uses The timber is used as keruing; *D. alatus* is a very important source of construction timber in Indo-China and Thailand.

Observations A medium-sized to fairly large tree of up to 40 m tall (but probably sometimes more), bole tall, straight, cylindrical, branchless for up to 20 m, up to 150 cm in diameter; buds lanceolate, yellow pubescent; leaves 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, petiole 2.5–4.5 cm long, stipules greyish-yellow 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. alatus* occurs gregariously along rivers in Indo-China and Thailand up to 500 m altitude. There it is a rapid colonizer of alluvial soils. In the Philippines it is rare, occurring in mixed dipterocarp forest in seasonal areas at low and medium altitudes. It was recently (1993) discovered that *D. alatus* and *D. philippinensis* are conspecific. The density of the wood is 620–905 kg/m^3 at 15% moisture content.

Selected sources 175, 235, 258, 579, 627, 628, 748.

Dipterocarpus applanatus v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 443, f. 5 (1940).

Vernacular names Indonesia: kekalup, keruing arong, lasang (East Kalimantan). Malaysia: keruing daun besar (Sabah), keruing arong (Sarawak).

Distribution Borneo.

Uses The timber is used as keruing.

Observations A large tree of up to 50 m tall, bole up to 160 cm in diameter, buttresses stout, up to 3 m tall, up to 2.5 m long, bark surface pale orange-brown, outer bark thin, brown, inner bark dark orange-brown, sapwood yellow, grading to a very hard orange-brown heartwood; buds broadly ellipsoid to falcate, tomentose; leaves broadly elliptical, undulate, 12–30 cm × 9–20 cm, glabrous, base obtuse to subcordate, apex abruptly acuminate, secondary veins 11–15 pairs, petiole 3.5–6 cm long, caducously shortly pubescent at base, stipules oblong, obtuse, concave; fruit calyx tube ovoid, 5-ribbed, glabrous, 2 larger fruit calyx lobes up to 19 cm × 4.5 cm, 3 shorter ones up to 1 cm × 1 cm. *D. applanatus* is locally common on sandy soils on sandstone, especially in valleys and on flat land near coasts. The density of the wood is 640–960 kg/m^3 at 15% moisture content content.

Selected sources 31, 258, 476, 748.

Dipterocarpus baudii Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 59, t. 5 (1841).

Synonyms *Dipterocarpus duperreana* Pierre

(1886), *Dipterocarpus scortechinii* King (1893), *Dipterocarpus pilosus* auct. non Roxb. p.p.

Vernacular names Indonesia: lagan sanduk, mara keluang (Sumatra). Malaysia: keruing bulu, keruing dadeh, damar minyak (Peninsular). Burma: kanyin wettaung, kahke. Thailand: yangkhon (general), yang-mot-khan, yung-daeng (peninsular). Vietnam: d[aaf]u l[oo]ng, d[aaf]u bao di.

Distribution Southern Burma, south-eastern and peninsular Thailand, southern Vietnam, Peninsular Malaysia and Sumatra.

Uses The timber is used as keruing. The wood yields an oleo-resin which is collected only locally and is used for caulking boats and illumination.

Observations A medium-sized tree of up to 30 m tall, bole branchless for up to 20 m, up to 64 cm in diameter, bark surface grey, diffusely lenticellate; buds lanceolate, tufted rufous tomentose; leaves more or less elliptical, 17–32 cm × 8–17 cm, base narrowly obtuse, acumen to 2 cm long, secondary veins 14–28 pairs, lower surface shortly tufted rufous tomentose, petiole 3–5 cm long, stipules lorate-lanceolate, fulvous stellate-tomentose; stamens 30; fruit calyx tube globose, smooth, glabrescent, 2 larger fruit calyx lobes up to 18 cm × 3 cm, 3 shorter ones to 2 cm × 1 cm. *D. baudii* occurs rather rare and scattered in low-lying, well-drained or semi-swampy forests or on low hills up to 800 m altitude. The density of the wood is 610–800 kg/m^3 at 15% moisture content. A natural hybrid between *D. baudii* and *D. grandiflorus* has been observed in Burma. See also the table on wood properties.

Selected sources 140, 235, 297, 417, 514, 628, 677, 748.

Dipterocarpus borneensis v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 445, f. 6 (1940).

Vernacular names Brunei: keruing sindor (Malay), resak kerangas (Iban). Indonesia: keruing daun halus (general), awang buah (East Kalimantan), tempudau (South Kalimantan). Malaysia: keruing sindor (Sarawak).

Distribution Eastern coastal Sumatra and Borneo (Kalimantan, Sarawak, Brunei).

Uses The timber is used as keruing, but is very resinous.

Observations A medium-sized tree of up to 30 m tall, bole often of poor shape, up to 64 cm in diameter and with low, rounded buttresses, bark surface with corky pustules, pale orange-brown, tending to turn pale greyish-white; buds ovoid, densely pinkish buff pubescent; leaves broadly ovate to elliptical, 7–12 cm × 3–7 cm, base obtuse or broadly cuneate, acumen to 8 mm long, secondary veins 9–12 pairs, lower surface sparsely shortly caducous pubescent on the veins, petiole 1.5–2.5 cm long, sparsely pubescent, stipules linear, acute; stamens about 25; fruit calyx tube narrowly ovoid to ellipsoid, with 5 narrow wings, glabrous, 2 larger fruit calyx lobes up to 7.5 cm × 1.8 cm, 3 shorter ones about 5 mm × 4 mm. *D. borneensis* is widespread but owing to its edaphic preferences mainly subcoastal. It occurs in heath forest on podzols or giant podzols below 350 m altitude. The density of the wood is 690–900 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 258, 748.

Dipterocarpus caudatus Foxw.

Philipp. Journ. Sc., Bot. 13: 177 (1918).

Vernacular names Brunei: keruing gasing. Malaysia: keruing gasing (Peninsular, Sarawak), keruing deran, songgi kuning (Peninsular). Philippines: tailed leaf apitong (general), apitong (Bikol).

Distribution Peninsular Malaysia, Sumatra, Borneo (Sarawak, Brunei, Sabah) and the Philippines.

Uses The wood is used as keruing; because of its comparative strength it is especially suitable for heavy construction work. The wood freely produces a wood-oil which has been commercially tapped.

Observations A large tree of up to 50 m tall, bole tall, straight, up to 125 cm in diameter, with low, rounded buttresses, bark surface greyish-brown, with small orange lenticels, flaky, inner bark pale yellow-brown, hard; buds narrowly falcate or linear, densely pale buff pubescent; leaves broadly elliptical (subsp. *caudatus*) or narrowly elliptical (subsp. *penangianus*), 7–11 cm × 3.5–5 cm, base cuneate, acumen up to 1.2 cm long, secondary veins 9–12 pairs, glabrous (subsp. *caudatus*) or sparsely pubescent (subsp. *penangianus*), petiole 1–1.5 cm (subsp. *caudatus*) or 1.5–2.5 cm long (subsp. *penangianus*), stipules linear, obtuse, shortly pubescent outside; stamens about 30; fruit calyx tube spherical to obovoid, minutely lenticillate, glabrous, 2 larger fruit calyx lobes up to 14 cm × 3 cm, 3 shorter ones 4–8 mm × 3–4 mm, recurved. *D. caudatus* is divided into two subspecies. Subsp. *caudatus* occurs in the Philippines, subsp. *penangianus* (Foxw.) P. Ashton (synonym: *D. penangianus* Foxw.) occurs in the other areas mentioned. *D. caudatus* occurs locally on well-drained flat or undulating land in the humid zone up to 600 m altitude. The density of the wood is 755–970 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 175, 253, 258, 497, 514, 579, 677, 737, 748.

Dipterocarpus caudiferus Merr.

Philipp. Journ. Sc. 29: 398 (1926).

Synonyms *Dipterocarpus macrorrhinus* v. Slooten (1927), *Dipterocarpus kutaianus* v. Slooten (1940).

Vernacular names Brunei: keruing puteh. Indonesia: andri, keruing anderi, keruing kutai (Kalimantan). Malaysia: keruing puteh (Sarawak, Sabah), keruing laran (Sarawak).

Distribution Borneo.

Uses The timber is an important source of keruing.

Observations A very large tree of up to 65 m tall, bole very tall, straight and cylindrical, up to 160 cm in diameter, buttresses few, up to 3.5 m tall, to 2 m long, and to 12 cm thick, bark surface pale pink-grey to pale brown, appearing smooth, inner bark pale yellow, turning pale yellowish-brown on exposure, hard, sapwood pale yellow, heartwood deep pinkish-brown; buds lanceolate, silky tomentose; leaves elliptical, 11–20 cm × 5–15 cm, base obtuse or cuneate, apex prominently acuminate, secondary veins 12–20 pairs, petiole 3–4 cm long, stipules linear; stamens 25; fruit calyx tube spherical, glabrous, smooth, 2 larger fruit calyx lobes 12–17 cm × 2–3 cm, 3 shorter ones 4–6 mm × 5–7 mm. *D. caudiferus* is a common lowland keruing in Borneo and occurs on clay soils in mixed dipterocarp forest on undulating land and hillsides below 800 m altitude. The density of the wood is 510–865 kg/m³ at 15% moisture content. The wood is considered poorly resistant to fungal decay, but not difficult to impregnate. See also the table on wood properties.

Selected sources 30, 258, 461, 476, 748, 790.

Dipterocarpus chartaceus Sym.

Gard. Bull. Str. Settl. 9: 322 (1938).

Synonyms *Dipterocarpus skinneri* auct. non King p.p.

Vernacular names Malaysia: keruing kertas, keruing bulu, getah (Peninsular). Thailand: yang-wat (general), yang-sian, yang-tang (peninsular).

Distribution Peninsular Thailand and Peninsular Malaysia.

Uses The timber is currently used as keruing. *D. chartaceus* is tapped for wood-oil which is used for varnish, caulking boats and illumination.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole with a diameter of up to 125 cm, buttresses absent, bark surface fissured, greyish-brown, scaly, sapwood rapidly becoming covered with oil; buds lanceolate-falcate, densely golden pubescent; leaves elliptical-ovate or rarely obovate, 8.5–19 cm × 4–9 cm, base cuneate, acumen to 1 cm long, secondary veins 10–12(–14) pairs, ascending, petiole 2.5–3 cm long, stipules lorate-lanceolate, short yellow pubescent; stamens 30; fruit calyx tube glabrescent, subglobose, smooth, 2 larger fruit calyx lobes up to 13 cm × 3 cm, 3 shorter ones up to 4 mm × 4 mm. *D. chartaceus* is comparatively rare and occurs in lowland dipterocarp forest or semi-swamp forest up to 600 m altitude. The density of the wood is 705–755 kg/m³ at 15% moisture content.

Selected sources 258, 264, 514, 628, 644, 677, 737, 748, 799.

Dipterocarpus confertus v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 322, f. 9 (1927).

Vernacular names Brunei: keruing kobis. Indonesia: kerubang tudang, keruing pungguh, keruing tempurung (Kalimantan). Malaysia: keruing kobis (Sabah, Sarawak), keruing kolong, keruing kelukop (Sabah).

Distribution Borneo.

Uses The timber is used as keruing. Wood-oil can be obtained from the bole which is locally known as 'tudan' and is used for torches.

Observations A medium-sized or rarely large tree of up to 50 m tall, bole cylindrical, up to 145 cm in diameter, buttresses up to 3 m tall, c. 15 cm thick, rounded, spreading, bark surface slightly ribbed, rust-red, or paler to grey, inner bark dark red-brown, sapwood pale yellow, heartwood light ashy red to reddish or dark brown; buds broadly ovoid, pale fulvous-brown tufted hispid; leaves broadly obovate to orbicular, (18–)22–35 cm × (14–)16–22 cm, base obtuse or subpeltate, apex obtuse or shortly acuminate, secondary veins 9–12 pairs, upper surface caducous hispid, venation beneath persistently tufted hispid, petiole 5–6 cm long, stipules broadly ovate, persistently hispid outside; stamens about 25; fruit calyx tube narrowly obovoid, with 5 indistinct ridges, densely tomentose, 2 larger fruit calyx lobes up to 14 cm × 3 cm, 3 shorter ones up to 1.7 cm × 0.7 cm. *D. confertus* is rather common but occurs scattered in mixed dipterocarp forest on low hills and undulating land below 800 m altitude. The density of the wood is 690–900 kg/m³ at 15% moisture content.

Selected sources 30, 31, 89, 251, 461, 476, 737, 746, 748.

Dipterocarpus conformis v. Slooten

Bull. Bot. Gard. Buitenzorg, ser. 3, 17: 102 , f. 13 (1941).

Vernacular names Brunei: keruing beludu kuning. Indonesia: keruing buah, lagan sanduk (Sumatra). Malaysia: keruing beludu kuning (Sabah, Sarawak).

Distribution Northern Sumatra and Borneo.

Uses The timber is used as keruing.

Observations A medium-sized to large tree of up to 50 m tall, bole straight, cylindrical, up to 125 cm in diameter, buttresses few, up to 2 m tall, up to 1 m long, rounded, thick, bark surface reddish to orange-brown or paler, flaking unevenly, outer bark thin, cork cambium grey, inner bark hard, brittle, red-brown, sapwood pale, dull, ochre-yellow; buds ovoid, pale pink-brown velutinate; leaves obovate, 20–40 cm × 12–15 cm (subsp. *conformis*) or 9–12 cm × 5–7 cm (subsp. *borneensis*), base obtuse or subcordate, narrowly subpeltate, acumen 4–8 mm long, secondary veins 13–15 pairs (subsp. *conformis*) or 15–18 pairs (subsp. *borneensis*), beneath persistently densely velutinous, petiole 1.5–6 cm long, stipules broadly ovate, outside pale pink-brown velutinous, caducous; stamens about 30; fruit calyx tube ellipsoid, persistently pubescent, with 5 incrassate wings, 2 larger fruit calyx lobes up to 10 cm × 2 cm, 3 shorter ones up to 8 mm × 8 mm. Within *D. conformis* two subspecies are recognized: subsp. *conformis* in Sumatra and subsp. *borneensis* P. Ashton in Borneo. It is comparatively rare and occurs on clay-rich soils in lowland or hill dipterocarp forest up to 800 m altitude. The density of the wood is 940–980 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 258, 476, 737, 746, 748.

Dipterocarpus cornutus Dyer

Fl. Brit. India 1: 296 (1874).

Vernacular names Indonesia: akas (East Kalimantan), keruing gajah (Sumatra, Kalimantan). Malaysia: keruing gombang, keruing pekat, keruing marah keluang (Peninsular).

Distribution Peninsular Malaysia, Sumatra, and southern and eastern Borneo.

Uses The wood is used as keruing and occasionally for charcoal production. The bole abundantly produces a wood-oil which is used as a varnish, for caulking boats and for illumination purposes.

Observations A very large tree, bole tall, bark surface pale, lighter than most other species; buds lanceolate, pale ochrous-cream puberulent; leaves broadly elliptical to oblong-ovate, 15–30 cm × 7.5–18 cm, base obtuse, apex obtuse or subretuse, secondary veins 18–21 pairs, densely persistently puberulent beneath, petiole 5–8.5 cm long, stipules lorate, narrowly obtuse, pale ochrous-cream puberulent outside; stamens 30; fruit calyx tube glabrescent, subglobose with 5 prominent distal tubercles, 2 larger fruit calyx lobes up to 21 cm × 5 cm, 3 shorter ones up to 15 mm × 15 mm. The density of the wood is 655–935 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 102, 253, 258, 264, 297, 318, 417, 461, 503, 514, 670, 737, 748, 799.

Dipterocarpus costatus Gaertner f.

Fruct. 3: 50, t. 187 (1805).

Synonyms *Dipterocarpus insularis* Hance (1876), *Dipterocarpus artocarpifolius* Pierre ex Lanessan (1889), *Dipterocarpus parvifolius* Heim (1903).

Vernacular names Malaysia: keruing bukit (Peninsular). Burma: kanyin in, kanyin po, kanyin-ywet-the. Cambodia: chhë: ti:ël bângku:ëy, chhë: ti:ël ni:ëng daèng. Laos: nha:ng dè:ng. Thailand: yang-pai (general), yang-khao (north-eastern), yang-kabueang (peninsular). Vietnam: d[aaf]u m[is]t, d[aaf]u c[as]t.

Distribution Burma, Thailand, Laos, Cambodia, Vietnam and Peninsular Malaysia.

Uses The timber is used as keruing. A wood-oil is collected from the tree.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole branchless for up to 20 m, with a diameter of up to 160 cm, and no buttresses, bark surface scaly, outer bark rather thick, reddish-brown; buds ovoid to lanceolate, pale golden-brown pubescent; leaves ovate or elliptical, 5.5–17 cm × 3–7 cm, base obtuse or broadly cuneate, acumen up to 6 mm long, secondary veins 11–13(–15) pairs, ascending, midrib densely persistently pubescent above, beneath sparsely, somewhat caducously pubescent, petiole 1.5–3 cm long, stipules lorate, tapering and subacute, adpressed pubescent; stamens 18–20; fruit calyx tube sparsely, somewhat caducously pubescent with 5 wings of up to 2 mm wide, 2 larger fruit calyx lobes up to 11.5 cm × 2.5 cm, 3 shorter ones to 15 mm × 15 mm. *D. costatus* occurs scattered or semi-gregariously on well-drained, acid soils in lowland and hill dipterocarp forest, in humid and seasonally dry areas, up to 1200 m altitude. The density of the wood is 740–970 kg/m^3 at 15% moisture content. A natural hybrid between *D. costatus* and *D. obtusifolius* has been observed in Thailand and Burma, and between *D. costatus* and *D. gracilis* in Thailand and Peninsular Malaysia.

Selected sources 102, 235, 253, 258, 389, 628, 677, 748.

Dipterocarpus costulatus v. Slooten

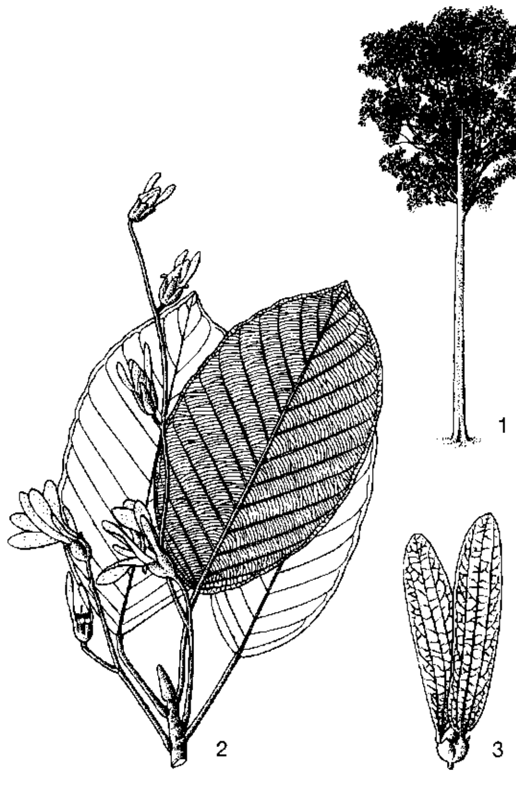
Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 315, f. 7 (1927).

Vernacular names Brunei: keruing kipas. Indonesia: keruing bajan (Sumatra, Kalimantan), keruing ladan, kyakat (West Kalimantan). Malaysia: keruing kipas (general), keruing marah keluang (Peninsular), kerubang (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *D. costulatus* is an important source of keruing.

Observations A large tree of up to 50 m tall, bole branchless for up to 35 m, up to 127 cm in diameter, buttresses rounded, up to 1.5 m tall, up to 1 m long, stout, bark surface grey or pale greenish-cream, uneven, but overall smooth, outer bark brown, inner bark dark pinkish ochre-brown to lighter ochre, sapwood light yellow-ochre, heartwood ochre-brown; buds falcate, glabrous and frequently pruinose; leaves broadly elliptical to ovate, 12–20 cm × 7–14 cm, base prominently cuneate, apex obtuse to shortly acuminate, persistently folded between the 11–14 pairs of secondary veins, glabrous, petiole 3–6 cm long, stipules lorate, subacute, shortly buff pubescent outside; stamens 24; fruit calyx tube glabrous, subglobose, with 5 prominent flange-like tubercles, 2 larger fruit calyx lobes up to 20 cm × 4 cm, 3 shorter ones up to 7 mm × 6 mm. *D. costulatus* occurs locally, on poor, often sandy soils on flat and undulating or sometimes periodically inundated land up to 600 m altitude. The density of the wood is 800–980 kg/m^3 at 15% moisture content.



Dipterocarpus costulatus v. Slooten – 1, tree habit; 2, flowering twig; 3, fruit.

Selected sources 31, 258, 476, 514, 677, 737, 748.

Dipterocarpus crinitus Dyer

Fl. Brit. India 1: 296 (1874).

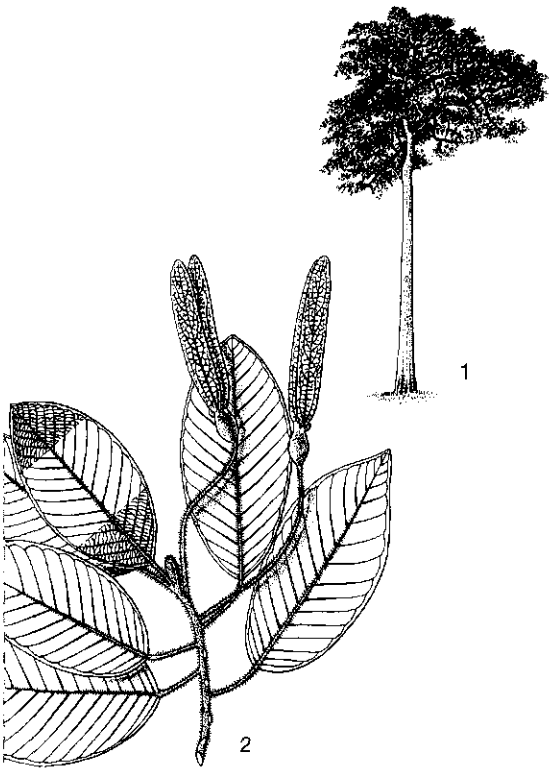
Synonyms *Dipterocarpus hirtus* Vesque (1874), *Dipterocarpus tampurau* auct. non Korth.

Vernacular names Brunei: keruing (m)empelas. Indonesia: keruing bulu (Sumatra, Kalimantan), amperok (East Kalimantan), mara keluang (Sumatra). Malaysia: keruing (m)empelas (general). Thailand: yang-khai (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses *D. crinitus* is an important source of keruing. The wood is occasionally used for pulp and paper production. Wood-oil, which is abundant, is collected from the bole. The bark is used for local houses.

Observations A large to very large tree of up to 60 m tall, bole tending to become irregular with age, up to 200 cm in diameter, buttresses absent or low, sometimes continuing up to 3 m as ridges, rounded, strongly concave, bark surface dark orange-brown to greyish, scaly, outer bark yellowish-brown to cream; buds oblong, golden-brown tufted tomentose; leaves elliptical, 6–9 cm × 3–5 cm, base obtuse, apex obtuse or shortly acuminate, secondary veins 13–15 pairs, fugaceous pubescent above and on the veins beneath, petiole 1.5–2.5 cm long, stipules lanceolate, obtuse, persistently golden tomentose outside; stamens 15; fruit calyx tube glabrous, spherical, smooth, 2 larger fruit calyx lobes up to 8 cm × 1.5 cm, 3 shorter ones up to 3 mm long. *D. crinitus* is widespread and occurs in mixed dipterocarp forest on



Dipterocarpus crinitus Dyer – 1, tree habit; 2, fruiting twig.

undulating land and low hills, on leached clay-rich soils, at low altitudes or rarely up to 850 m altitude. The density of the wood is 740–1070 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 102, 140, 258, 297, 318, 417, 461, 479, 514, 628, 677, 685, 737, 748, 799.

Dipterocarpus dyeri Pierre

Lanessan, Pl. util. colon. franç.: 297 (1886).

Vernacular names Malaysia: keruing etoi, keruing daun besar (Peninsular). Burma: kanyin thi. Cambodia: chhë: ti:ël chngâ:(r), chhë: ti:ël pruhs, chngâ:(r). Thailand: yang-klong (general), yang-man-mu, yang-sian (peninsular). Vietnam: d[aaf]u song n[af]ng.

Distribution Burma, Cambodia, Vietnam, Thailand and Peninsular Malaysia.

Uses The timber is used as keruing. Wood-oil is tapped from the bole.

Observations A medium-sized to fairly large semi-deciduous tree of up to 40 m tall, bole branchless for up to 25 m and up to 125 cm in diameter, buttresses low, bark surface pale grey or blackish-brown, outer bark yellowish-brown; buds ovoid-lanceolate, rufous silky velutinous; leaves narrowly ovate to elliptical, 16–40 cm × 7.5–14 cm, base broadly cuneate to subcordate, acumen up to 5 mm long, secondary veins 24–30 pairs, ascending, midrib above sparsely velutinous, below caducously sparsely velutinous, petiole 4–6 cm long, stipules lanceolate, subacute, persistently velutinous outside; stamens about 30; fruit calyx tube ellipsoid, glabrous, with 5 narrow ridges running from the apex along 2/3 of the length of the tube, 2 larger fruit calyx lobes up to 20 cm × 5.5 cm, 3 shorter ones up to 15 mm × 6 mm. *D. dyeri* occurs in semi-evergreen dipterocarp forest and *Schima*-bamboo forest, often along streams, on swamp edges or in valleys at low elevation. The density of the wood is 630–830 kg/m^3 at 15% moisture content.

Selected sources 102, 140, 162, 235, 258, 628, 677, 748, 799.

Dipterocarpus elongatus Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 62 (1841).

Synonyms *Dipterocarpus apterus* Foxw. (1932).

Vernacular names Brunei: keruing latek (Malay), ran (Iban, Dusun), kudan (Murut). Indonesia: keruing tempudau (Kalimantan), keruing pasir (Sumatra). Malaysia: keruing latek (Peninsular, Sarawak), keruing kasugoi (Sabah), keruing gumbang (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as keruing. The fruits are boiled and eaten as a vegetable.

Observations A large to very large tree of up to 60 m tall, bole straight, cylindrical, up to 175 cm in diameter, buttresses large, straight, up to 3 m tall, up to 2 m long, c. 20 cm thick, bark surface pale greyish, appearing smooth, sapwood pale pink-brown, heartwood darker; buds falcate, with a long red-brown tufted tomentum, sometimes glabrescent; leaves elliptical, 28–50 cm × 13–20 cm, base obtuse, apex shortly abruptly acuminate, secondary veins 25–38 pairs, beneath sparsely tomentose to glabrous, petiole 5–7 cm long, stipules hastate, acute, tufted tomentose outside; fruit calyx tube at first obovoid, later globose, with 5 obtuse distal tubercles, at first tomentose, later glabrescent, fruit calyx lobes equal, vestigial, up to 8 mm long, becoming recurved, obtuse. *D. elongatus* occurs in freshwater swamps, usually on sandy, periodically inundated soils at low altitude and is locally common in both primary and secondary forest. The density of the wood is 500–760 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 31, 89, 102, 140, 253, 258, 461, 677, 737, 746, 748.

Dipterocarpus eurynchus Miq.

Fl. Ind. Bat., Suppl. 1 (Prodr. Fl. Sum.): 485 (1861).

Synonyms *Dipterocarpus appendiculatus* R. Scheffer (1870), *Dipterocarpus eurynchoides* R. Scheffer (1870), *Dipterocarpus basilanicus* Foxw. (1918).

Vernacular names Brunei: keruing baran. Indonesia: keruing minyak (general), ansang ansang, keruing senium (Sumatra). Malaysia: keruing baran, keruing padi (Peninsular). Philippines: basilan apitong (general).

Distribution Peninsular Malaysia, Sumatra, Borneo and the southern Philippines.

Uses *D. eurynchus* supplies a general-purpose keruing timber.

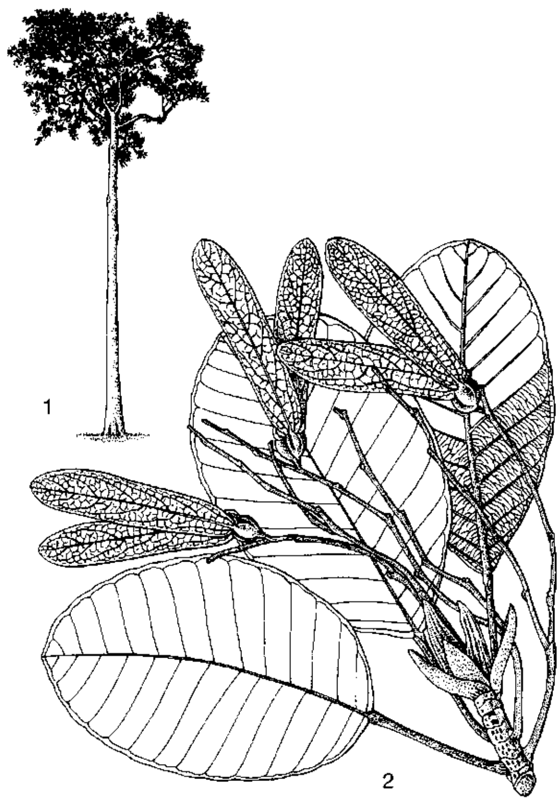
Observations A medium-sized to very large tree of up to 65 m tall, bole tall, straight or twisted, up to 110 cm in diameter, buttresses low, rounded, bark surface pale greyish-brown, irregularly cracked and flaked, inner bark hard, sapwood cream, hard, merging to the reddish-brown heartwood; buds conical, buff tomentose; leaves elliptical to obovate, 4–6(–10) cm × 2–3.5(–4.5) cm, base cuneate, apex subacute to shortly acuminate, secondary veins 8–9 pairs, sparsely pubescent beneath, petiole 0.5–1 cm long, stipules narrowly oblong, subacute, persistently pale grey-brown pubescent; fruit calyx tube glabrous, 5-winged, wings c. 2.5 mm wide, 2 larger fruit calyx lobes up to 8 cm × 2 cm, 3 shorter ones up to 7 mm × 5 mm. *D. eurynchus* is a polymorphic, comparatively rare and local species, and occurs on leached clay soils, undulating land and ridge tops in mixed dipterocarp forest up to 700 m altitude. The density of the wood is 590–800 kg/m³ at 15% moisture content.

Selected sources 30, 140, 461, 677, 737, 746, 748.

Dipterocarpus geniculatus Vesque

Compt. Rend. Hebd. Séances Acad. Sc. 78: 626 (1874).

Vernacular names Brunei: keruing kerubong, keruing guntang, keruing belimbing. Malaysia: keruing kerubong (Sarawak), keruing tangkai panjang (Sabah).



Dipterocarpus geniculatus Vesque – 1, tree habit; 2, fruiting twig.

Distribution Borneo.

Uses *D. geniculatus* is locally an important source of keruing.

Observations A large to very large tree of up to 60 m tall, bole tall, cylindrical, up to 200 cm in diameter, buttresses low and broadly rounded, sometimes continuing as ridges up to 2 m tall, bark surface pale or dark blackish-brown, very flaky, outer bark brown, inner bark reddish-brown, sapwood yellowish, inside pinkish-ochre, heartwood reddish-brown; buds broadly ovoid, pale cream tomentose; leaves elliptical to obovate, 7–12 cm × 5–7 cm (subsp. *geniculatus*) or 20–35 cm × 12–16 cm (subsp. *grandis*), base obtuse, apex obtuse or shortly acuminate, secondary veins 10–12 pairs, beneath sparsely pubescent to glabrescent, petiole 3–10 cm long, stipules broadly lanceolate, acute, shortly pale cream tomentose; stamens 30; fruit calyx tube obovoid, shortly densely persistently pubescent, 5-ridged, 2 larger fruit calyx lobes up to 12 cm × 2.5 cm (subsp. *geniculatus*) or 15 cm × 4 cm (subsp. *grandis*), 3 shorter ones about 1 cm × 1.5 cm. *D. geniculatus* is divided into two subspecies: subsp. *geniculatus* and subsp. *grandis* P. Ashton. It occurs on leached clay soils in lowland dipterocarp forest up to 400 m altitude. The density of the wood is 730–760 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 89, 258, 476, 748.

Dipterocarpus globosus Vesque

Compt. Rend. Hebd. Séances Acad. Sc. 78: 627 (1874).

Synonyms *Dipterocarpus beccarianus* Vesque (1874).

Vernacular names Brunei: keruing buah bulat. Malaysia: keruing buah bulat (Sarawak), keruing bulat (Sabah).

Distribution Borneo (Brunei, Sabah and Sarawak).

Uses The timber is used as keruing.

Observations A very large tree of up to 65 m tall, bole tall, cylindrical, up to 190 cm in diameter, buttresses many, up to 3.5 m tall, up to 2 m long, very broad and rounded, strongly concave, bark surface very pale brown; buds ovoid, chestnut tomentose; leaves broadly ovate, 10–14 cm × 7–9 cm, base broadly cuneate, acumen c. 4 mm long, prominently plicate, secondary veins 12–14 pairs, below fugaceous pubescent, petiole 2–2.5 cm long, stipules narrowly lanceolate, acute, outside persistently chestnut tomentose; stamens 24; fruit calyx tube ovoid, glabrous, usually 5-ribbed, sometimes smooth, 2 larger fruit calyx lobes 11–15 cm × 2.5–3.5 cm, 3 shorter ones 4–5 mm × 4–5 mm. *D. globosus* is locally abundant in mixed dipterocarp forest and heath forest on podzols below 400 m altitude. The density of the wood is about 870 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 89, 258, 737, 748.

Dipterocarpus gracilis Blume

Bijdr. fl. Ned. Ind. 5: 224 (1825).

Synonyms *Dipterocarpus pilosus* Roxb. (1832), *Dipterocarpus marginatus* Korth. (1841), *Dipterocarpus vernicifluus* (Blanco) Blanco (1845).

Vernacular names Brunei: keruing kesat. Indonesia: keruing keladan (general), wuluk bulan (Java), damar kacawai (southern Sumatra). Malaysia: keruing kesat (general), keruing kesugoi (Sabah). Philippines: panau (general), aganan (Bikol), lalian (Tagalog). Burma: kanyin, kanyin-ni. Thailand: yang-sian (general), yang-daeng (south-eastern), yung-hua-waen (peninsular).

Distribution Bangladesh, Burma, Thailand, Peninsular Malaysia, Sumatra, West Java, Borneo and the Philippines.

Uses *D. gracilis* is an important source of keruing, especially in Indo-China. A wood-oil can be obtained from the bole and is used as a varnish and for illumination.

Observations A large tree of up to 50 m tall, bole branchless for 30 m or more, cylindrical, up to 180 cm in diameter, buttresses small to large, rounded, bark surface reddish-brown, older patches pink-brown or grey, outer bark grey-brown, inner bark reddish-brown, brittle, sapwood ochre; buds narrowly conical, scabrid rufous tomentose; leaves elliptical to ovate, 8–15 cm × 4–10 cm, base obtuse, apex shortly acuminate, with 12–20 pairs of secondary veins, petiole 2–2.5 cm long, stipules narrowly lanceolate, outside persistently rufous tomentose; 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. 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. The density of the wood is 580–1000 kg/m^3 at 15% moisture content. See also the table on wood properties. A natural hybrid between *D. gracilis* and *D. costatus* has been observed in Thailand and Peninsular Malaysia.

Selected sources 30, 31, 35, 102, 140, 175, 235, 253, 258, 264, 318, 461, 472, 476, 483, 497, 579, 628, 677, 737, 748.

Dipterocarpus grandiflorus (Blanco) Blanco

Fl. Filip. ed. 2: 314 (1845).

Synonyms *Dipterocarpus griffithii* Miq. (1864), *Dipterocarpus pterygocalyx* R. Scheffer (1870).

Vernacular names Indonesia: aput (South Kalimantan), tempudau tunden (East Kalimantan), lagan bras (Sumatra). Malaysia: keruing belimbing (Peninsular, Sabah), keruing pekat (Peninsular). Philippines: apitong (general), dauen (Ibanag), hapitong (Tagalog). Burma: kanyin-byan. Thailand: yang-yung (general), yang-tang, yung-krabueang (peninsular). Vietnam: d[aaf]u d[oj]t t[is]m.

Distribution The Andaman Islands, Burma, Thailand, Vietnam, Peninsular Malaysia, Sumatra, Borneo and the Philippines.

Uses *D. grandiflorus* is an important source of keruing. The wood is used as pulp in the production of paper. Large quantities of oleo-resin (called 'balau' or 'minyak keruing') can be obtained from the wood. A tannin-formaldehyde adhesive can be produced from bark extracts.

Observations A medium-sized to large tree of up to 43 m tall, bole straight, cylindrical, branchless for up to 30 m, up to 135 cm in diameter, buttresses absent or few, up to 1.5 m high and 1 m long, blunt, bark surface slightly fissured, grey or light yellowish, sapwood not sharply contrasted from the reddish-brown heartwood; buds ovoid, pale buff pubescent; leaves ovate, 10–18 cm × 5–12 cm, base obtuse or subcordate, acumen up to 1 cm long, secondary veins 15–17 pairs, glabrous, petiole 3–9 cm long, stipules oblong-lanceolate, subacute, outside densely buff pubescent; stamens 30; fruit calyx tube ellipsoid, 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. 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. The density of the wood is 650–945 kg/m^3 at 15% moisture content. See also the table on wood properties. A natural hybrid between *D. grandiflorus* and *D. baudii* has been observed in Burma.

Selected sources 102, 140, 162, 175, 235, 253, 258, 297, 417, 449, 461, 466, 476, 497, 501, 514, 565, 579, 607, 628, 632, 677, 737, 748, 815.

Dipterocarpus hasseltii Blume

Fl. Java 2: 22, t. 6 (1829).

Synonyms *Dipterocarpus tampurau* Korth. (1841), *Dipterocarpus balsamiferus* Blume (1852), *Dipterocarpus subalpinus* Foxw. (1913).

Vernacular names Indonesia: keruing bunga (general), jempinang (Java), keruing tampudan (Kalimantan). Malaysia: keruing ropol, keruing laut (Peninsular), keruing kerukup kechil (Sabah). Philippines: Hasselt's panau, Palawan panau, highland panau (general). Thailand: yang-kliang, yang-tai (general), yang-man-sai (peninsular). Vietnam: d[aaf]u r[as]i.

Distribution Vietnam, peninsular Thailand, Peninsular Malaysia, Sumatra, Java, Bali, Borneo and the Philippines.

Uses *D. hasseltii* is an important source of keruing timber. The wood-oil is frequently collected and used locally for caulking boats, varnish and illumination.

Observations A large tree of up to 45 m tall, bole strongly tapering, up to 150 cm in diameter, buttresses flattish, bark surface greyish-green, outer bark thin, inner bark pinkish to red-brown, sapwood ochre, heartwood red-brown; buds falcate-lanceolate, glabrous; leaves elliptical, 9–16 cm × 5–10 cm, base cuneate, acumen up to 1 cm long, secondary veins 11–14 pairs, ascending, glabrescent or the veins beneath sparsely puberulent, margin more or less prominently crenate, petiole 2.5–4 cm long, stipules lorate-lanceolate, subacute, glabrous; stamens 30; fruit calyx tube subglobose, smooth, 2 larger fruit calyx lobes up to 22 cm × 3 cm, 3 shorter ones up to 15 mm × 13 mm. *D. hasseltii* occurs mostly on well-drained but moist fertile red soils in lowland dipterocarp forest in valleys and on hillsides, up to 600 m altitude. The density of the wood is 500–980 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 35, 102, 140, 162, 175, 189, 253, 258, 318, 461, 476, 514, 628, 677, 737, 748, 761.

Dipterocarpus humeratus v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 308, f. 4 (1927).

Synonyms *Dipterocarpus gibbosus* v. Slooten (1927), *Dipterocarpus ursinus* v. Slooten (1961).

Vernacular names Brunei: keruing latek bukit, keruing latek (Malay), ran (Iban). Indonesia: jelatong bulan, lagan (Sumatra). Malaysia: keruing kerukup (Sabah), keruing latek bukit (Sarawak).

Distribution Northern and eastern Sumatra and Borneo.

Uses The timber is used as keruing.

Observations A large tree of up to 50 m tall, bole tall, straight, cylindrical, up to 110 cm in diameter, buttresses up to 2 m tall, up to 8 cm thick, bark surface pink-brown, smooth, outer bark thin, inner bark dull pinkish-brown, sapwood pale ochre; buds narrowly conical, fulvous tomentose; leaves broadly ovate, 20–38 cm × 12–23 cm, base obtuse, apex obtuse to shortly acuminate, secondary veins about 20 pairs, beneath persistently shortly pubescent, petiole 4–6 cm long, stipules narrowly lanceolate, obtuse, outside long fulvous tomentose; stamens about 40; fruit calyx tube globose, glabrous, with 5 obtuse tubercles, 2 longer fruit calyx lobes up to 18 cm × 5 cm, 3 shorter ones up to 1.5 cm × 1.5 cm. *D. humeratus* occurs scattered or semi-gregariously on undulating land and clay ridges below 700 m altitude. The density of the wood is 730–800 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 258, 469, 476, 737, 746, 748.

Dipterocarpus kerrii King

Journ. As. Soc. Beng. 62(2): 93 (1893).

Synonyms *Dipterocarpus obconicus* Foxw. (1913), *Dipterocarpus cuneatus* Foxw. (1918), *Dipterocarpus perturbinatus* Foxw. (1918).

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

Distribution The Andaman Islands, peninsular Burma, peninsular Thailand, Peninsular Malaysia, northern Sumatra, Sabah and the Philippines.

Uses The timber is used as keruing. *D. kerrii* is regarded as the most important source of keruing wood-oil known as 'damar minyak' or 'gurjun balsam'.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole tall, branchless for up to 25 m, up to 150 cm in diameter, buttresses blunt, bark surface non-fissured, dark grey to yellowish-grey, flaky, outer bark thin, grey, inner bark pinkish-brown, brittle, sapwood pale ochre; buds lanceolate-falcate, glabrous; leaves 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, petiole 2–3 cm long, stipules linear-lanceolate, subacute, inside silky tomentose; 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. *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. The density of the wood is 555–875 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 140, 175, 253, 258, 264, 270, 297, 417, 476, 497, 514, 580, 628, 677, 737, 748, 799.

Dipterocarpus kunstleri King

Journ. As. Soc. Beng. 62(2): 96 (1893).

Synonyms *Dipterocarpus speciosus* Brandis (1895), *Dipterocarpus exalatus* v. Slooten ex Wood (1960).

Vernacular names Brunei: keruing kuntum puteh. Indonesia: keruing lagan (Kalimantan, Sumatra), lagan laweh daun (Sumatra), kambalong (Kalimantan). Malaysia: keruing gombang merah (general), keruing rapak (Sabah), keruing salatus (Peninsular). Philippines: broad-winged apitong, broadleaf apitong (general), hagakhak (Tagalog).

Distribution Peninsular Malaysia, Sumatra, Borneo and the Philippines.

Uses The timber is used as keruing. Wood-oil can be obtained from the bole.

Observations A small to fairly large tree of up to 40 m tall, bole straight but tending to branch low, up to 100 cm in diameter, buttresses usually few and small, up to 1 m tall, up to 1 m long, rather thin, bark surface brown or pale orange-brown, rarely grey, thinly flaky, outer bark thin (2.5 mm), inner bark red-brown grading inwards to yellowish-brown, sapwood pale brown to yellowish, heartwood dark brown; buds narrowly falcate, pale grey adpressed puberulent; leaves elliptical to broadly lanceolate, 13–22 cm × 7–10 cm, base cuneate, apex shortly acuminate, secondary veins 16–18 pairs, beneath glabrous or puberulent, petiole 2–3 cm long, stipules linear, outside densely minutely puberulent; stamens 30; fruit calyx tube glabrous, ellipsoid, 5-ribbed or almost winged, 2 larger fruit calyx lobes up to 11 cm × 1.5 cm, very variable in length, sometimes no longer than the shorter ones, 3 shorter ones to 6 mm × 5 mm. *D. kunstleri* is widespread and locally common on undulating or flat land, especially on clay alluvium. The density of the wood is 510–890 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 31, 102, 140, 175, 253, 258, 297, 306, 417, 461, 476, 514, 677, 737, 746, 748.

Dipterocarpus lowii Hook.f.

Trans. Linn. Soc., London 23: 160 (1860).

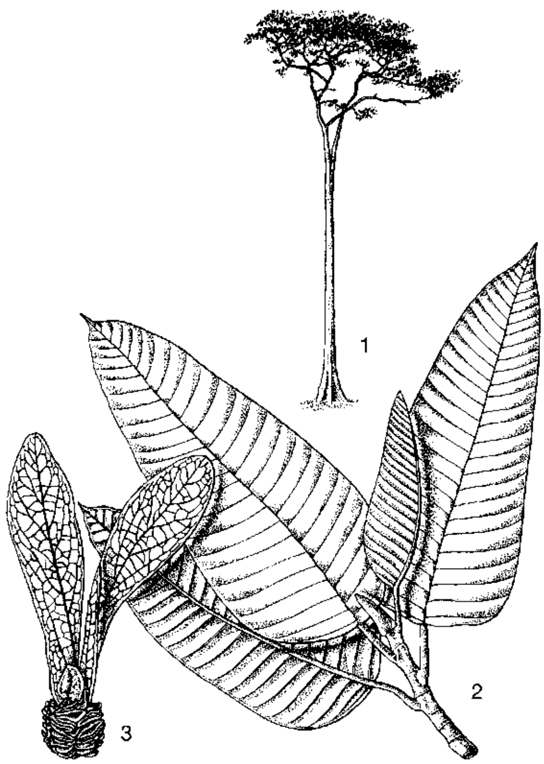
Synonyms *Dipterocarpus undulatus* Vesque (1874).

Vernacular names Brunei: keruing sol (Malay), resak butoh biawak (Iban). Indonesia: keruing batu (Sumatra, Kalimantan), sindur betul (West Kalimantan). Malaysia: keruing sol (general), kalup puteh (Sabah), keruing macham (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *D. lowii* is an important source of keruing timber. The bole contains abundant wood-oil.

Observations A large tree of up to 55 m tall, bole straight, up to 190 cm in diameter, buttresses up to 2.5 m high, spreading, bark surface chocolate-brown, evenly grey-brown flaked, not shaggy; buds broadly conical, frequently falcate, pale gold-



Dipterocarpus lowii Hook.f. – 1, tree habit; 2, sterile twig; 3, fruit.

en-brown pubescent; leaves ovate-lanceolate, 15–20 cm × 6–10 cm, base obtuse or cordate, apex obtuse or with up to 6 mm long narrow acumen, strongly plicate between the 15–20 pairs of secondary veins, midrib and veins below more or less densely caducously pubescent, petiole 1.5–3 cm long, stipules broadly deltoid, acute; stamens about 30; fruit calyx tube globose, glabrescent, with 5 wings completely hiding the tube by inward folds, 2 larger fruit calyx lobes up to 14 cm × 3.5 cm, 3 shorter ones 1.5–2 cm × 2 cm. *D. lowii* occurs on well-drained, leached, usually sandy soils in lowland dipterocarp forest up to 400 m altitude. It is locally common on ultrabasic soil in Sabah. The density of the wood is 770–930 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 31, 89, 140, 253, 258, 297, 417, 461, 476, 677, 737, 748.

Dipterocarpus mundus v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 446, f. 7 (1940).

Vernacular names Indonesia: kamurai, kensurai bukit, kerosit (Kalimantan).

Distribution Central Borneo.

Uses The timber is used as keruing.

Observations A large tree of up to 50 m tall, bole tall, straight, cylindrical, up to 95 cm in diameter, buttresses low, rounded, bark surface orange-brown, flaky; buds slender, glabrous; leaves narrowly elliptical to obovate, 5.5–16 cm × 2.5–7.5 cm, base narrowly obtuse, acumen to 8 mm long, secondary veins 8–10 pairs, straight, glabrous, petiole 1.5–3 cm long, stipules linear, caducous, inside pubescent; stamens 15; fruit calyx tube fusiform, glabrous, with 5 wings, each up to 7 mm wide, 2 larger fruit calyx lobes up to 11 cm × 2.5 cm, 3 shorter ones up to 8 mm × 8 mm. *D. mundus* occurs locally frequent in small scattered groups on ridges above 500 m altitude. The density of the wood is 785–940 kg/m³ at 15% moisture content.

Selected sources 31, 258, 748.

Dipterocarpus oblongifolius Blume

Mus. Bot. Lugd.-Bat. 2: 36 (1852).

Synonyms *Dipterocarpus stenopterus* Vesque (1874), *Dipterocarpus pulcherrimus* Ridley (1893).

Vernacular names Brunei: keruing neram (Malay), ensurai (Iban), kesugoi (Murut, Dusun). Indonesia: (b)ansurai (West Kalimantan). Malaysia: keruing neram (general), denderam (Peninsular), ensurai (Sarawak). Thailand: yang-khlong (general).

Distribution Peninsular Thailand, Peninsular Malaysia and Borneo.

Uses The timber is used as keruing; it is used locally for large padi-husking tables.

Observations A small or medium-sized tree of up to 35 m tall, bole often gnarled and twisted, up to 190 cm in diameter, bark surface pale grey, inner bark pink-brown, sapwood pinkish, heartwood soft, deep pink; buds linear, pale yellow tomentose; leaves narrowly elliptical to lanceolate, 14–18(–25) cm × 4–7(–9) cm, base cuneate, apex gradually tapering, acumen up to 1 cm long, slender, secondary veins 16–20 pairs, below densely more or less caducously tomentose, petiole 1.5–2 cm long, stipules linear, obtuse, outside pale yellow tomentose; stamens 15; fruit calyx tube narrowly obovoid or fusiform, with 5 wavy, narrow wings, 2 larger fruit calyx lobes 10–12 cm × 1.5 cm, 3 shorter ones about 10 mm × 3 mm. *D. oblongifolius* grows gregariously on the banks of fast-flowing inland rivers. Seeds germinate and seedlings become established below the flood-line. The density of the wood is 625–850 kg/m³ at 15% moisture content.

Selected sources 30, 31, 89, 102, 124, 140, 253, 258, 476, 514, 515, 602, 628, 677, 737, 748.

Dipterocarpus obtusifolius Teijsm. ex Miq.

Ann. Mus. Bot. Lugd.-Bat. 1: 214 (1863).

Synonyms *Dipterocarpus vestitus* Wallich ex Dyer (1874), *Dipterocarpus punctulatus* Pierre (1889).

Vernacular names Malaysia: keruing beludu, atoi (Peninsular). Burma: in bo, in byu, in hmwe sok. Cambodia: (daëm) thbaèng, thbaèng ba:y sra:, thbaèng snaèng. Laos: (maiz) s'a:d. Thailand: yang-hiang (general), krat (Thai, northern), ko satiang (Lua, peninsular). Vietnam: d[aaf]u tr[af] beng.

Distribution Burma, Cambodia, Laos, Vietnam, Thailand and Peninsular Malaysia.

Uses The timber is used as keruing.

Observations A small to medium-sized deciduous tree of up to 30 m tall, bole often of poor form, up to 20 m long, up to 80 cm in diameter, bark surface deeply fissured, greyish-brown; buds lanceolate, pale fulvous to buff hirsute or glabrous; leaves broadly ovate, 14–22 cm × 10–16 cm, base obtuse or subcordate, apex obtuse or subacute, prominently plicate, crenate in the distal half, secondary veins 14–20 pairs, ascending, petiole 2.5–4 cm long, stipules lorate, obtuse, outside tomentose; stamens about 30; fruit calyx tube subglobose, smooth, glabrescent, 2 larger fruit calyx lobes up to 15 cm × 3 cm, 3 shorter ones up to 15 mm × 10 mm. *D. obtusifolius* is a characteristic and frequently gregarious, fire-resistant tree in dry dipterocarp or bamboo forest. In Indo-China a glabrous form is distinguished and called var. *subnudus* Ryan & Kerr. The density of the wood is 750–900 kg/m^3 at 15% moisture content. A natural hybrid between *D. obtusifolius* and *D. costatus* has been observed in Thailand and Burma.

Selected sources 140, 235, 258, 628, 677, 748, 756.

Dipterocarpus palembanicus v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 336, f. 12 (1927).

Vernacular names Brunei: keruing ternek. Indonesia: lagan daun halus (southern Sumatra), lagan torop (northern Sumatra). Malaysia: keruing ternek (Peninsular, Sarawak), keruing palembang (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as keruing. The bole is tapped for oil in Peninsular Malaysia.

Observations A medium-sized to large tree of up to 50 m tall, bole straight, cylindrical, up to 120 cm in diameter, buttresses up to 1.5 m tall, bark surface orange-red, outer bark brown, thin, inner bark ochre, sapwood ochre; buds shortly oblong to conical, fulvous hirsute; leaves broadly elliptical to ovate (subsp. *palembanicus*) or oblong to ovate (subsp. *borneensis* P. Ashton), 10–14 cm × 5–9 cm (subsp. *palembanicus*) or 7–11 cm × 3–6 cm (subsp. *borneensis*), base obtuse or cuneate, acumen short or up to 2 cm long, secondary veins 12–14 pairs, beneath densely shortly puberulent, petiole 1.5–3 cm long, stipules narrowly hastate, acute, outside densely fulvous hirsute; stamens 15; fruit calyx tube narrowly ellipsoid, glabrous, broadly 5-winged, 2 larger fruit calyx lobes up to 10 cm × 3.5 cm, 3 shorter ones to 5 mm × 10 mm. *D. palembanicus* occurs locally on clay soils in mixed dipterocarp forest on hills up to 650 m altitude. The density of the wood is 595–785 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 140, 183, 258, 476, 677, 748, 799.

Dipterocarpus retusus Blume

Cat. 's-Lands Plantentuin: 77 (1823).

Synonyms *Dipterocarpus trinervis* Blume (1823), *Dipterocarpus macrocarpus* Vesque (1874), *Dipterocarpus pubescens* Koord. & Valeton (1899).

Vernacular names Indonesia: keruing gunung (Java, Sumatra), palahlar minyak (Java), jati olat (Sumbawa). Malaysia: keruing gunong (Peninsular). Cambodia: chhë: ti:ël prenh. Thailand: yang-khuan (general), tian kahom (Chong, south-eastern). Vietnam: ch[of] n[aa]u.

Distribution India (Assam), Burma, Laos, Cambodia, Vietnam, Peninsular Malaysia, Sumatra, Java and the Lesser Sunda Islands (Bali, Lombok, Sumbawa).

Uses The timber is used as keruing. The wood-oil is used for illumination.

Observations A medium-sized to large tree of up to 48 m tall, bole cylindrical, branchless for 15–20 m, up to 150 cm in diameter, bark surface slightly fissured, grey; buds ovoid-lanceolate, pale orange-rufous silky tomentose or glabrous; leaves broadly elliptical-oblong, 16–28(–50) cm × 7–17 (–20) cm, base obtuse, apex obtuse to emarginate, prominently plicate, secondary veins 16–19 pairs, ascending, glabrous, petiole 2.5–7 cm long, stipules lanceolate, acute, pale orange-rufous silky pubescent, glabrescent; stamens 30; fruit calyx tube subglobose, smooth, 2 larger fruit calyx lobes up to 25 cm × 4.5 cm, 3 shorter ones up to 2 cm × 1.5 cm. *D. retusus* is locally common and semi-gregarious and occurs in moist, evergreen to semi-deciduous montane forest, at 800–1500 m altitude, but as low as 100 m in seasonal areas. The density of the wood is 640–770 kg/m^3 at 15% moisture content.

Selected sources 35, 102, 140, 235, 253, 258, 318, 461, 466, 527, 628, 677, 737, 748, 793.

Dipterocarpus rigidus Ridley

Journ. Str. Br. Royal As. Soc. 82: 171 (1920).

Vernacular names Indonesia: bayan tuwung (South Kalimantan), keruing likat (Sumatra), tuyong (East Kalimantan). Malaysia: keruing chogan (Peninsular, Sarawak), keruing utap (Sarawak), keruing kelewar (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as keruing.

Observations A large tree of up to 50 m tall, bole up to 95 cm in diameter, buttresses up to 1 m tall, stout, concave, bark surface rust-brown, shallowly patchily flaked; buds conical, tomentose but glabrous on mature trees; leaves ovate, 13–25 cm × 8–16 cm, base broadly cuneate, acumen up to 1 cm long, secondary veins 12–16 pairs, beneath shortly densely pubescent, petiole 3–6 cm long, stipules lorate, subacute, outside tomentose but glabrescent; stamens 24; fruit calyx tube subglobose, 5-tuberculate, glabrous, 2 larger fruit calyx lobes up to 18 cm × 5 cm, 3 shorter ones up to 8 mm × 8 mm. *D. rigidus* is locally abundant and sometimes semi-gregarious in forest on dry soils on coastal hills. The density of the wood is 705–965 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 102, 140, 189, 253, 258, 677, 737, 746, 748.

Dipterocarpus sublamellatus Foxw.

Mal. For. Rec. 10: 92, pl. 8 (1932).

Vernacular names Indonesia: lagan buih, masibuk (Sumatra), malitan (East Kalimantan). Malaysia: keruing kerut (general), keruing padi, keruing sugi (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *D. sublamellatus* is an important source of keruing timber in Peninsular Malaysia. A wood-oil can be obtained from the bole.

Observations A large or very large tree of up to 70 m tall, bole tall, up to 255 cm in diameter, buttresses low, 10–15 cm thick, straight to slightly concave, bark surface scaly, dark orange-brown, outer bark brown, inner bark orange-brown, sapwood straw-yellow, grading into the hard rusty-brown heartwood; buds ellipsoid-ovoid, pale fulvous hirsute, rarely glabrous; leaves ovate to elliptical, 5–15 cm × 3.5–8 cm, base broadly cuneate, acumen short, up to 1 cm long in young trees, secondary veins 8–12 pairs, beneath sparsely caducously pubescent, petiole 1.5–3 cm long, stipules lorate, acute, outside densely hirsute; stamens about 24; fruit calyx tube globose, with 5 undulate wings, 2 larger fruit calyx lobes up to 12 cm × 3 cm, 3 shorter ones up to 5 mm × 7 mm. *D. sublamellatus* is locally common, especially in moist places and occurs on undulating land and low hills up to 500 m altitude. The density of the wood is 675–880 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 140, 253, 258, 297, 417, 476, 677, 748, 799.

Dipterocarpus tempehes v. Slooten

Reinwardtia 5: 468, f. 4 (1961).

Vernacular names Indonesia: keruing tempehes (general), bayan (South Kalimantan), karup (East Kalimantan). Malaysia: keruing assam (Sabah), keruing tepayang (Sarawak).

Distribution Borneo.

Uses *D. tempehes* is an important source of keruing timber in Sabah and parts of Sarawak, less so elsewhere.

Observations A medium-sized to large tree of up to 45 m tall, bole up to 110 cm in diameter, buttresses up to 2 m tall, up to 3 m long, about 10 cm thick, bark surface flaky, yellow-brown, papery, outer bark pale greyish-brown, inner bark reddish-brown, sapwood pale ochre; buds lanceolate, buff pubescent; leaves broadly elliptical to obovate, 6–12 cm × 3.5–8 cm, with broadly cuneate base and acute to shortly abruptly acuminate apex, with 9–12 pairs of sharply ascending secondary veins, petiole 1–2 cm long, stipules lorate, acute, outside shortly buff pubescent; stamens about 30; fruit calyx tube glabrous, turbinate, with unraised but prominent pale lenticels, the 5 calyx lobes vestigial. *D. tempehes* is locally abundant and occurs on flat, low-laying clay soils, generally near freshwater swamps or on stream banks. The density of the wood is 530–805 kg/m^3 at 15% moisture content.

Selected sources 31, 258, 466, 476, 746, 748.

Dipterocarpus validus Blume

Mus. Bot. Lugd.-Bat. 2: 36 (1852).

Synonyms *Dipterocarpus affinis* Brandis (1895), *Dipterocarpus warburgii* Brandis (1895), *Dipterocarpus lasiopodus* Perkins (1904).

Vernacular names Indonesia: kambong, kaladan (south-eastern Kalimantan). Malaysia: keruing kasugoi (Sabah). Philippines: hagakhak (general), anahauon (Bikol), kamuyau (Ibanag).

Distribution Borneo and the Philippines; also as a plantation tree in the Philippines.

Uses *D. validus* supplies a general-purpose keruing timber. Wood-oil exudes copiously from the bole.

Observations A medium-sized or large tree of up to 50 m tall, bole branchless for up to 30 m, up to 175 cm in diameter, buttresses frequent on older trees, blunt or thin, up to 2.5 m tall and 1.5 m long, bark surface smooth, on older trees scaly, pale yellowish-brown or grey; buds lanceolate, rufous tomentose; leaves elliptical-oblong to ovate, 15–25 cm × 7.5–12 cm, base cuneate to obtuse, apex acute to acuminate with an up to 1 cm long acumen, secondary veins 22–28 pairs, straight, beneath sparsely puberulent, petiole 3.5–5 cm long, stipules lorate, outside densely long rufous tomentose; stamens about 30; fruit calyx tube turbinate, smooth, glabrous, 2 larger fruit calyx lobes up to 25 cm × 3.5 cm, 3 shorter ones up to 6 mm × 6 mm. *D. validus* is common and frequently gregarious both in primary and secondary forest and occurs on flat land, in freshwater swamp and on river banks or occasionally on low hills up to 300 m altitude. The density of the wood is 720–870 kg/m^3 at 15% moisture content.

Selected sources 175, 258, 476, 579, 746, 748.

Dipterocarpus verrucosus Foxw. ex v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 293 (1927).

Vernacular names Brunei: keruing merah. Indonesia: keruing beras (Kalimantan, Sumatra), ariung (East Kalimantan, Sumatra), bajan halus daun (South Kalimantan). Malaysia: keruing merah (general), keruing chayer, keruing terenek (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *D. verrucosus* is an important source of keruing timber, especially in Brunei and parts of Peninsular Malaysia. A wood-oil can be obtained from the bole.

Observations A large to very large tree of up to 60 m tall, bole straight, cylindrical, branchless for up to 35 m, up to 160 cm in diameter, buttresses up to 2 m tall, broad, bark surface flaky, uniform pale orange-brown or buff; buds narrowly falcate to narrowly conical, adpressed tufted golden-brown pubescent; leaves ovate, 6–12 cm × 3.5–6 cm, base cuneate, apex subacute or with an up to 5 mm long acumen, secondary veins 9–14 pairs, prominent, glabrous, petiole 1–2 cm long, stipules narrowly oblong, obtuse, outside sparsely pubescent; stamens 15; fruit calyx tube globose to slightly ovoid, smooth but verrucose lenticelled, glabrescent, 2 larger fruit calyx lobes up to 9 cm × 2 cm, 3 shorter ones up to 3 mm × 2 mm. *D. verrucosus* is locally frequent or semi-gregarious and occurs in mixed dipterocarp forest on clay-rich soil, with a preference for ridges below 650 m altitude. The density of the wood is 675–920 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 31, 140, 253, 258, 297, 417, 461, 476, 677, 737, 748.

T. Smitinand (general part, selection of species),
C. Phengklai (general part, selection of species),
W.C. Wong (properties),
J. Ilic (wood anatomy),
L.E. Groen (selection of species)

Dryobalanops Gaertner f.

Fruct. 3: 49 (1805).

DIPTEROCARPACEAE

$x = 7$; *D. oblongifolia, D. sumatrensis*: $2n = 14$

Trade groups Kapur: medium-heavy hardwood, e.g. *Dryobalanops oblongifolia* Dyer, *D. sumatrensis* (J.F. Gmelin) Kosterm. (until recently known as *D. aromatica* Gaertner f.).

Vernacular names Kapur: Borneo camphorwood, Brunei teak, Mahoborn teak (En). Capur (Fr). Indonesia: kamper (general). Malaysia: kapor, paiji (Sabah), kapur bukit (Sarawak). The names with 'camphor' and 'teak' should be avoided in view of possible confusion with true camphor wood (*Cinnamomum*) and true teak (*Tectona*), respectively.

Origin and geographic distribution *Dryobalanops* consists of 7 species and is confined to Peninsular Malaysia, Sumatra, Borneo and intervening islands. Two species (*D. oblongifolia* and *D. sumatrensis*) occur throughout this area, five others are confined to Borneo. Fossil records have shown that *Dryobalanops* occurred in West Java and southern India in the Tertiary.

Uses Kapur is an important construction timber for local use. It is used for both heavy and light construction in locations free of termites. Contradictory reports have been published about its usefulness in conditions where the wood is in contact with the ground. Kapur is used for furniture, joinery and heavy-duty packing cases; also for joints and beams, columns, poles, mining timber, handles, toys and coffins. Treated kapur is generally used for wharf deckings, bridges, ship building, vehicle bodies and railway sleepers. As a flooring timber it is suitable for conditions with medium-heavy traffic. Kapur is extensively used for plywood.

The construction of chipboard from kapur is regarded as commercially unattractive because the product is not particularly good and the wood, being comparatively dense, is expensive to pulp. Paper made of kapur is not of high quality because of the short fibres; long-fibred material has to be added.

Camphor can be yielded in crystalline form from cavities in the wood or as an oil from holes cut in the trunk. In former times, the yield of this camphor from *D. sumatrensis* was commercially much more important than the timber. The Dutch East India Company traded this camphor and exported it to China and Japan. The camphor has about the same properties as true camphor (from *Cinnamomum camphora* (L.) Presl). Kapur camphor has been used medicinally both externally and internally against coughs, asthma, headache, pains in the stomach or liver, and diseases in the urinogenerative system as well as against ulcers in mouth and nose, rheumatism, burns and wounded eyes. The camphor is also used in local ceremonies. The fruits (nuts) of some species are edible (e.g. *D. sumatrensis* and *D. oblongifolia*).

Production and international trade Kapur is a commercially important timber, particularly in Borneo. The export of round logs from Sabah in 1987 was 863 000 m^3 with a value of US$ 70 million, and in 1992 267 000 m^3 of logs and 97 000 m^3 of sawn timber with a total value of US$ 55 million. In Indonesia statistics on export of kapur are combined with those of keruing (*Dipterocarpus* spp.); the value of exported sawn timber of the combined group kapur/keruing was almost US$ 100 million in 1989. However, kapur only constituted about 18% of this value; the volume exported in 1989 was 83 000 m^3. Kapur is also important in Peninsular Malaysia, where in 1992 the export of sawn timber was 80 000 m^3 worth US$ 13 million.

Properties Kapur is a moderately heavy timber. The colour of the heartwood is rose-red to dark reddish-brown; the sapwood is yellowish-brown or pinkish. The planed surface is not particularly lustrous and the radial section shows a faint stripe figure. The density of the wood is 600–940(–1010) kg/m^3 at 15% moisture content. The grain is straight, shallowly to heavily interlocked or spiral, texture moderately coarse to coarse but even. Freshly cut wood has a distinct camphor-like odour which can be rather persistent in some species.

At 15% moisture content the modulus of rupture is 62–114 N/mm^2, modulus of elasticity 10 900–18 700 N/mm^2, compression parallel to grain 38–62 N/mm^2, compression perpendicular to grain 5-6 N/mm^2, shear 4–10.5 N/mm^2, cleavage 39–56 N/mm radial and 51–65 N/mm tangential, Janka side hardness 2330–5910 N and Janka end hardness 2265–7320 N.

The rates of shrinkage are medium to high: from green to 15% moisture content 1.7–2.1% radial and 3.8–4.6% tangential, from green to 12% moisture content 2.1–3.5% radial and 3.8–8.0% tangential, and from green to oven dry up to 4.4% radial and 9.6% tangential. Kapur timber seasons without any real difficulty, but is somewhat prone to splitting, end checking and surface checking. It takes respectively 2 and 5 months to air dry 12 mm and 38 mm thick boards of *D. sumatrensis*. For kiln drying, schedule E is used in Malaysia. Boards of 25 mm thick of *D. sumatrensis* can be kiln dried from 50% to 10% moisture content in 14 days, which is comparatively long for medium-heavy hardwood. Kapur is prone to warping, surface checking and end splitting during kiln drying. The boards should be end-coated and properly stacked.

The working qualities of kapur are moderately good. When green, the timber is easy to saw, although sawteeth may become clogged by resin; dabbing the saw blade with diesel oil minimizes this problem. Dry timber is less easy to saw because of the presence of silica. Saws with tip-hardened teeth are needed. Cross cutting is generally easy. Planing, boring and turning are easy, giving a smooth to moderately smooth surface. The nailing property is rated as poor. Kapur does not take a high polish without some filling.

Kapur is commercially peeled for making plywood, but the frequent presence of pinholes lowers the grade of the veneer. The extractives present may interfere with the gluing process and cause occasional delamination, especially when kapur veneers are glued together.

Kapur timber has a rather exaggerated reputation for durability. It may be rapidly destroyed by termites and should not be used in contact with the ground in the tropics. However, it is resistant

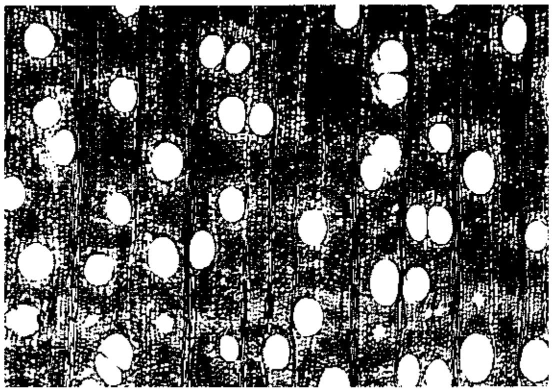
to fungi. Standard graveyard tests of sticks of *D. sumatrensis, D. oblongifolia* and *D. rappa* in Malaysia showed an average service life of 6.0, 1.9 and 2.5 years, respectively. The heartwood is resistant to impregnation with preservatives, even under pressure. The average absorbtion of an equal mixture of creosote and diesel fuel is 48 kg/m^3. The sapwood is liable to attack by powder-post beetles, but is permeable for preservatives.
Wood of *D. sumatrensis* contains 60% cellulose, 27% lignin, 16% pentosan, 0.8% ash and 0.6% silica. The solubility is 2.7% in alcohol-benzene, 2.6% in cold water, 3.9% in hot water and 12.9% in a 1% NaOH solution. The energy value is 18 800 kJ/kg.
Borneo camphor, found in cavities in the wood of *D. sumatrensis*, is crystallized oil. It consists of almost pure borneol.

Description Large or very large, occasionally medium-sized trees, up to 60(–75) m tall, with a straight, columnar bole, often branchless for 30 m or more and up to 150(–200) cm in diameter; buttresses well-developed and spreading; bark shaggily flaked, purplish-brown, the new bark yellowish-brown with very small lenticels; mature crown very large, but rather narrowly conical or dome-shaped, consisting of a few large and twisted branches; branchlets numerous, crowded towards the ends, slender and ribbed. Leaves alternate and simple, leathery, rounded to oblong, prominently acuminate, glossy green and with a camphor-like odour when crushed, with many, slender and straight secondary veins linked at the margin by a more or less visible intramarginal vein; petiole slender, distinctly channelled above; stipules linear, caducous. Inflorescence paniculate, lax and diffuse, few-flowered. Flowers bisexual, actinomorphic; calyx 5-lobed with imbricate, glabrous lobes; petals 5, united at base and falling from the tree to the ground in a rosette, white and glabrous; stamens c. 30, glabrous, with short, broad filaments connate at base and linear anthers crowned by small appendages; pistil 1, glabrous, with ovoid ovary, style c. 3 times longer than ovary, stigma minute. Fruit a comparatively large, glabrous nut, enclosed by but free from the fruit calyx which forms a cup at base with 5 subequal wings. Seed 1–2 cm long. Seedling with epigeal germination and 2 reniform, unequal, succulent cotyledons; first two pairs of leaves opposite, developed in one flush, next leaves arranged spirally.

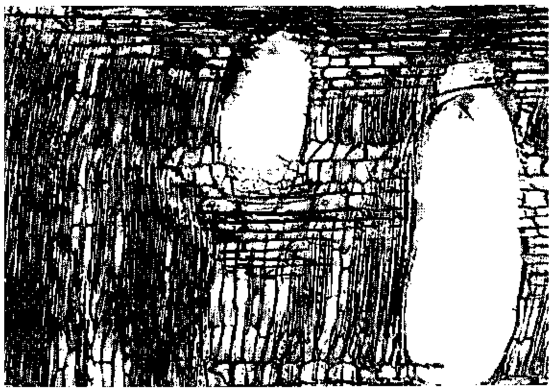
Wood anatomy

– Macroscopic characters:

Heartwood pink-brown or red-brown, darkening



transverse section (×25)



radial section (×75)

tangential section (×75)

Dryobalanops sumatrensis

on exposure to dark red-brown, clearly demarcated from the yellow-brown or pinkish sapwood (50–100 mm thick). Grain straight, occasionally wavy to interlocked. Texture medium to coarse, even; fiddleback figure sometimes present, fleck figure well pronounced on quartersawn wood, with medium lustre. Growth rings indistinct, but concentric bands of resin canals may give impression of growth rings on backsawn surfaces; vessels visible to the naked eye, tyloses variable, few to abundant; parenchyma moderately abundant, rays individually visible to the naked eye; ripple marks most prominent in *D. sumatrensis*, less so in other species, indistinct in *D. rappa*. Axial gum canals in tangential bands forming continuous lines, considerably smaller than vessels and filled with white contents, more obvious on backsawn surfaces. Freshly cut wood with pronounced camphor-like odour, persisting in *D. sumatrensis*.

– Microscopic characters:

Growth rings indistinct. Vessels diffuse, (5–)8–12(–17)/mm^2 (5/mm^2 in *D. fusca*, 17/mm^2 in *D. rappa*), solitary (90–95%), remainder in pairs, round to oval, average tangential diameter (130–)160–220(–240) μm (130 μm in *D. rappa*); perforation plates simple; intervessel pits rare, loosely alternate, vestured, pit border diameter 5–7 μm; vessel-ray pits simple, rounded, with large apertures of c. 20 μm; tyloses absent, or few to abundant. Vasicentric tracheids scarce to common. Fibres 1.5–1.7 mm long, non-septate, moderately thick- to thick-walled (in species with denser wood), pits indistinctly bordered to distinct and conspicuous, mainly in radial walls. Parenchyma paratracheal, incompletely vasicentric with an aliform tendency, sometimes diffuse tending to short aggregates, also surrounding canals; strand length 1–4 cells, distinctly storied in *D. sumatrensis*. Rays 4–6(–8)/mm, uniseriate and 3–6-seriate, the latter up to 1 mm high, weakly heterocellular with 1–3 rows of square to upright marginal cells (Kribs type heterogeneous III and II), uniseriates few, short; sheath cells occasionally present. Silica bodies sparse in parenchyma cells of *D. beccarii* and *D. oblongifolia*; coloured deposits common; silica bodies abundant in ray cells (sparse in *D. rappa*). Prismatic crystals in chambered strands of parenchyma in *D. keithii*, *D. lanceolata*, *D. oblongifolia*, abundant in *D. rappa*. Horizontal intercellular canals absent. Axial intercellular canals in tangential lines or bands, average diameter of gum canals 40–70 μm, commonly occluded with chalky white deposits.

Species studied: *D. beccarii*, *D. fusca*, *D. keithii*, *D. lanceolata*, *D. oblongifolia*, *D. rappa*, *D. sumatrensis*.

The axial gum canals distinguish kapur from non-dipterocarps, the arrangement of the axial canals in tangential lines (bands) from *Anisoptera*, *Cotylelobium*, *Dipterocarpus*, *Upuna* and *Vatica*. *Dryobalanops* differs from *Shorea* (meranti) by the presence of fibre-tracheids, the greater abundance of solitary pores, and the camphor-like odour.

Growth and development Kapur trees are evergreen, and flowering of trees in certain areas is more or less concurrent. Like most western Malesian dipterocarps, they flower and fruit profusely at irregular intervals, but more frequently than other genera in this area except for *Neobalanocarpus*. The trees are capable of rapid growth, and girth increments of as much as 12.5 cm per year have been recorded for *D. oblongifolia* in Peninsular Malaysia. This is, however, exceptional, and under normal conditions the trees have shown a mean annual girth increment of 3.4 cm. They may be expected to attain a diameter of about 65 cm in 60 years, but *D. lanceolata* has been recorded to grow 1.4 cm in diameter per year over 20 years.

Often the trees start to flower at the age of about 20 years. This is earlier than for most other *Dipterocarpaceae* but at almost the same age as *Anisoptera* and *Parashorea*. The flowers are pollinated by honey bees (*Apis* spp.). Kapur seeds have been observed to germinate before they are shed. Established seedlings can survive in the shade for a considerable time and can gradually grow through stands of secondary species. Seedlings of *D. lanceolata* are exceptional among dipterocarps in being highly shade tolerant, yet at the same time respond to full sunlight with height and diameter growth which is faster than any other dipterocarp.

Metamorphosis has been described for *D. sumatrensis*, i.e. loss of architectural model with the development of many subcrownlets which subsequently develop mutual avoidance.

Other botanical information The genus *Dryobalanops* is homogeneous and well-defined. It is closely related to *Parashorea*. It was recently discovered that *D. sumatrensis* is the correct name for the well-known species *D. aromatica*.

Ecology Kapur often occurs gregariously as a canopy tree in lowland dipterocarp forest and mixed peat-swamp forest; sometimes also in kerangas (heath forest) vegetation. The trees often grow on hillsides, ridges or near streams, up to 800 m altitude.

Propagation and planting The seed weight is about 10 g for *D. sumatrensis* and about 6 g for *D. lanceolata*. Seeds can only be stored for a short period (up to 16 days) at a temperature of 14°C and moisture content of 30%. Seed collection should begin as soon as the seed wings start to turn brown.

Seeds germinate rapidly: after 1–2 weeks for *D. sumatrensis* and after 2–3 weeks for *D. oblongifolia*. Germination in the nursery is usually good and simultaneous. The best response in height increment of first year *D. sumatrensis* seedlings in a shaded nursery in Malaysia was to 50 mg P_2O_5 and 300 mg nitrogen (such as ammonium sulphate) per pot, the nitrogen being applied in 3 doses at 2-month intervals. Like all dipterocarps, kapur roots are associated with mycorrhizae, and mycorrhiza infection should be realized for optimal growth of the seedlings. Seedlings at least 30 cm tall from nurseries or from natural regeneration are used for enrichment planting. Saplings of 40–70 cm tall can be cut and used as stump material. When planted in the field, spacing is 3 m × 2 m or 4 m × 3 m. Saplings of *D. sumatrensis* that were 11 years old, planted in the shade of a 7-year-old stand of *Leucaena leucocephala* (Lamk) de Wit in East Kalimantan, showed a survival rate of 84% after 4 months.

Silviculture and management Kapur is suitable for management under the selective logging system. Where kapur trees are abundant, it is not difficult to convert the forest into a practically pure stand in a single rotation. In years when trees fruit abundantly, natural regeneration occurs profusely. Opening of the canopy and removing undesirable species enhances the growth of seedlings. In areas with poor regeneration, enrichment planting of kapur may be practised and the success rate is higher than with other dipterocarps because of the drought tolerance of the seedlings.

Diseases and pests Brown pinhead spot caused by *Colletotrichum gloeosporioides* is reported as a leaf disease of *D. sumatrensis* in Malaysia. Seedlings in nurseries are reported to be susceptible to damage by termites, seedlings in the field to destruction by porcupines. Weevils of the genera *Alcidodes* and *Nanophyes* can attack the seeds.

Harvesting Kapur logs are subject to ambrosia beetle attack after felling, and often the trees are infested by a minute, unidentified borer, a beetle of the family *Lymexylonidae*, which does not affect the strength of the timber but detracts from its appearance. Neither the beetle nor the borer can survive in seasoned wood and quick extraction of the logs from the felling areas may be important. Camphor oil can be obtained by tapping the bole. To collect the solid camphor, the tree must be felled.

Yield Measurements of trees in Peninsular Malaysia have shown that trees with a mean diameter of 107 cm have an average timber volume of 18.2 m^3. In a 36-year-old plantation with a mean bole diameter of 27.4 cm the timber volume was 263 m^3/ha.

Genetic resources Since *Dryobalanops* species often occur gregariously or semi-gregariously, natural regeneration is usually abundant, even in logged-over forest. Thus, kapur is not very liable to genetic erosion unless the forest is destroyed completely.

Prospects Kapur seems very suitable for timber production in sustainably managed forest. As this form of forest management will gain more importance, kapur might be one of the most important timber producers in the near future.

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Selection of species

Dryobalanops beccarii Dyer

Journ. Bot. 12: 100 (1874).

Synonyms *Dryobalanops oocarpa* v. Slooten (1932).

Vernacular names Sabah kapur (En). Brunei: kapur bukit, kapur ranggi. Indonesia: kapur sintuk, keladan (Kalimantan). Malaysia: kapur bukit, kapur ranggi (Sabah, Sarawak), kapur merah (Sabah).

Distribution Borneo, except for the southern part.

Uses The timber is used as kapur; in Brunei it is valued as the best quality of kapur. The wood is said to yield camphor oil.

Observations A large to very large tree up to 65 m tall, with a straight bole up to 100 cm in diameter; bark yellowish, slash aromatic but without dammar; leaves ovate to lanceolate, 5–8 cm × 1.5–3 cm, with an up to 17 mm long acumen, glabrous; fruit calyx lobes up to 6.5 cm × 0.8 cm, finally patent, bordering a cup which is considerably narrower than the nut. *D. beccarii* is not common, but occurs locally abundantly on leached sandy soils on hills and ridges below 700 m altitude; also along streams and in seasonal swamps. The density of the wood is 600–710 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 318, 461, 561, 748.

Dryobalanops fusca v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 12: 39 (1932).

Vernacular names Indonesia: kapur empedu (Kalimantan). Malaysia: empedu, kapur empedu (Sarawak).

Distribution Western Borneo (southern Sarawak, West Kalimantan).

Uses The timber is used as kapur.

Observations A large tree reaching at least 50 m in height; slash lacking camphor smell; leaves broadly lanceolate, 5–10 cm × 2–4 cm, with a slender, up to 15 mm long acumen, densely shortly tomentose beneath; fruit calyx lobes up to 6 cm × 1.3 cm, bordering a cup which is up to 3 mm deep and up to 7 mm in diameter. *D. fusca* is locally common on sandy, podzolic soils on low ridges and raised beaches, and in kerangas vegetation. The density of the wood is 780–900 kg/m^3 at 15% moisture content.

Selected sources 31, 461, 561, 740, 748.

Dryobalanops keithii Sym.

Gard. Bull. Str. Settl. 10: 379 (1939).

Vernacular names Malaysia: kapur gumpait, kapur daun besar (Sabah).

Distribution Sabah.

Uses The timber is used as kapur.

Observations A medium-sized to fairly large tree up to 37 m tall, with bole up to 70 cm in diameter and often of poor form; leaves narrowly oblong to lanceolate or oblanceolate, 14–33 cm × 5–10 cm, with an up to 10 mm long acumen, glabrous and with depressed veins on upper surface; fruit calyx lobes broadly spatulate, up to 4 cm × 2 cm, bordering an up to 6 mm deep and up to 10 mm wide cup. *D. keithii* is locally common and always occurs near water on undulating land, up to 250 m altitude. The density of the wood is 700–835 kg/m^3 at 15% moisture content.

Selected sources 100, 561, 748.

Dryobalanops lanceolata Burck

Ann. Jard. Bot. Buitenzorg 6: 244 (1887).

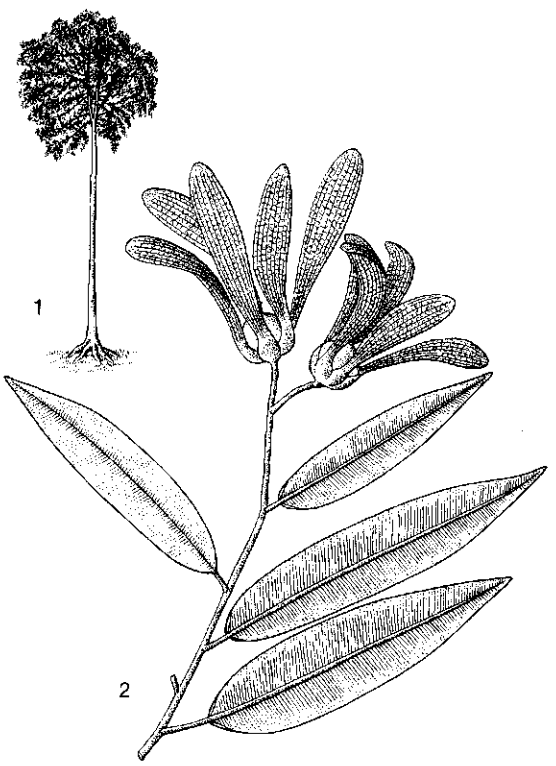
Synonyms *Dryobalanops kayanensis* Becc. (1902).

Vernacular names Sabah kapur (En). Brunei: kapur daram, kapur bukit. Indonesia: kapur tanduk (Kalimantan). Malaysia: kapur paji (Sabah, Sarawak), sesuan (Murut), tepurau (Kayan).

Distribution Northern and eastern Borneo.

Uses *D. lanceolata* is the most valuable kapur timber in Borneo. It is also the main source of Borneo camphor.

Observations A very large tree, occasionally up to 75 m tall, with a straight bole, branchless for 35 m or more, and having a diameter of up to 145 cm and buttresses of up to 4 m high and 3 m long; bark dull slate-grey or greenish-khaki, slash strongly aromatic; leaves lanceolate, 7–10 cm × 2–3.5 cm, with an up to 10 mm long acumen, glabrous; fruit calyx lobes spatulate, up to 9 cm × 2 cm, bordering a cup up to 5 mm deep and up to 20 mm wide. *D. lanceolata* is the tallest known dipterocarp, is common on fertile clayey soils on undulating land, and also grows on basic volcanic soils and calcareous shale, up to 800 m altitude; it is less frequent on ridges than other *Dryobalanops* spp. The density of the wood varies from 600–1010



Dryobalanops lanceolata Burck – 1, tree habit; 2, fruiting twig.

kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 318, 461, 561, 748.

Dryobalanops oblongifolia Dyer

Journ. Bot. 12: 100 (1874).

Vernacular names Indonesia: kapur guras, petanang (Sumatra). Malaysia: keladan, kapur paya (Peninsular), kelansau (Sarawak).

Distribution Eastern Peninsular Malaysia, eastern Sumatra and Borneo (Sarawak, East Kalimantan).

Uses The timber is used as kapur similar to that of *D. sumatrensis,* although the wood is sometimes regarded as slightly inferior. The fruit (nut) is edible.

Observations A large to very large tree, up to 55 m tall, with a straight bole free of branches for 20 m or more, having a diameter of up to 150 cm, and large buttresses; bark purplish-grey or light red-brown, slash aromatic and without dammar; leaves narrowly oblong, 6–20 cm × 2–5(–6.5) cm, with an up to 15 mm long acumen, glabrous; fruit calyx lobes shorter than nut, up to 0.5 cm × 0.7 cm, bordering an up to 15 mm deep and 15 mm wide incrassate cup. Two subspecies are distinguished: subsp. *oblongifolia* from Borneo, and subsp. *occidentalis* P. Ashton from Peninsular Malaysia and Sumatra, the latter differing in smaller leaves, less deep fruit calyx tube and striate but otherwise smooth nut (lenticellate in subsp. *oblongifolia*). *D. oblongifolia* occurs in low-lying, periodically inundated or poorly drained forest, and on hillsides below 600 m altitude. The density of the wood varies from 600–930 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 89, 102, 297, 417, 561, 664, 677, 679, 748.

Dryobalanops rappa Becc.

Nelle for. Born.: 572 (1902).

Vernacular names Swamp kapur (En). Brunei: kapur paya. Indonesia: kapur kayatan (West Kalimantan). Malaysia: kapur paya (Sabah, Sarawak), kapur ranggi, kapur rappa (Sarawak).

Distribution Northern and western Borneo.

Uses The timber is used as kapur, although it is often considered to be of inferior quality. It is more liable to splitting than the timber of other species, and logs often show severe heart-rot. The bark is used locally for walls.

Observations A large to very large tree, up to 55 m tall, with a straight bole up to 100(–160) cm in diameter and large buttresses up to 5 m high and 3 m wide; bark dark rufous brown, slash aromatic; leaves ovate-lanceolate, 6–11 cm × 2.5–4 cm, with an up to 10 mm long acumen, caducous or persistent rufous tomentose beneath; fruit calyx lobes oblong to spatulate, up to 5 cm × 0.6 cm, bordering an up to 3 mm deep and 5–8 mm wide cup. *D. rappa* is locally dominant in peat-swamp forest and kerangas on sandy hills, up to 650 m altitude. The density of the wood is 660–960 kg/m³ at 15% moisture content.

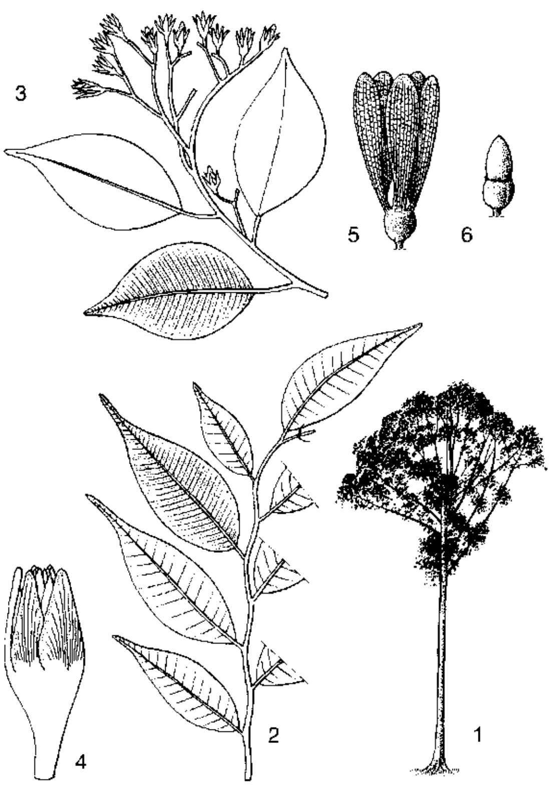
Selected sources 30, 89, 100, 159, 461, 561, 740, 748.

Dryobalanops sumatrensis (J.F. Gmelin) Kosterm.

Blumea 33: 346 (1988).

Synonyms *Dryobalanops aromatica* Gaertner f. (1805), *Dryobalanops camphora* Colebr. (1816).

Vernacular names Brunei: kapur anggi, kapur peringgi. Indonesia: kapur singkel, kapurun, pokok kapur barus (Sumatra). Malaysia: kapur (Peninsular), kapur biasa (Sabah), kapur peringgi (Sarawak).



Dryobalanops sumatrensis (J.F. Gmelin) Kosterm. – 1, tree habit; 2, sterile twig; 3, flowering twig; 4, flower bud; 5, fruit; 6, nut.

Distribution Peninsular Malaysia, north-western and eastern Sumatra, the Riau and Lingga archipelago, and northern and western Borneo.

Uses *D. sumatrensis* represents the most important source of kapur timber as well as of camphor in Peninsular Malaysia and Sumatra. The bark is used locally for walls and floors of houses and for baskets. Powder made from the kernel of the fruit is used medicinally against, for instance, stomachache and for staunching blood. The fruit (nut) is also edible.

Observations A very large tree up to 60(–67) m tall, with a straight and cylindrical bole, branchless for up to 40 m, having a diameter of up to 200(–340) cm and buttresses up to 5 m high; bark yellowish-brown, slash strongly aromatic but at first not exuding any dammar; leaves broadly ovate, 4–6 cm × 2–4 cm, with an up to 15 mm long acumen, glabrous; fruit calyx lobes spatulate, 4–6 cm × 0.8–2 cm, bordering a 6–8 mm deep and 8–15 mm wide cup. *D. sumatrensis* favours well-drained, yellow, leached, sandy-clayey soils and performs best on lower and middle slopes, less so in valleys or on ridges, up to 400 m altitude. It grows locally dominant or gregarious. The density of the wood is 630–940 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 2, 3, 30, 89, 100, 102, 159, 297, 306, 318, 383, 417, 461, 489, 523, 561, 664, 677, 679, 685, 740, 748, 816.

H.S. Lee (general part),
W.C. Wong (properties),
J. Ilic (wood anatomy),
M.S.M. Sosef (selection of species)

Endospermum Benth.

Fl. Hongk.: 304 (1861).
EUPHORBIACEAE
x = unknown

Trade groups Sesendok: lightweight hardwood, e.g. *E. diadenum* (Miq.) Airy Shaw, *E. moluccanum* (Teijsm. & Binnend.) Kurz, *E. peltatum* Merr.

Vernacular names Sesendok: cheesewood, white milkwood (En). Brunei: terbulan. Indonesia: kayu labu (general). Malaysia: membulan (Peninsular), sendok (Sabah), terbulan (Sarawak). Papua New Guinea: basswood. Philippines: gubas (general). Thailand: taphong (Trat), lokhao (Trang), famo (Surat Thani).

Origin and geographic distribution *Endospermum* consists of 13 species and is widely distributed from Assam (India) throughout mainland South-East Asia and China towards the Malesian archipelago where it occurs in Peninsular Malaysia, Sumatra, Borneo, the Philippines, northern Sulawesi, the Moluccas and New Guinea, and further east towards Fiji and south to northern Queensland. Almost all (12) species occur within the Malesian area. The 3 most widespread ones are *E. diadenum*, *E. moluccanum* and *E. peltatum*.

Uses Sesendok can be used for a variety of purposes where lightweight, comparatively soft and light-coloured hardwood is required. The wood is non-durable when used in contact with the ground, hence all applications should be under cover. The wood is favoured for match boxes and splints and recommended for chopsticks, popsicle sticks, medical sticks (spatula), ice-cream spoons, toothpicks, carvings and handicraft. It is also suited for pattern making, drawing boards, pencil slats, blockboard, trays, furniture parts, picture frames, plywood chests, packing cases and crates, and buoys and floats. Sesendok also supplies suitable material for toys and indoor laminated wood, panelling and moulding. It is favoured for soles and clogs. When treated, the wood can be used for roofing shakes and shingles. Sesendok is in general not suitable for plywood manufacture because of extensive splitting. Its long fibres make it ideal for pulp and paper production as well as fibreboard production. Spiral shavings of the wood of *E. peltatum* are used as core material in the manufacture of a panel locally known in the Philippines as 'placarol' because of their resistance to compression perpendicular to the direction of the spiral. Whole trunks are sometimes used as masts for local vessels. Several species are used quite extensively for reforestation, especially in Peninsular Malaysia and the Philippines. Sesendok can be used for reclamation of denuded areas.

The bark and leaves have purgative properties; young leaves are slightly purgative but a decoction of old ones can be a strong laxative. Young leaves of some species are sometimes eaten as a vegetable. Seeds have also been reported to be edible. There are reports (unverified) that the thin roots of *E. moluccanum* have been used as an antidote against arrow poison.

Production and international trade Significant volumes of sesendok logs are exported from Papua New Guinea and the Solomon Islands. Small amounts of sesendok timber on the world market originate from Malaysia (Sabah), Thailand, Indonesia (Sumatra), the Philippines and Fiji. Few export figures are available. In 1978 Sabah exported approximately 1000 m^3 of sesendok logs with a value of US$ 68 000, and in 1992 525 m^3 (80% as sawn timber) with a value of US$ 57 000. In 1980 approximately 2000–3000 t of sesendok logs per month were required by the match factories in Peninsular Malaysia. In Papua New Guinea sesendok is classified in the MEP (Minimum Export Price) trade group 3 and fetched a minimum export price for saw logs of US$ 50/m^3 in 1992. Japan is the main importer of sesendok timber.

Properties Sesendok is a lightweight, comparatively soft and weak wood, resembling that of pulai (*Alstonia* spp.). The heartwood is yellowish-white to bright yellow, with a greenish tinge when freshly cut, weathering to straw-coloured, not distinctly demarcated from the sapwood. The density is 300–650 kg/m^3 at 12% moisture content. The grain of the wood is straight, interlocked or wavy, texture moderately coarse to coarse but even. The surfaces are lustrous, lacking figure.

At 12% moisture content, the modulus of rupture is 57–79 N/mm^2, modulus of elasticity 7900–10 700 N/mm^2, compression parallel to grain 36–46 N/mm^2, compression perpendicular to grain 4–6.5 N/mm^2, shear 5–12 N/mm^2, cleavage c. 31 N/mm tangential, Janka side hardness 1600–1825 N Janka end hardness c. 2670 N.

The rates of shrinkage are low to moderate, from green to 15% moisture content c. 1.2% radial and 1.3% tangential, from green to 12% moisture content 1.2–2.1% radial and 2.1–4.0% tangential, and from green to oven dry 1.5–3.0% radial and 3.1%–5.0% tangential. The wood air dries and kiln dries rapidly and without serious degrade, but care should be taken to prevent blue stain, to which the wood is very susceptible. Slight checking may occur during drying. Boards of 15 mm thick take about 2 months to air dry, boards of 40 mm thick about 3 months. In Malaysia kiln schedule J is recommended. Boards with a thickness of 25 mm take approximately 5 days to kiln dry. The timber should be chemically treated or given high temperature treatment to prevent stain and insect attack. After drying, the wood is stable in service.

Sesendok is easy to saw by hand and machine tools, producing smooth surfaces but these may become woolly due to the occasional presence of tension wood. Usually the surface can be planed to a smooth and lustrous finish. Sesendok does not dull sawteeth and edges because the wood is non-siliceous. Boring and turning is easy but fibrous surfaces must be corrected occasionally by sanding. Gluing, painting, screwing and nailing cause no problems. Sesendok has good peeling properties; it peels easily producing good-quality veneer without pretreatment. The gluing properties of the veneer are good, but sesendok is not recommended for the production of plywood, as the veneer may check badly during drying operations.

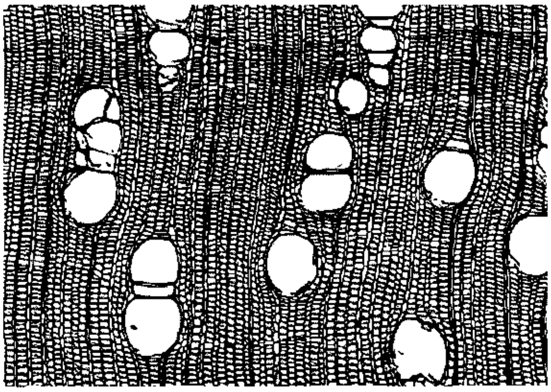
Sesendok is not durable when used outdoors or in contact with the ground. Tests in Malaysia showed an average service life in contact with the ground of 1 year. The wood is very susceptible to blue stain, termite, pinhole borer and marine borer attack and, when sawn, to longicorn beetle attack. It is, however, easy to treat with preservatives. Using the open tank system and an equal mixture of creosote and diesel fuel, an average absorption of over 320 kg/m^3 can be achieved.

Description Medium-sized to large, dioecious or rarely monoecious, unarmed trees of up to 40 (–50) m tall; bole stout, columnar, up to 80(–150) cm in diameter, occasionally buttressed; bark surface smooth but becoming rugose to scaly, hooped, inner bark exuding a watery or coloured sap; crown monopodial, at first pagoda-like or conical, later dome-shaped; branches curving steep upwards, with pith or hollow. Leaves arranged spirally, petioled, simple; leaf peltate or non-peltate, herbaceous to coriaceous, margin entire, sometimes revolute, usually palmately, rarely pinnately veined, with an indumentum of simple or stellate hairs, often with glands at the base and/or in the forks of the lateral veins beneath and/or along the margin above; primary and secondary veins stout, extending to near the margin, looped and joined, tertiary veins fine, perpendicular to the larger ones; petiole generally constricted at one or both ends, leaving large, conspicuous scars; stipules small, narrowly triangular, hairy. Inflorescence axillary, thyrsoid, usually branched but sometimes simple, hairy; bracts and bracteoles small, ovate to deltoid, concave, brownish, hairy. Flowers subsessile to distinctly pedicellate, unisexual or occasionally bisexual, actinomorphic, apetalous; calyx gamosepalous, campanulate, 3-6-lobed, pubescent outside, glabrous inside; male flower with 5-12 stamens arranged spirally on an androphore and with peltate, (3-)4-celled, elliptical anthers dehiscing by a longitudinal slit; female flower with a more or less globose, 1-7-celled, hairy ovary with a single ovule per cell and a sessile, discoid, lobed stigma, rudimentary androecium absent; bisexual flower with an indistinctly lobed calyx and the stamens either at the base of the ovary or arranged spirally on a very short androgynophore, otherwise like the male and female flowers. Fruit more or less drupaceous, indehiscent, with a persistent stigma; exocarp thin to rather thick and fleshy, endocarp thin and woody, fibrous. Seed without caruncle; testa hard, reticulately ribbed, black; radicle triangular, acute. Seedling with epigeal germination; cotyledons leafy; hypocotyl elongated; leaves arranged spirally.

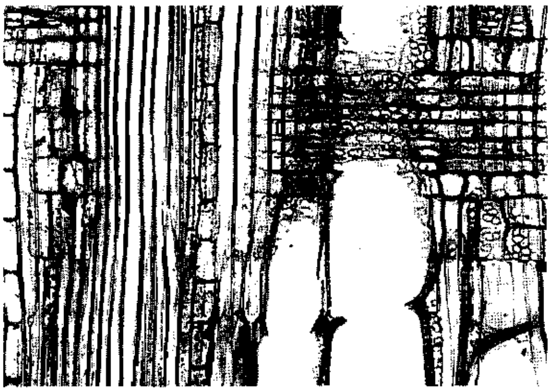
Wood anatomy

- Macroscopic characters:

Sapwood pale, white to creamy yellow, sometimes with a slight greenish hue, turning to light yellow-brown or straw-coloured, not demarcated from the heartwood. Grain straight to shallowly interlocked, slightly wavy or spiral. Texture coarse but even; wood fissile and with some lustre. Growth rings usually indistinct, sometimes evident due to darker layers of denser wood; vessels medium to large, conspicuously open, discernible to the naked eye, infrequently blocked with tyloses;



transverse section (×25)



radial section (×75)

tangential section (×75)

Endospermum diadenum

parenchyma abundant, narrow bands regularly spaced, visible to the naked eye; rays fine, barely discernible to the naked eye as individual rays, inconspicuous on the radial surface.

– Microscopic characters:

Growth rings, if present, evident due to differences in fibre wall thickness on either side of the growth ring boundary. Vessels diffuse, 1–1.5/mm^2, solitary and in radial multiples of 2–3(–4), rarely in clusters, mostly oval, average tangential diameter c. (200–)250 μm; perforations simple; intervessel pits alternate, round to polygonal, pit border diameter 12–16 μm; vessel-ray pits with reduced borders to almost simple, mostly rounded, sometimes irregular in shape, c. 28 μm; tyloses sparse. Fibres (1.2–)1.6–2.1 mm long, non-septate, thin-walled, moderately thick-walled in latewood zones, with minutely bordered to simple pits mainly in radial walls. Parenchyma usually abundant, apotracheal, in narrow more or less continuous, regularly spaced bands, 1–2 cells wide (reticulate), sometimes discontinuous portions tending to diffuse-in-aggregates, in 4–8(–10)-celled strands. Rays 8–10/mm, narrow, 1–2(–3)-seriate, c. 0.6 mm high, highest rays up to 1.3 mm, typically the 2–3-seriate portion as wide as uniseriate portion, heterocellular (Kribs type heterogeneous II and I), uniseriate rays mostly made up of upright cells. Prismatic crystals sometimes in chambered vertical parenchyma cells, more frequently in single upright or sometimes in chambered ray cells; starch grains frequent in parenchyma and ray cells; cells otherwise clear of extraneous coloured materials.

Species studied: *E. chinense* Benth., *E. diadenum*, *E. medullosum*, *E. moluccanum*, *E. peltatum*.

Superficially, *Endospermum* wood resembles the wood of *Alstonia*, *Dyera*, *Hevea* and *Aleurites*. It can be differentiated easily from *Alstonia* and *Dyera* by the absence of latex tubes, latex traces and vestured pits. *Aleurites* wood has narrower and very heterocellular rays, *Hevea* wood has more abundant tyloses and more extraneous materials, and the wood has a pinkish tinge.

Growth and development Sesendok is a light-demander and hence is one of the pioneer species in logged-over or secondary forest. Young trees grow fast in sunlight. On optimal sites in Malaysia, 3-year-old trees of *E. diadenum* may reach 9.5 m height and 13.5 cm diameter. However, the maximum diameter attained at 40 years for the same species in Malaysia was only 42 cm.

The architecture of sesendok trees is according to Aubréville's model. The trunk is monopodial and the growth is rhythmic. The crown of young trees is usually pagoda-like, but in mature trees it becomes dome-shaped.

Sapling leaves are often strongly peltate. Usually, trees flower every year, and in Malaysia *E. diadenum* often even flowers twice a year. Mature fruits are present 2–3 months after flowering. Trees 3 years old may already produce viable seeds. *E. diadenum* is strictly dioecious, just like most other *Endospermum* species; female trees were found to have on average a thicker bark than male trees. The branches of some species are hollow and inhabited by ants (e.g. *Camponotus quadriceps*). The occurrence of ants in the branches is mainly confined to *E. moluccanum* and *E. myrmecophilum*, but sometimes they are also present in *E. medullosum*. The ants are probably attracted by gland secretion.

Other botanical information The genus *Endospermum* belongs to the tribe *Gelonieae* and the subtribe *Endosperminae*. When sterile, species of *Endospermum* are sometimes confused with *Macaranga* which belongs to a different tribe. *Endospermum* differs from the latter by the filaments which are united at base (free in *Macaranga*), the broad, discoid stigma (short to long but never discoid in *Macaranga*), the drupaceous fruit (capsular in *Macaranga*), and, moreover, *Endospermum* trees are generally much bigger. There are distinct anatomical differences between the two genera too.

Although *E. malaccense* is a full synonym of *E. diadenum*, it is still often used, especially within Malaysia, which causes some confusion.

The wood of *E. chinense* Benth. is used in its area of distribution, which covers Assam (India), Burma, Thailand, northern Vietnam and southern China.

Ecology Sesendok occurs in both primary and secondary forest and is often associated with streams or is found in waterlogged or even swampy forest. However, it also occurs on well-drained sites. It generally occurs scattered but stands where sesendok is dominant or even almost pure stands have been reported. Sesendok is often found in association with other typical swamp forest species such as *Campnosperma* spp., *Cratoxylum* spp., *Lophopetalum* spp. and *Terminalia* spp. Most *Endospermum* species, but especially *E. diadenum*, are known as opportunist species characteristic of gaps in the forest and hence are common in areas with shifting cultivation. This is surprising, as the proportion of viable seeds may be as low as 0.1%. It is not clear how a pioneer species can succeed with such a low reproductive rate. Sesendok generally grows on low, flat to undulating country or sometimes on hillsides from sea-level up to 1000(–2000) m altitude and generally in areas without a pronounced dry season.

Propagation and planting Seeds of *E. diadenum* are often heavily predated by insects, making it difficult to obtain viable seeds. In the Philippines *E. peltatum* is, however, propagated mainly by seeds. The fruits are soaked in water for 24 hours and then macerated to separate the seeds. These are sun dried for 2–3 days. They can be stored in polyethylene bags at a temperature of 15.5°C. If stored for more than one month, the seeds become dormant and can only be used for sowing in the next season. Seeds buried 30 cm deep retain their viability for more than 9 months. Before sowing the seeds are soaked in water overnight.

The seeds are broadcast in raised seed-beds. In Malaysia the highest germination rate (80%) was obtained when using a 1 : 3 mixture of sand and organic topsoil. After sowing, the seeds are covered with about 2 cm of soil, and the seed-bed is mulched with dry grass, and subsequently watered. Usually the seeds start to germinate after about 24 days. Seedlings are potted when they have 2–4 leaves (about 20 days after germination) in a sterilized mixture of 50% organic topsoil and 50% sandy loam. Only vigorous seedlings of 20–30 cm tall should be planted into the field.

In Malaysia it is suggested to use wildlings for planting because seed is scarce. Transplanted wildlings suffer high mortality unless care is taken to minimize root damage, but with appropriate care the survival rate may be as high as 70%. The survival rate of young trees of *E. diadenum* after 2 years is 70–90%.

In the Philippines (Mindoro and Mindanao) natural regeneration of *E. peltatum* is abundant 2–3 months after logging along with other secondary species. Approximately 35% of the seedlings survive after 6 months.

Silviculture and management Natural stands of sesendok are managed in the same way as a mixed dipterocarp forest; this generally means selective cutting systems with a diameter limit of 50 cm or 60 cm, and, when necessary, enrichment planting.

Seedling growth may be improved by applying fertilizer at the time of planting. The logging system employed for plantations is either clear cutting or by diameter limit (for matchwood and pulpwood often 30 cm). The rotation for clear cutting depends on site productivity; for *E. peltatum* it is often 15–20 years.

Diseases and pests Nursery seedlings may suffer from damping-off. To prevent this disease, a copper oxychloride solution is often applied. In Peninsular Malaysia, fruits of *E. diadenum* are subject to a high degree of insect predation, resulting in a very small proportion of seeds reaching maturity. *E. diadenum* can be heavily defoliated by caterpillars of the moth *Uraptevoides astheniata*, with devastating effect on its growth.

Harvesting The logs float in water and can be transported by river. Sesendok wood is easily affected by sapstain fungi. If processing of logs is delayed, appropriate prophylactic treatment must be applied to minimize unsightly discoloration of the wood.

Yield The mean annual increment of *E. peltatum* in the Philippines is reported as 2.1–2.2 m^3/ha, in terms of stocked volume. For an average site, the yields of plantations of 10 years old, 15 years old and 20 years old are 67 m^3/ha, 140 m^3/ha and 236 m^3/ha, respectively.

Genetic resources A fair supply of the major species of sesendok is still available in the Malesian region (particularly *E. diadenum* and *E. peltatum*). They do not seem to be in immediate risk of genetic erosion, as they occur and regenerate particularly in secondary forest and in former shifting cultivation areas. Besides, plantations have already been established to some extent, e.g. in the Philippines and Peninsular Malaysia. Because most sesendok species are pioneers, they will not easily become endangered.

Several species are only known from one or a few collections. They are apparently rare and need protection. These are *E. banghamii* Merr. from northern Sumatra, *E. domatiphorum* J. Schaeffer from Papua New Guinea, *E. ovatum* Merr. from Mindanao (the Philippines), *E. quadriloculare* Pax & Hoffm. from southern Sumatra, and *E. ronaldii* J. Schaeffer from Peninsular Malaysia.

Prospects Sesendok has merit as a plantation species, although it has a rather broad crown. It grows well in open areas, and it can also be used for enrichment planting in logged-over forest. The wood can be used for various end products, although it is not very suitable for construction purposes. However, information on nursery practices is still sporadic. The development of appropriate methods of propagation should be a research priority.

Literature |1| Ang, L.H., 1990. Effect of open and under planting on early survival and growth of Endospermum malaccense (sesendok), Alstonia angustiloba (pulai) and Shorea parvifolia (meranti sarang punai). Journal of Tropical Forest Science 3: 380–384. |**2**| Burgess, P.F., 1966. Timbers of Sabah. Sabah Forest Records No 6. Forest Department, Sabah, Sandakan. pp. 267–270. |**3**| Chew, T.K., 1980. Observations on the growth and seed production of planted sesendok (Endospermum malaccense) at Tekam F.R., Pahang. Malaysian Forester 43: 532–537. |**4**| Chinte, F.O., 1949. Growth and development of young stands of gubas (Endospermum peltatum Merr.). Philippine Journal of Forestry 6: 245–264. |**5**| Generalao, M.L. & Torrenueva, A.T., 1972. Silvical characteristics of gubas. Silvical Leaflet 12. Bureau of Forestry, Philippines. 14 pp. |**6**| Keating, W.G. & Bolza, E., 1982. Characteristics, properties and uses of timbers. Vol. 1. South-east Asia, northern Australia and the Pacific. Inkata Press Proprietary Ltd., Melbourne, Sydney & London. pp. 139–141. |**7**| Mohammed Shukari Midon, 1982. Malaysian timbers – sesendok. Malaysian Forest Service Trade Leaflet No 66. Malaysian Timber Industry Board, Kuala Lumpur. 6 pp. |**8**| Schaeffer, J., 1971. Revision of the genus Endospermum Bth. (Euphorbiaceae). Blumea 19: 171–192. |**9**| Whitmore, T.C., 1983. Euphorbiaceae, 31. Endospermum. In: Whitmore, T.C. (Editor): Tree flora of Malaya. 2nd edition. Vol. 2. Malayan Forest Records No 26. Longman Malaysia SDN Berhad, Kuala Lumpur. pp. 93–94. |**10**| Yap, S.K. & Razali Husin, 1980. The reproductive behaviour of sesendok (Endospermum malaccense). Malaysian Forester 43: 37–43.

Selection of species

Endospermum diadenum (Miq.) Airy Shaw

Kew Bull. 14: 395 (1960).

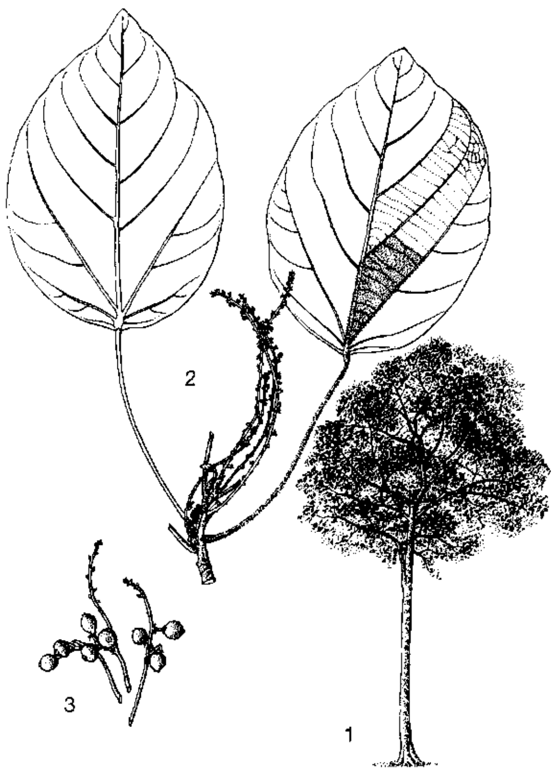
Synonyms *Endospermum borneense* Benth. (1864), *Endospermum malaccense* Benth. (1864), *Endospermum beccarianum* Pax & Hoffm. (1912).

Vernacular names Indonesia: madang tapak kudu (western Sumatra), kayu labuh (Palembang, Sumatra), garung (Kalimantan). Malaysia: membulan (Peninsular), terbulan (Sarawak), sendok (Sabah). Thailand: taphong (Trat), lokhao (Trang), famo (Surat Thani).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, Borneo and intervening islands.

Uses The timber is an important source of sesendok; it is one of the favourite timbers for clogs. *E. diadenum* is also used for reforestation and as a shade tree. The bark is used to cure dropsy and the roots are applied to injuries.

Observations A medium-sized to fairly large tree of up to 35(–40) m tall, bole stout, columnar, up to 150 cm in diameter, with thick buttresses, bark surface smooth, becoming rugose to scaly in patches, grey-fawn, inner bark thick, cream with orange flecks; leaves non-peltate (sometimes peltate in saplings), obovate to broadly ovate or cordate, 7–25 cm × 4–22 cm, palmately 3–9-veined, the midrib with 3–5 pairs of lateral veins, petiole with 0–2 small glands at the apex; inflorescence long and simple or the male one with short side-axes; male flowers with 9–11 stamens, female flowers with a 2–3-celled ovary and a 1.5 mm wide stigma. *E. diadenum* occurs in primary forest and particularly in secondary forest on low, undulating country or along streams and occasionally on permanently inundated sites, up to 1000 m altitude; sometimes in association with *Sapium bac-*



Endospermum diadenum (Miq.) Airy Shaw – 1, tree habit; 2, flowering twig; 3, fruits.

catum Roxb. The density of the wood is 300–650 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 10, 22, 23, 45, 89, 100, 102, 131, 307, 318, 355, 359, 492, 513, 514, 604, 646, 683, 704, 755, 779, 805, 812.

Endospermum medullosum L.S. Smith

Proc. Roy. Soc. Queensl. 58: 53, pl. 1 (1947).

Vernacular names Indonesia: siamena (Irian Jaya, Vogelkop), jumkejuk (northern Irian Jaya), jurasan (southern Irian Jaya). Papua New Guinea: basswood.

Distribution New Guinea, New Britain, the Solomon Islands and northern Queensland.

Uses The timber is used as sesendok for light framing and construction, joinery work, turnery, plywood, furniture and cabinet work from selected stock, locally also for making canoes. Young leaves are sometimes eaten as a vegetable.

Observations A medium-sized to large tree of up to 35(–50) m tall, bole up to 60(–80) cm in diameter; leaves non-peltate, occasionally peltate, ovate to orbicular, 11–23 cm × 9–17 cm, cordate to rounded or broadly truncate at base, palmately 3–7-veined, the midrib with 6–9 pairs of lateral veins, petiole with 2 shortly cylindrical or subglobose glands at the apex; inflorescence paniculiform; male flowers with 5–7 stamens, female flowers with a 1-celled ovary and a 1 mm wide stigma. *E. medullosum* is locally common in primary or sometimes secondary forest at low elevations but occasionally up to 2000 m altitude. The density of the wood is 365–450 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 10, 67, 199, 238, 359, 604, 704.

Endospermum moluccanum (Teijsm. & Binnend.) Kurz

Journ. Bot. 5: 23 (1867).

Synonyms *Endospermum formicarum* Becc. (1884), *Endospermum labios* Schodde (1967).

Vernacular names Indonesia: kayu raja (Moluccas), pohon semut (Ambon), wakopak (Irian Jaya). Papua New Guinea: basswood.

Distribution Northern Sulawesi, the Moluccas, New Guinea, New Britain and the Solomon Islands.

Uses The timber is used as sesendok, e.g. for masts as it is flexible; young trunks are used for floaters. The thin roots are said to contain an antidote against arrow poison. Young leaves are eaten as a vegetable and also applied medicinally against stomachache and vomiting; old leaves are strongly laxative.

Observations A small to medium-sized tree of up to 30 m tall, bole branchless for up to 20 m, up to 50 cm in diameter, sometimes with low buttresses, bark surface smooth, grey-green to yellow-brown, inner bark yellow-brown to white; leaves peltate, ovate, 13–26 cm × 11–23 cm, with a broadly subtruncate base, palmately 8–10-veined, the midrib with 3–4 pairs of lateral veins, petiole with 2 glands at the apex; inflorescence racemiform; male flowers with 9–12 stamens, female flowers with a 4–7-celled ovary. *E. moluccanum* occurs in primary and secondary forest, often in very wet sites, on flat country up to 1000 m altitude.

Selected sources 10, 102, 199, 318, 345, 574, 604.

Endospermum myrmecophilum L.S. Smith

Proc. Roy. Soc. Queensl. 58: 56, pl. 2 (1947).

Vernacular names Papua New Guinea: basswood.

Distribution Southern and eastern Papua New Guinea.

Uses The timber is possibly used as sesendok.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole branchless for up to 17 m, up to 50(–100) cm in diameter, with small buttresses, bark surface grey-brown to yellowish, inner bark white to straw-coloured; leaves usually peltate, ovate, 8–18 cm × 10–22 cm, rounded to broadly truncate at base, palmately 8–9-veined, the midrib with 4–5 pairs of lateral veins, petiole with 2 flattened, elliptic glands at the apex; inflorescence paniculiform; male flowers unknown, female flowers with a 1-celled ovary and a 0.8–1 mm wide stigma. *E. myrmecophilum* occurs in primary mixed forest and swamp forest, also near or along streams, up to 500 m altitude.

Selected sources 604.

Endospermum peltatum Merr.

Publ. Govt. Lab. Philipp. 35: 35 (1905).

Vernacular names Brunei: takaliu. Indonesia: bunkul tekaya, kejo luk long (Kalimantan), mapoopo (Sulawesi). Malaysia: takaliu (Sarawak), buah icras, maram pangi (Sabah). Philippines: gubas (general), kabal (Tagalog), mulang (Zambales).

Distribution Peninsular Thailand, the Andaman Islands, Borneo, northern Sulawesi and the Philippines. Fairly commonly planted in the Philippines.

Uses *E. peltatum* is an important source of sesendok timber; the wood is especially used for matches, various kinds of sticks and wooden shoes. It is used in reforestation projects. The seeds are reported to be edible.

Observations A medium-sized to fairly large tree of up to 35(–45) m tall, bole branchless for up to 20 m, up to 60 cm in diameter, bark surface smooth, grey-brown with an orange tinge and an unpleasant odour, inner bark hard, yellow-brown; leaves sometimes peltate, elliptical to ovate-oblong, 11–25 cm × 9–18 cm, rounded to cordate at base, palmately 7–9-veined, the midrib with 4–9 pairs of lateral veins often carrying a gland beneath, petiole with 2 cylindrical glands at the apex; inflorescence paniculiform, long; male flowers with about 11 stamens, female flowers with a 2–3-celled ovary. *E. peltatum* is fairly common in forests in humid localities, along rivers or on hillsides, up to 1000 m altitude. The density of the wood is 335–460 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 10, 19, 20, 100, 132, 145, 219, 267, 385, 484, 486, 497, 544, 573, 579, 604, 646, 683.

W.M. America (general part, selection of species),
D.S. Alonzo (properties),
J. Ilic (wood anatomy),
Nguyen Ba (wood anatomy),
Nguyen Dinh Hung (wood anatomy)

Eucalyptus L'Hér.

Sert. angl. 18 (1788), t. 20 (1792).
MYRTACEAE
$x = 11$; $2n = 22$ for the vast majority of species, *E. citriodora*: $2n = 20, 22, 28, 44$

Trade groups Eucalypt: lightweight to medium-weight or heavy hardwood, e.g. *Eucalyptus alba* Reinw. ex Blume, *E. deglupta* Blume, *E. urophylla* S.T. Blake.

Vernacular names Eucalypt: eucalyptus (Fr). Indonesia: ampupu, leda. Papua New Guinea: kamerere. Philippines: bagras. Thailand: yukhalip (general). Vietnam: b[aj]ch d[af]n d[or].

Origin and geographic distribution *Eucalyptus* is a genus of over 500 species, most of them endemic to Australia. Only 2 species are confined to the Malesian area (New Guinea, the Moluccas, Sulawesi, the Lesser Sunda Islands and the Philippines). Several species extend from northern Australia towards eastern Malesia. At present over 10 species are known from the southern region of New Guinea. As botanical exploration of the savanna and monsoon forests of this region continues, the number of species encountered here is expected to increase. The largest diversity is in the coastal regions of New South Wales and in south-western Australia. At present, many species are being cultivated outside their natural distribution area, for example in the Malesian area but also in continental Asia, tropical and subtropical Africa, southern Europe and South and Central America.

Uses The wood of eucalypt is used as a general-purpose timber. It is suitable for light or heavy construction. In house building its applications are for doors, window frames, interior finish and both light and heavy duty flooring. Because of its moderate durability and moderate resistance to insect attacks the timber is also applied in contact with the ground, in railway sleepers, poles and posts. Other applications are in ship and boat building, vehicle bodies, joinery, boxes and crates, vats, carving, turnery, handles, sporting goods and agricultural implements. The timber is suitable for the production of veneer and plywood, particle board, hardboard and wood-wool boards. One of the major uses of eucalypt is the production of pulp for paper manufacture. Eucalypt is also a very important supplier of firewood, which generally burns very quickly because of the high oil content, while many produce a good-quality charcoal. Several species are being used in reforestation projects.

The leaves and twigs of many *Eucalyptus* species contain eucalypt oil which is an important product for pharmaceuticals (for example as a liniment or cough medication), perfumes, and soaps and detergents. The oil is also used as a disinfectant and pesticide. Many species of *Eucalyptus* produce gum (kino), which often runs down the bole in large quantities. The bark of some species has tanning properties. The flowers of many species produce good pollen and nectar for honey. Some species are planted as ornamentals.

Production and international trade Little information is available on production and trade of eucalypt timber and pulp. However, eucalypt is becoming increasingly important, as it is nowadays used on a large scale for reforestation. In Papua New Guinea *E. deglupta* is one of the major export timbers; it is ranked in the MEP (Minimum Export Prices) group 3 and fetched a minimum export price for saw logs of US$ 50/m³ in 1992. In Thailand the export of eucalypt chips and particles in 1989 was 28.6 million kg (with a value of US$ 2.4 million) and in 1990 52.2 million kg (with a value of US$ 5.8 million). The export of eucalypt wood of small dimensions (to be used for implements, sticks, etc.) in Thailand in 1989 was 73.7 million kg (with a value of US$ 3.4 million) and in 1990 40.6 million kg (with a value of US$ 1.8 million). The export is mainly to Japan and Taiwan.

Properties Eucalypt wood is light, medium-weight or heavy. The heartwood is light brown to reddish-brown, sometimes dark reddish-brown on exposure, the sapwood is white, cream or light pinkish, 20–60 mm thick and more or less distinctly demarcated from the heartwood. The density of the wood varies greatly between species and also between provenances of a single species (e.g. planted or natural-growing, young or old trees); at 12% moisture content it may be as low as 400 kg/m^3 for plantation-grown *E. deglupta* (trees of 11–13 years old) to as high as 800 kg/m^3 for *E. deglupta* trees of natural stands, 980 kg/m^3 for *E. camaldulensis* and even 1010 kg/m^3 for *E. alba*. The grain is straight to interlocked, texture moderately coarse to coarse. A ribbon figure is often present on quarter-sawn surfaces.

At 12% moisture content the modulus of rupture is (50–)67–142 N/mm^2, modulus of elasticity 8000–18 800 N/mm^2, compression parallel to grain 39–76 N/mm^2, shear 7–17 N/mm^2, cleavage 59–89 N/mm radial and 56–98 N/mm tangential, Janka side hardness 5030–10 100 N and Janka end hardness 5870–10 410 N.

The rates of shrinkage are moderate to high, from green to 12% moisture content 1.8–3.0(–4.4)% radial and 3.4–7.0(–8.9)% tangential. Care is needed during seasoning, especially with the heavier timber, as backsawn boards tend to check; close spacing of stacking strips is important. Kiln drying of heavier grades of eucalypt timber is only practicable in boards up to 25 mm in thickness. It is strongly recommended to air dry the wood to 30% moisture content prior to kiln drying. Boards of *E. deglupta* wood of 25 mm thick will require about 4 months air drying and 3 days kiln drying, boards of 50 mm thick about 6 months air drying and 4 days kiln drying.

Wood of *E. deglupta* works well with hand and machine tools, although it has a slight tendency to tear out in machining and boring and to slight chipping of sharp edges in turning. Heavier grades of timber are rather difficult to work with hand tools, and sharp edges are required in planing to prevent picking up. With care a smooth finish can be obtained. Eucalypt wood glues well, but pre-boring is advisable for screwing and nailing to prevent end splitting. It stains and paints well. It slices well if the wood has a high moisture content, and the veneer often has an attractive figure; the veneer dries satisfactorily. Kraft pulping of *E. deglupta* wood gives a yield of 50%, and a pulp of good brightness and satisfactory handsheet strength properties.

The durability may differ considerably; natural rain forest material is rated as moderately durable to durable, but plantation material is non-durable. Growth site and provenance may also affect durability. Wood of *E. deglupta* is liable to termite and *Lyctus* attack (particularly sapwood), and also to marine borers. The heartwood is usually resistant to preservative treatment and the sapwood permeable, but in plantation-grown material the uptake of copper-chrome-arsenate salts may be fair; plantation-grown wood of *E. deglupta* is significantly easier to impregnate than wood from natural forest.

The wood is non-siliceous, tasteless and odourless. Wood of *E. deglupta* contains 51% cellulose, 30% lignin, 14.5% pentosan and 1.2% ash. The energy value of eucalypt wood is 18 500–21 100 kJ/kg.

The chief constituent of *Eucalyptus* oil is eucalyptol. The oil has a camphor-like odour and a spicy, cooling taste. It is practically insoluble in water, but miscible with alcohol, chloroform, ether, glacial acetic acid and oils.

Description Small to very large trees of up to 60(–87) m tall; bole generally well-shaped, up to more than 200 cm in diameter; bark surface smooth, fibrous, stringy or tessellated. Plant heterophyllous, i.e. with juvenile and adult phases occurring in most species; adult leaves generally alternate but sometimes opposite, simple, pendulous, rarely erect, lanceolate, often falcate, with a distinct midrib, pinnately veined or with parallel veins, aromatic when crushed, glabrous. Inflorescence an umbelliform condensed and reduced dichasium usually called a conflorescence, pedunculate, solitary or paired in a leaf axil, or in a terminal sometimes corymbose panicle; 3 or more flowers per umbel, rarely only one. Flowers regular, bisexual or sometimes male, bud clearly divided into calyx tube or hypanthium (lower part) and operculum (upper part); sepals and petals forming an outer and inner operculum respectively or sepals and petals adnate and forming a single operculum that is shed at anthesis, sepals rarely free; stamens numerous, usually on a staminophore, outer stamens fertile or sterile; ovary 3–7-

locular, inferior or partly superior, with many ovules. Fruit a dry thin-walled capsule enclosed in a woody hypanthium, opening with valves, rarely circumscissile, with scars of operculum and staminophore at the rim. Seeds several to many, brown, grey or black. Seedling with epigeal germination; cotyledons equal, bisected, bilobed or reniform, often broader than long; first pairs of leaves decussate on a square stem.

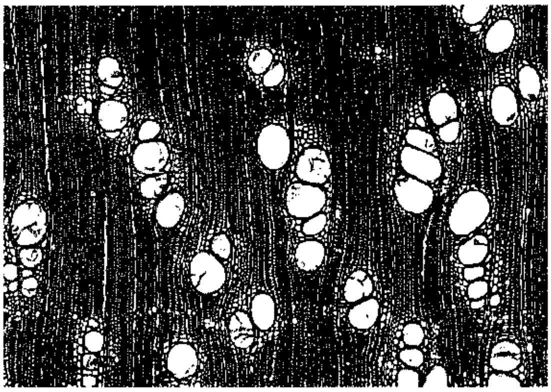
Wood anatomy

– Macroscopic characters:

Heartwood varying from light to dark reddish-brown except in *E. citriodora* where it is light brown to grey-brown and sometimes waxy to the touch; sapwood whitish, pinkish or cream, usually 25–60 mm wide but width varying with growth rate. Grain straight to interlocked, forming a ribbon stripe when quarter-sawn, fiddleback figure sometimes evident in *E. citriodora*. Texture rather coarse with a slight lustre in *E. deglupta*. Growth rings apparent in *E. camaldulensis*, but not distinct in other species; vessel lines always conspicuous, longitudinal surface of *E. citriodora* with very conspicuous vessel lines. Kino veins (gum veins) are a prominent feature of the genus.

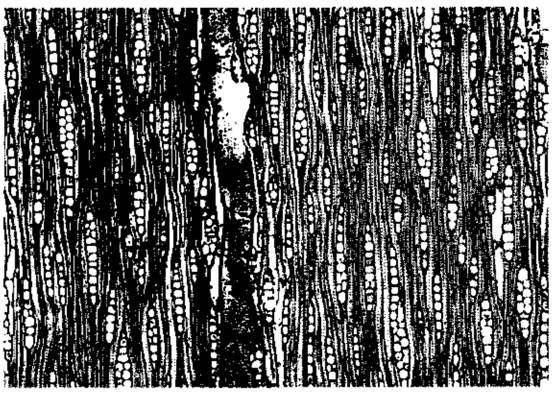
– Microscopic characters:

Growth rings generally indistinct, sometimes evident in *E. camaldulensis*, having some thick-walled latewood cells. Vessels diffuse, (4–)7–9 (–11)/mm^2, predominantly solitary in *E. camaldulensis* and *E. deglupta*, in short to long radial multiples of up to 4(–5), sometimes with clusters in *E. alba* and *E. citriodora*, variable in size, (90–) 160–190(–240) μm, particularly large in *E. deglupta* (190(–240) μm), oblique arrangement prominent but less marked in *E. alba*; perforation plates exclusively simple; intervessel pits alternate, 7–12 μm; vessel-ray pits with reduced borders to almost simple, round to oval, 10–12 μm; tyloses moderately abundant to very abundant. Vasicentric tracheids usually abundant. Fibres (800–)1000–1300 (–1400) μm long, 14–16(–18) μm in diameter, non-septate, thin- to thick-walled, with conspicuously bordered pits mainly on radial walls. Parenchyma moderately abundant to abundant, paratracheal and apotracheal types present, diffuse and vasicentric parenchyma present in all species, aliform to confluent in *E. citriodora* (may include sporadic, narrow wavy bands), tending to aliform around smaller pores of *E. alba*, strand length 4–8 cells. Rays (7–)10–14(–16)/mm, 1–3-seriate, (13–) 16–21(–26) cells high, homogeneous to weakly heterogeneous with one to several rows of procumbent cells on ray margins with greater vertical di-



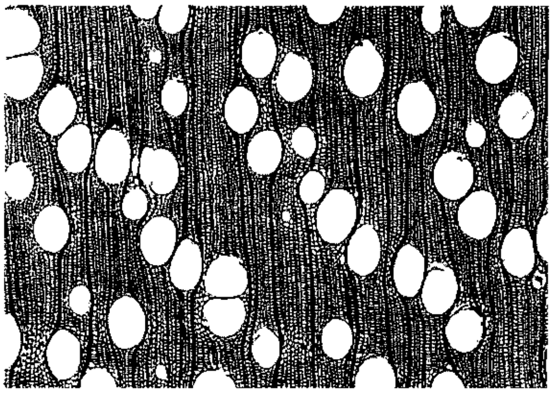
transverse section (×25)

radial section (×75)

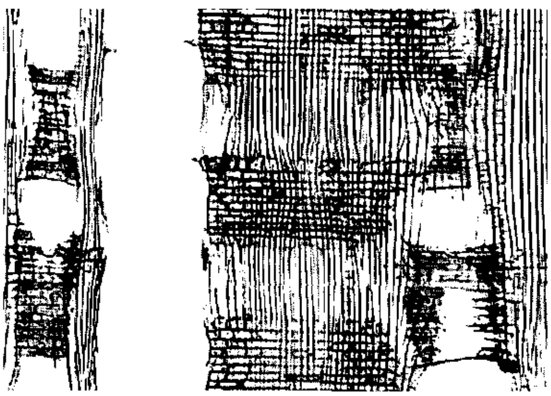


tangential section (×75)

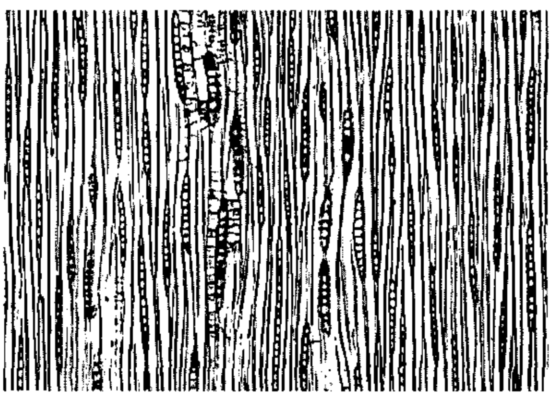
Eucalyptus citriodora



transverse section (×25)



radial section (×75)



tangential section (×75)

Eucalyptus deglupta

mensions than the central procumbent cells. Chambered crystal strands very prominent in *E. deglupta* and sometimes present in *E. citriodora*; silica bodies absent. Traumatic axial gum canals (known as 'kino veins') frequently present in all species.

Species studied: *E. alba, E. camaldulensis, E. citriodora, E. deglupta.*

Eucalyptus can be divided into two distinct groups based on the presence or absence of vessel multiples and axial parenchyma. The first group, comprising *E. alba* and *E. citriodora*, possesses vessel multiples, paratracheal and apotracheal parenchyma, abundant in *E. citriodora*; species in the second group, comprising *E. camaldulensis* and *E. deglupta*, have predominantly solitary pores and fewer parenchyma.

Growth and development Seeds of *E. deglupta* have a germination rate of 50–60% and one gram of dry seeds produces 1000–2000 seedlings. Shoot growth of young trees appears to be continuous, provided soil moisture is adequate. Young trees have a conical crown with a definite leader and almost horizontal branches. As the tree ages, branches curve up at the ends and the leader becomes less dominant. In time the tree acquires a spreading, flat-topped crown. The average annual volume increment of *E. deglupta* in plantations is 15 m^3/ha but is occasionally as much as 50 m^3/ha. At the age of 25 years the trees reach an average height of 42 m and an average bole diameter of 40 cm. *E. urophylla* is also a fast grower; at the age of 8 years the trees have an average height of 27 m and an average diameter of 23 cm, the average annual volume increment being 20–30 m^3/ha. *E. platyphylla* grows more slowly; the average height of trees in plantations in Java is only 13 m at 7 years old (average diameter 13.5 cm).

In *E. deglupta* flowering may occur within the first year but more often it takes place after 2 years and annually thereafter. Flowering can occur in all months of the year depending on locality. In New Britain seeds are shed between December and April which are the wetter months of the year. In Indonesia *E. deglupta* flowers during the whole year and bears fruits at the beginning of the rainy season. *E. urophylla* flowers during the rainy season.

In New Britain it has been noted that seeds of *E. deglupta* are often dispersed by river. The flooding rivers in the wet season deposit the seeds mixed with humus on uncolonized alluvium in full sunlight; this constitutes ideal conditions for germination.

Other botanical information The large genus *Eucalyptus* belongs to the group of 'capsular-fruited' *Myrtaceae* and is divided into several (7 to 10 depending on the author) subgenera which are in turn divided into many sections and series. Its closest relative is probably the genus *Angophora* but others, like the New Caledonian genus *Arillastrum* and *Eucalyptopsis*, are also closely related to *Eucalyptus*. The results of phylogenetic studies within *Eucalyptus* suggest that the genus is polyphyletic, hence not of a single evolutionary origin, and consequently it has been proposed to divide the genus into several distinct genera. This has not yet been done, mainly because of the nomenclatural whirlpool this would bring about.
Several species which are not treated under the selection of species have gained interest as plantation trees recently in South-East Asia, e.g. *E. exserta* F. v. Mueller and *E. pellita* F. v. Mueller.

Ecology Almost all species of *Eucalyptus* are adapted to a monsoon climate. Many species can even survive a severe dry season, e.g. the cultivated species *E. alba*, *E. camaldulensis*, and *E. citriodora*. *E. deglupta* is the only species of *Eucalyptus* which is adapted to lowland and lower montane rain forest habitats. It does not grow naturally in areas with a pronounced dry season, but it occurs in areas where the annual rainfall is 2500–5000 mm and the monthly rainfall usually exceeds 150 mm. Because of this, *E. deglupta* is widely planted throughout the wet tropics. It occurs from sea-level up to 1800 m altitude. Monthly temperatures in lowland habitats are 23°C (mean minimum) to 31°C (mean maximum). In highland areas temperatures range from 13°C (mean minimum) to 29°C (mean maximum). *E. deglupta* may grow in cooler environments but does not tolerate frosts. The species does not withstand prolonged flooding and is highly sensitive to fires. It requires full overhead light for development and dense stands are commonly found along rivers where it has colonized newly formed sand banks. *E. deglupta* is also found on sites that have been cleared or disturbed in some way, e.g. by landslides, volcanic eruptions, or shifting cultivation. It is a rapid colonizer of such sites. In time, however, other species colonize and form a dense understorey which prevents subsequent *E. deglupta* regeneration. The other eucalypt species occurring naturally in southern New Guinea are generally found in dry seasonal open forest or savanna-like vegetations on alluvial plains, hills and plateaus, sometimes also on ridges and on loamy and lateritic, sometimes clayey soils.

Propagation and planting Eucalypts can be propagated easily from seed and sometimes from cuttings. Seeds germinate in 4–20 days. Seedlings are best raised in trays filled with sterile, fine, loamy sand. The trays should be kept in the shade for the first few days after sowing but light can be gradually increased to 50% full sunlight. Seedlings can be transferred to planting tubes when they have 2–3 leaf pairs. Further growth requires full sunlight. The seedlings are ready for planting in the field when they are 25–30 cm in height, usually after 3–4 months. About 2 weeks before planting into the field, they should be gradually hardened off by reducing watering and removing shade. Seeds of many *Eucalyptus* species can be imported from commercial suppliers in Australia. The weight of 1000 seeds of *E. citriodora* is 4.5–7.1 g, for *E. urophylla* it is 2.5–4.8 g, for *E. grandis* 1.5–1.7 g, for *E. camaldulensis* 1.3–1.4 g and for *E. deglupta* 0.3–0.5 g. Hence, the seeds are very light. Eucalypt seeds can be stored for several years when kept dry, cool and airtight. Annual seedling production of eucalypts was approximately 2 million in Thailand in the early 1980s.
Vegetative propagation is possible from branch cuttings, but these must be taken from trees less than 2 years old. Best results are obtained from cuttings containing a stem node and a segment of a leaf. Hormones such as indole-acetic acid, indole-butyric acid or naphthalene-acetic acid will improve the success rate.
Plantations can be established at 3–4 m regular spacings, but spacing of 3 m × 2 m is also practised. In Java stumps are used for planting *E. platyphylla* with a spacing of 3 m × 1 m. The preferred length of the stem of the stump is 10 cm with a diameter of 0.5–1.5 cm, and the length of the root 20 cm.

Silviculture and management Good weed control (usually a 1 m strip along each planting line) is essential and 4–5 weedings each year for 2 years may be necessary before site occupancy is achieved. Growth is usually rapid and subsequent management depends on the purpose for which the trees are being grown. If grown for pulpwood, trees can be harvested after 6–10 years. Plantations grown for sawlogs will require thinning. In Papua New Guinea, malformed trees and those with double leaders are removed at 5 years; the stand is then thinned to 250 trees/ha at 10 years, 100 trees/ha at 15 years and the final harvest is at 25 years. *E. deglupta* does not coppice vigorously and must be replanted. Other species such as *E. camaldulensis*, *E. grandis* and *E. urophylla* do coppice well. *E. deglupta* has been used in enrichment planting trials in logged-over forest and shows considerable promise. Favourable response to boron and nitrogen fertilizers has been obtained in plantations in Papua New Guinea. Foliar analyses suggest that the critical leaf nitrogen concentration is 2.1% and the optimum nitrogen/phosphorus ratio about 10. In the Philippines 6–7 g of fertilizer is used per seedling 2 months after transplanting. *E. camaldulensis* in the Philippines responds well to moderate levels of both nitrogen (30 g/plant) and phosphorus (30 g/plant) when applied within 3 months after planting.

Diseases and pests Heart rot is sometimes found in older trees of *E. deglupta* but is unlikely to be a problem in trees grown on a short (e.g. 10 years) rotation. Field observations suggest that heart rot is more common in trees growing on less well-drained sites. Eucalypt seedlings are susceptible to damping-off in the nursery. Regular application of a fungicide can control this problem.

Various stem-borers have caused damage in some areas. In Papua New Guinea the most serious of these is the buprestid beetle (*Agrilus opulentus*). It mainly attacks small suppressed trees and can kill them by girdling the stem. There is strong evidence that susceptibility to *Agrilus* varies with provenance. In trials in Papua New Guinea *E. deglupta* originating from Mindanao were most resistant to attack, while trees originating from Sulawesi and the highlands of mainland Papua New Guinea were most susceptible. In Malaysia a cossid moth (*Zeuzera coffea*) has also caused stem damage. Other pests include the ring bark borer *Endoclita hosei* and the leaf defoliator *Hypomecas squamosus* in Malaysia, the termite *Nasutitermes novarumhebridarum* (in Papua New Guinea) and the coreid bug *Amblypelta cocophaga* (in the Solomon Islands). Some control of the latter pest has been achieved by introducing the ant *Oecophylla smaragdina* from Papua New Guinea and by clearing vegetation between the planting lines. Clearing appears to benefit the plantation trees by removing alternative insect host plants. Aphids have occasionally been a problem in eucalypt plantations in Indonesia. Application of dieldrin to the potting medium of seedlings reduces the damage caused by termites to the root system of young plants. In New Britain the giant snail *Athatina fulica* may cause a loss of up to 40% of unprotected seedlings; a bamboo ring dipped in creosote and placed around each seedling achieves effective control.

Harvesting Eucalypt plantations are clear-cut when the rotation age has been reached, and subsequently replanted with nursery-raised seedlings. Buttresses, often 3–4 m high, are frequent on specimens of *E. deglupta* growing on river alluviums and non-stable soils in the natural area of distribution of the species; to harvest the logs, scaffolding has to be built so the stem can be sawn through above the buttresses.

Yield Mature eucalypt trees may yield much timber. Occasionally the logs of *E. deglupta* trees in New Britain are branchless for 45 m and have a diameter of 2.3 m, yielding 175 m^3 of timber per tree. *E. deglupta* is one of the fastest growing hardwood trees in the world. In pulpwood plantations yields of 200–300 m^3/ha at 10–12 years of age are commonly achieved. High yields can also be obtained from plantations managed for sawlog production. A 20-year-old plantation in New Britain yielded 520 m^3/ha from trees 54.5 m tall on average with mean diameter of 49.5 cm at breast height. Yields can be substantially reduced by seasonal drought stress.

Genetic resources Provenance trials in Papua New Guinea using seed collected across the whole range of *E. deglupta* show variability in morphology, growth, and susceptibility to pests. Mindanao, Sulawesi and New Britain provenances appear to be better than the mainland Papua New Guinea ones. The trials included most of the mainland Papua New Guinea provenances of *E. deglupta* but not many from Indonesia or the Philippines. In view of the variability already evident, it is highly desirable that the remaining provenances be tested as soon as possible, especially as some may be threatened by clearing for agriculture.

In other species, there is also substantial provenance variation, e.g. in *E. camaldulensis* in Australia; some provenances are outstanding for tropical climates, some for alkaline soils, etc. Provenance variation is also considerable in *E. grandis* (Australia), and *E. urophylla* (Indonesia).

Prospects *E. deglupta* shows great promise for reforestation and afforestation in wet tropical lowland areas without a pronounced dry period. It has particularly high potential for industrial pulp production because of its rapid growth and excellent wood properties. Locally, it is already planted on a large scale, for instance in East Kalimantan. Where heart rot and insect pests have been reported they appear to be only locally significant. Further, because of the genetic variability of *E. deglupta* and its very short reproduction period, there are good prospects for tree improvement which may help overcome these problems.

Other species are particularly suited for planting in dry areas (e.g. *E. camaldulensis)* or mountainous areas (e.g. *E. urophylla).* These species also have great potential for use as firewood in coppice systems.

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Selection of species

Eucalyptus alba Reinw. ex Blume

Bijdr. fl. Ned. Ind. 17: 1101 (1827).

Synonyms *Eucalyptus leucadendron* Reinw. ex de Vriese (1856).

Vernacular names Poplar gum, khaki gum (En). Indonesia: ampupu. Vietnam: b[aj]ch d[af]n tr[aws]ng.

Distribution Timor, Papua New Guinea and widespread in northern Australia. Planted elsewhere in Malesia and mainland South-East Asia.

Uses The wood is used for heavy-duty construction, as mine timber, for boat building, furniture, handles, sporting goods, agricultural implements, joinery, railway sleepers, poles and carvings but also often for fuelwood. The bark contains a high percentage of tannin.

Observations A small to medium-sized deciduous tree of up to 26 m tall, bole often of poor form, up to 60 cm in diameter, bark smooth, with pink-red to whitish patches; juvenile leaves alternate, ovate to suborbicular, green, discolorous, adult leaves alternate, narrow to broadly lanceolate or ovate, 7–21 cm × 2–5 cm, acuminate, green, concolourous, petiole 10–33 mm long; inflorescence axillary, solitary, 7-flowered; flower buds globular to ovoid, operculum hemispherical, 3–5 mm × 4–7 mm; fruit hemispherical to obconical, 4–7 mm × 5–8 mm, with 3 or 4 exserted valves. *E. alba* grows on flat and undulating country, often near the coast or near watercourses, on heavy soil in woodland and open forest from sea-level to 700 m altitude. The density of the wood is 900–1010 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 52, 62, 63a, 64, 232, 322a, 343, 359, 540, 659.

Eucalyptus camaldulensis Dehnh.

Cat. pl. horti camald. 2nd ed.: 6, 20 (1832).

Synonyms *Eucalyptus rostrata* Schlechtendal (1847).

Vernacular names River red gum, red gum (En).

Distribution Native to most parts of Australia. Cultivated throughout Malesia and in many tropical and subtropical parts of the world.

Uses Because of its great strength and good durability the wood is suitable for many structural applications, even in situations of high hazard, e.g. for railway sleepers, poles, posts, flooring, wharfs, ship building and heavy construction. But above all it is used for firewood and pulp production. *E. camaldulensis* is sometimes planted as a reforestation tree. It produces a good-quality charcoal. The bole yields kino which can be used as a dye. The flowers produce a first grade honey.

Observations A small to medium-sized, sometimes large tree of up to 20(–45) m tall, bole often rather crooked, bark smooth, white, grey, brown or red; juvenile leaves alternate, ovate to broadly lanceolate, petiolate, adult leaves alternate, lanceolate to narrowly lanceolate, slightly discolorous, 8–30 cm × 0.7–2 cm, acuminate, green or grey-green, petiole 12–15 mm long; inflorescence axillary, solitary, 7–11-flowered; flower buds globular-rostrate or ovoid-conical, operculum hemispherical, rostrate or conical, 4–6 mm × 3–6 mm, obtuse;

fruit hemispherical or ovoid, 5–8 mm × 5–8 mm with 3–5 exserted valves. *E. camaldulensis* is the most widespread eucalypt of Australia and occurs mainly along watercourses up to 600 m altitude. There is considerable morphological variation within the species, which is not surprising given its wide geographic distribution. The density of the wood is 900–980 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 63a, 66, 130, 202, 232, 322a, 343, 362, 540.

Eucalyptus citriodora Hook.

T.L. Mitchell, Journ. exped. trop. Australia: 235 (1848).

Synonyms *Eucalyptus melissiodora* Lindley (1848), *Eucalyptus variegata* F. v. Mueller (1859), *Eucalyptus maculata* Hook. var. *citriodora* (Hook.) Bailey (1900).

Vernacular names Lemon-scented gum, spotted gum (En). Vietnam: b[aj]ch d[af]n d[or].

Distribution Native to Queensland, Australia. Commonly planted throughout the tropics and in the Mediterranean area; in the Malesian area mainly in Peninsular Malaysia.

Uses The timber is used for general construction, bridges, railway sleepers, flooring, poles, sporting goods, agricultural implements and tool handles. The tree is planted as one of the better eucalypts for low regions in tropical and subtropical regions for pulp production, eucalypt oil and also as an ornamental or for reforestation.

Observations A medium-sized to large tree of up to 40(–50) m tall, bole straight, bark smooth, white, powdery, sometimes pink, red or blue-grey; juvenile leaves alternate, ovate to broadly lanceolate, sometimes setose, petiolate, sometimes peltate, adult leaves alternate, lanceolate to narrowly lanceolate, 8–16 cm × 0.5–2 cm, acuminate, strongly lemon-scented when crushed, petiole 13–20 mm long; inflorescence terminal and compound or axillary and simple, umbels with 3 flowers; flower buds clavate, operculum hemispherical, 3–4 mm × 4–5 mm, apiculate; fruit ovoid or urceolate, 7–15 mm × 7–11 mm, often warty, with 3–4 deeply included valves. *E. citriodora* grows naturally on undulating country, in open forest and woodland, generally on poor soils from 80–800 m altitude. The density of the wood is 785–990 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 63a, 66, 97, 232, 322a, 343, 540.

Eucalyptus deglupta Blume

Mus. Bot. Lugd.-Bat. 1: 83 (1849).

Synonyms *Eucalyptus multiflora* Rich. ex A. Gray non Poir. (1854), *Eucalyptus naudiniana* F. v. Mueller (1886), *Eucalyptus schlechteri* Diels (1922).

Vernacular names Mindanao gum, deglupta (En). Indonesia: leda (general), galang (Sulawesi), aren (Moluccas). Papua New Guinea: kamarere. Philippines: bagras (general), banikag (Agusan), amamanit (Zamboanga). Vietnam: b[aj]ch d[af]n v[or] d[aaf]y.

Distribution The Philippines (Mindanao), Sulawesi, Seram, New Guinea and New Britain. Widely planted throughout the wet tropics.

Uses *E. deglupta* is one of the most important eucalypts of humid tropical regions and is a source of general-purpose timber, but it is also a major plantation tree for pulp production. The wood is also used for veneer and plywood, particle board, hardboard and wood-wool board. *E. deglupta* is also used for reforestation and firewood.

Observations A huge evergreen tree of up to

Eucalyptus deglupta Blume – 1, tree habit; 2, flowering twig.

60(–75) m tall, bole generally of good form, 50–70% of the tree height, up to 240 cm in diameter, sometimes with buttresses of 3–4 m high, bark smooth, yellow, brown, and purple, but green after flaking, twigs square, often with 4 longitudinal wings; juvenile leaves opposite, ovate-lanceolate, adult leaves opposite, subopposite to alternate, held almost horizontal on branches, ovate to ovate-lanceolate, 7.5–15(–20) cm × 5–7.5(–10) cm, rounded to acute or slightly acuminate, shortly petiolate; inflorescence compound, axial and terminal, umbels 3–7-flowered; flower buds globular to subclavate, apiculate, operculum hemispherical, broader than long, double, the outer one early caducous; fruit ovoid to club-shaped or globose, 3–5 mm × 3–5 mm, with 3–4 very small valves. *E. deglupta* prefers non-stagnant river flats with adequate soil moisture and grows best on deep, moderately fertile sandy loams but also on volcanic ash, pumice and gravel soils. It grows typically in pure stands from sea-level up to 1800 m altitude. The density of the wood is 390–810 kg/m^3 at 15% moisture content but the wood of young provenances is lighter. See also the table on wood properties.

Selected sources 52, 62, 69, 97, 102, 130, 159, 169, 170, 175, 223, 228, 229, 232, 236, 310, 314, 343, 359, 394, 462, 540, 551, 659, 714, 729, 769.

Eucalyptus grandis W. Hill ex Maiden

Cat. timbers Queensland (London exhib.): 25 (1862).

Vernacular names Flooded gum, rose gum (En).

Distribution Native to coastal areas in southern Queensland and northern New South Wales, Australia. Plantations exist in Peninsular Malaysia. It is an important plantation tree in the tropics and subtropics.

Uses The wood is used especially for boat building, flooring, plywood, panelling and general construction.

Observations A medium-sized to very large tree of up to 55 m tall, bole straight, up to 30 m long and up to 200 cm in diameter, bark smooth, roughly flaky at the base, white, grey-white or blue-grey; juvenile leaves alternate, ovate, adult leaves alternate, lanceolate, 10–16 cm × 2–3 cm, petiole 15–20 mm long; inflorescence solitary, umbels 7–11-flowered; flower buds ovoid to broadly fusiform, apiculate, operculum conical or slightly rostrate; fruit somewhat pear-shaped, 5–8 mm × 4–7 mm, with 4–5 exserted, incurved valves. *E. grandis* grows under moist, subtropical conditions at low altitudes, and performs best on deep, well-drained, fertile loam or clay-loam soils, in natural conditions often on slopes and in valleys, in tall open forest and rain forest edges. *E. grandis* is closely related to *E. saligna* from which it is distinguished most easily by the shape of the fruiting valves.

Selected sources 63a, 85, 232, 322a, 343, 359, 540.

Eucalyptus gummifera (Sol. ex Gaertner) Hochr.

Candollea 2: 464 (1925).

Synonyms *Eucalyptus corymbosa* J.E. Smith (1795).

Vernacular names Red bloodwood, bloodwood (En).

Distribution Native from south-eastern Queensland to eastern Victoria, Australia. Cultivated in Peninsular Malaysia.

Uses The wood is used especially for poles, railway sleepers, mining construction and hardboard, but its use is limited due to the occurrence of gum veins.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole generally well-shaped, bark tessellated throughout, grey-brown or brown; juvenile leaves alternate, ovate to broadly lanceolate, discolorous, adult leaves alternate, broadly lanceolate to lanceolate, 10–14(–16) cm × 2–4(–5) cm, acuminate; inflorescence a large terminal panicle, umbels 7-flowered; operculum hemispherical-conical, apiculate; fruit urceolate, 15–20 mm × 11–15 mm, the 3 or 4 valves deeply enclosed. *E. gummifera* occurs on sandy soils, on flat land and low hills in open forest up to 500 m altitude.

Selected sources 63a, 85, 232, 322a, 343, 540.

Eucalyptus papuana F. v. Mueller

Descr. notes Papuan pl. 1: 8 (1875).

Vernacular names Ghost gum, desert gum, cabbage gum (En).

Distribution Northern half of Australia and Papua New Guinea. Cultivated in Papua New Guinea and Indonesia.

Uses The timber is used, e.g. for fencing, steps and door and window sills.

Observations A small to medium-sized tree of up to 25 m tall, bole sometimes stunted, but straight in other provenances, up to 6 m long and up to 70 cm in diameter, bark smooth, white or grey-white; juvenile leaves oblong or elliptical to broadly lanceolate, acute or acuminate, undulate, adult leaves alternate, narrowly to broadly lanceolate, 5–18 cm × 1.2–4.5 cm, petiole 1–2.5 cm long; inflorescence a condensed corymbose panicle, umbels 7–11-flowered; flower buds ovoid to clavate, operculum hemispherical; fruit cylindrical, 7–10 mm × 6–9 mm, abruptly rounded at base. *E. papuana* occurs preferably on swampy sites or river flats but also on hills and plateaus, on loamy and lateritic soils at low altitudes. The density of the wood is about 950 kg/m³ at 12% moisture content.

Selected sources 232, 359, 540.

Eucalyptus platyphylla F. v. Mueller

Journ. Proc. Linn. Soc., Bot. 3: 93 (1859).

Vernacular names Poplar gum (En).

Distribution Eastern Queensland, Australia. Planted in the lowlands of Java.

Uses The wood is used for construction purposes and as fuelwood.

Observations A small tree of up to 20 m tall, bark smooth, white, grey, or tan, often powdery; juvenile leaves alternate, broadly lanceolate to ovate, adult leaves alternate, orbicular, cordate or rhomboid, rarely lanceolate, 7–13 cm × 5–9 cm, rounded or apiculate at apex, petiole 30–40 mm long; inflorescence simple, umbels 3–7-flowered; flower buds ovoid, operculum hemispherical, sometimes apiculate; fruit hemispherical to turbinate, 5–6 mm × 7–9 mm, several-ribbed, with 3 or 4 exserted valves. *E. platyphylla* occurs on fertile flats which may be moist for long periods but also on ridges, generally on clayey soils. The name *E. platyphylla* has been used incorrectly for the hybrid between *E. alba* and *E. urophylla*. The density of the wood is 900–1010 kg/m³ at 12% moisture content.

Selected sources 232, 343, 659.

Eucalyptus robusta J.E. Smith

Spec. bot. New Holland 1: 39 (1795).

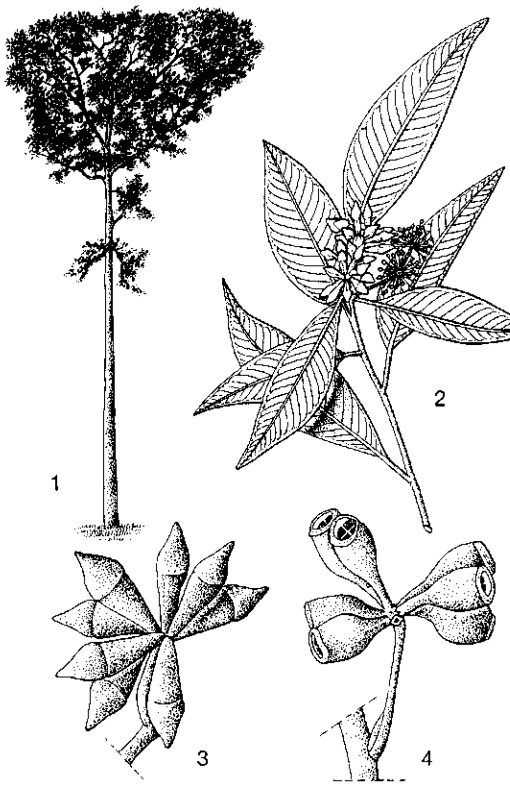
Synonyms *Eucalyptus multiflora* Poir. (1812).

Vernacular names Swamp mahogany (En).

Distribution Native to Queensland and New South Wales, Australia. Planted in the Philippines, Peninsular Malaysia, Papua New Guinea and elsewhere in the tropics and subtropics.

Uses The wood is mainly used for general construction but also for shingles, ship building, wharf construction and wheelwrights work. It is also used as a pulpwood and the species is used for reforestation purposes.

Observations A medium-sized tree of up to 30 m tall, bole often rather short, bark rough, soft, spongy, subfibrous, red-brown; juvenile leaves alternate, ovate, discolorous, adult leaves alternate,



Eucalyptus robusta J.E. Smith – 1, tree habit; 2, flowering twig; 3, flower buds; 4, infructescence.

broadly lanceolate, 10–16 cm × 2.5–4.5 cm, long-acuminate, petiole 20–35 mm long; inflorescence simple, umbels 9–15-flowered; flower buds rostrate or more or less fusiform, operculum conical, rostrate; fruit campanulate, slightly constricted above the middle, 10–18 mm × 6–11 mm, with 3 or 4 included to slightly exserted valves. *E. robusta* grows in swampy places, often near the sea, sometimes on slopes and often in pure stands.

Selected sources 63a, 175, 232, 322a, 343, 540.

Eucalyptus saligna J.E. Smith

Trans. Linn. Soc., London 3: 285 (1797).

Vernacular names Sydney blue gum (En).

Distribution Native to south-eastern Queensland and New South Wales, Australia. Planted in the highlands of Java and in Africa and South America.

Uses The wood is used as a general-purpose hardwood and also as a fuelwood. *E. saligna* is used for reforestation purposes. The leaves yield eucalypt oil.

Observations A very large tree of up to 55 m tall, bole straight, 50–70% of the total height, up to 200 cm in diameter, bark smooth, flaky at the base, white or blue-grey; juvenile leaves first opposite, then alternate, ovate to broadly lanceolate, discolorous, adult leaves alternate, lanceolate, 9–17 cm × 2–3 cm, petiole 15–25 mm long; inflorescence simple, umbels 7–11-flowered; flower buds fusiform or more or less ovoid, operculum conical; fruit cylindrical, campanulate or subpyriform, 5–8 mm × 4–7 mm, with 3–4 exserted valves curved outwards. *E. saligna* occurs on tableland and slopes in open forest and is generally planted in tropical mountainous areas or subtropical areas.

Selected sources 63a, 85, 232, 322a, 343, 359, 540, 659.

Eucalyptus tereticornis J.E. Smith

Spec. bot. New Holland 1: 41 (1795).

Synonyms *Eucalyptus subulata* Cunn. ex Schauer (1843), *Eucalyptus insignis* Naudin (1891), *Eucalyptus umbellata* (Gaertner) Domin (1928) non Desf.

Vernacular names Forest red gum (En).

Distribution Southern Papua New Guinea, eastern Queensland, New South Wales and Victoria, Australia. Cultivated in Papua New Guinea, on a large scale in India, less extensively in other tropical countries.

Uses The wood is used for heavy construction, railway sleepers, piles, poles and as a mining timber. It is also used for fuelwood, charcoal, pulpwood, hardboard and particle board. The species is used for reforestation. *E. tereticornis* is a major source of pollen and nectar; the nectar has a caramel flavour.

Observations A large tree of up to 50 m tall, bole straight, up to 200 cm in diameter, bark smooth throughout, white, grey or grey-blue; juvenile leaves first opposite, then alternate, ovate, slightly discolorous, adult leaves alternate, narrowly lanceolate to lanceolate, 10–20 cm × 1–2.5 cm, acuminate, petiole 13–24 mm long; inflorescence simple, umbels 7–11-flowered; flower buds conical, operculum conical; fruit subglobular to ovoid, 5–7 mm × 4–8 mm, with 4 or 5 strongly exserted valves. *E. tereticornis* grows scattered in open forest on alluvial flats up to 1000 m altitude.

Selected sources 63a, 85, 130, 232, 322a, 343, 359, 540.

Eucalyptus torelliana F. v. Mueller

Fragm. 10: 106 (1877).

Vernacular names Cadaga, cadaghi (Australia).

Distribution Eastern Queensland, Australia. Planted in Papua New Guinea, Peninsular Malaysia, tropical Africa and India.

Uses The wood is not durable in contact with the ground and has been used previously for vehicle bodies and bridge deckings. *E. torelliana* might be suitable as a shade or afforestation tree.

Observations A small to medium-sized tree of up to 30 m tall, bole of good shape, bark smooth but scaly and subfibrous at base and tessellated up to 5 m high; juvenile leaves opposite at first, broadly ovate, peltate, adult leaves alternate, narrowly to broadly lanceolate, 10–14 cm × 1–3.5 cm, acuminate, petiole 5–20 mm long; inflorescence a terminal corymbose panicle, umbels 3-flowered; flower buds ovoid, operculum hemispherical, apiculate; fruit globular-urceolate to ovoid, 8–10 mm × 8–10 mm, with 3 deeply included valves. *E. torelliana* grows in and around tropical rain forest on slopes of coastal areas up to 800 m altitude.

Selected sources 232, 343, 359, 540.

Eucalyptus urophylla S.T. Blake

Austrobaileya 1(1): 7 (1977).

Synonyms *Eucalyptus alba* auct. non Reinw. ex Blume, *Eucalyptus decaisneana* auct. non Blume.

Vernacular names Timor white gum (En). Indonesia: ampupu (Timor). Vietnam: b[aj]ch d[af]n d[or].

Distribution The Lesser Sunda Islands (Timor, Wetar, Flores, Adonara, Lomblem and Alor). Planted in many tropical parts of the world.

Uses *E. urophylla* is an important source of heavy eucalypt timber. The wood is also used for pulp production, as a fuelwood and for charcoal production. The bark has a tannin content of over 10%.

Observations A medium-sized to very large tree of up to 55 m tall, bole straight, up to 200 cm in diameter, bark rough, fissured, scaly-fibrous, reddish-brown or pearl-grey; juvenile leaves subopposite, ovate or elliptical, adult leaves alternate, straight to slightly falcate, narrowly to very narrowly ovate, 7–20 cm × 0.7–3 cm, caudate-acuminate, discolorous, petiole 12–30 mm long; inflorescence axillary, simple, umbels 5–8-flowered; flower buds ellipsoid or obovoid, shortly acuminate, operculum equal or slightly longer than the calyx tube; fruit cup-shaped or obconical, 6–10 mm × 7–12 mm, with 3 or 4 included or partly exserted valves. *E. urophylla* occurs in open, often secondary montane forest and performs best on deep, moist, well-drained soils at (350–)500–3000 m altitude. Until 1977 *E. urophylla* was not treated as a species distinct from *E. alba*. As *E. alba* has been widely cultivated throughout the world (also under the name *E. decaisneana*) there is some confusion about the true nature of several provenances. The occurrence of hybrids between *E. alba* and *E. urophylla* as well as between the latter and *E. saligna* or *E. tereticornis* enhances the confusion.

Selected sources 16, 52, 62, 130, 193, 322a, 343, 540, 659, 715.

D. Lamb (general part),
R.J. Johns (general part),
W.G. Keating (properties),
J. Ilic (wood anatomy),
C.C.H. Jongkind (selection of species)

Eusideroxylon Teijsm. & Binnend.

Natuurk. Tijdschr. Ned. Ind. 25: 292 (1863).
LAURACEAE
x = unknown

Trade groups Ulin: a single species, *Eusideroxylon zwageri* Teijsm. & Binnend., Natuurk. Tijdschr. Ned. Ind. 25: 292 (1863), synonym: *Bihania borneensis* Meissner (1864).

Vernacular names Ulin: ironwood, billian (En). Bilian, bois de fer (Fr). Brunei: belian. Malaysia: belian (Sarawak, Sabah), tambulian (Sabah), im muk (Cantonese, Sabah). Indonesia: belian (general), onglen (Sumatra), tulian, tebelian (Kalimantan). Philippines: tambulian, sakian, biliran (Sulu).

Origin and geographic distribution *Eusideroxylon* is monotypic and occurs in eastern and southern Sumatra, Bangka, Belitung, Borneo and the Sulu archipelago and Palawan (the Philippines).

Uses Ulin is one of the heaviest and most durable timbers of South-East Asia. As such, it is preferably used in marine constructions such as pilings, wharfs, docks, sluices, dams and ships (keels, ribs and decking), or in heavy constructions such as bridges, power line poles, masts, piles and house posts. Ulin is also used for the traditional houses ('longhouses') of the Dayak in Borneo. Another major use of ulin is for roof shingles ('sirap') which are reported to last 50 years to more than a century. Less important is the use of ulin as frame, board, for heavy duty flooring, floodgates, road pavement and foundations, railway sleepers, fencing, printing blocks, vehicle bodies, sleds for log skidding, furniture, chopsticks, blowpipes, poles (in pepper cultivation) and survey pegs. The wood is not suitable for plywood or particle board production.

The large fruits are poisonous and pulverized fruits have been used medicinally against swellings.

Production and international trade Ulin is primarily used locally, and in several areas it receives some protection. In 1981 the total amount of 'sirap' pieces produced was about 50 million. It is not exported on a large scale and only a few statistics are available. Sabah exports ulin; in 1987 the export of round logs was 38 000 m^3 with a value of US$ 3 million, and in 1992 the export of sawn timber was 7350 m^3 with a value of US$ 2.3 million.

Properties Ulin is a heavy hardwood. The heartwood is yellowish-brown to reddish-brown when freshly cut, but it becomes silvery brown, dark brown or almost black on exposure; the sapwood is sharply differentiated from the heartwood and bright yellow when freshly cut, darkening to yellowish-brown on exposure. The density is (830–)880–1190 kg/m^3 at 15% moisture content. Surfaces show some lustre, and there is no distinct figure except for an inconspicuous ray figure on quarter-sawn surfaces. Freshly cut wood has a fresh, slightly lemon-like odour. The grain is straight, occasionally slightly interlocked, texture moderately coarse and even.

In green condition, the modulus of rupture is 135 N/mm^2, modulus of elasticity 17 400–18 100 N/mm^2, compression parallel to grain 67–80 N/mm^2, compression perpendicular to grain 17.5 N/mm^2, shear 9.5–14 N/mm^2, cleavage 61–70 N/mm radial and 90–122 N/mm tangential, Janka side hardness 9730–12 150 N and Janka end hardness 10 700 N. See also the table on wood properties.

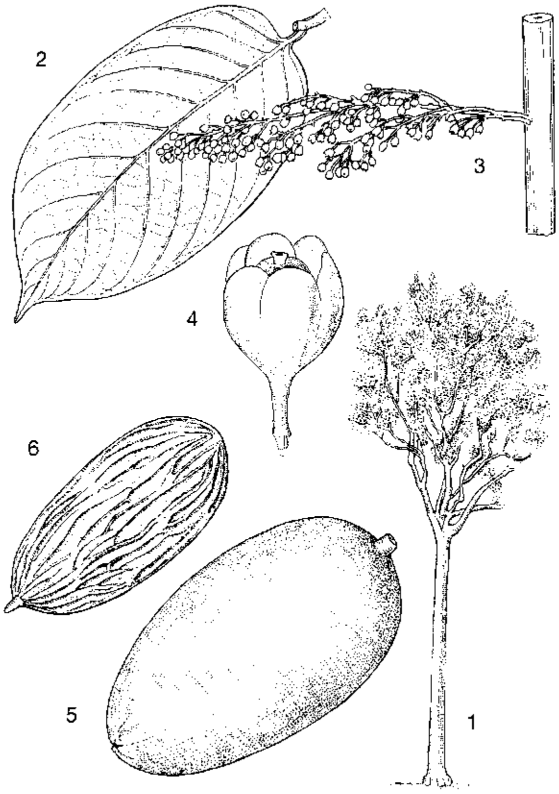
The rates of shrinkage are rather high, from green to 15% moisture content 2.0% radial and 4.5% tangential, from green to oven dry 4.2–4.3% radial and 7.5–8.3% tangential. Ulin dries slowly, although the moisture content of green wood is comparatively low (about 38%); it is liable to surface and end checking during drying. Air seasoning of 2.5 cm thick boards to 16% moisture content takes approximately 75 days. The recommended kiln schedule in Malaysia is B, in Indonesia a temperature of 40–60°C and corresponding relative humidity of 85% to 50% are suggested. Kiln drying of 2.5 cm thick boards takes about 8 days. Ulin tends to split when too dry.

Ulin can be sawn with good result, but it blunts sawteeth fairly rapidly, owing to its hardness; the sawteeth should be kept clean from accumulating oily deposits. Tests on the machining properties show good results for planing, shaping, boring, mortising, turning and sanding. Too high speeds in boring may cause burning. Because it tends to split in the radial plane when screwed or nailed, the wood must be pre-bored. The easy splitting in radial direction makes ulin excellent for making shingles, although sometimes pieces of wood with interlocked grain may cause problems. The wood is difficult to glue with synthetic adhesives; furniture, for instance, often fails at glued joints. In a general sense, ulin is too dense for plywood manufacture and insufficiently ornamental for sliced veneer, but tests indicate that good veneer can be made at a peeling angle of 92° after boiling for 24 hours, and that gluing of the veneer with urea-formaldehyde produces good plywood. The wood is unlikely to be suitable for the production of pulp, paper or fibreboard.

Ulin is rated as very durable. Graveyard tests with stakes showed an average service life in contact with the ground of 17.5 years under tropical conditions. Stockades and posts have been reported to last over 100 years, and pepper (*Piper nigrum* L.) support posts and shingles over 30 years. A life of up to 20 years can be expected in marine works. The wood is resistant to termite attack, although after long periods of exposure attack may occur. Ambrosia beetle attack is rare, but ulin is more commonly attacked by longicorn beetles, and the sapwood also by powder-post beetles. The wood is very resistant to wood-rotting fungi. The heartwood is extremely resistant to preservative treatment.

Ulin wood contains 58% cellulose, 29% lignin, 12.5% pentosan, 1.0% ash and up to 0.5% silica. The solubility is 5.2% in alcohol-benzene, 2.9% in cold water, 6.8% in hot water, and 18.2% in a 1% NaOH solution. The energy value is about 21 300 kJ/kg.

Description An evergreen tree of up to 40(–50) m tall; bole straight, branchless for up to 20 m but usually less, sometimes slightly fluted at the base, up to 150(–220) cm in diameter; buttresses many, small, rounded, giving the base an elephant-foot like appearance, in moist places the base often characteristically set with a mattress of slender rootlets; bark surface red or grey-brown with thin cracks, debarking in small scab-like subquadrangular pieces which are turned up at the lower side; exudate absent; crown dense, globular; twigs smooth, slightly angular, tomentellous. Leaves arranged spirally, simple, entire, leathery, elliptical to ovate, 14–18 cm × 5–11 cm, base rounded-subcordate, the apex obtuse to shortly acuminate, upper surface glabrous, lower surface hairy on the larger veins; petiole 6–15 mm; stipules absent. Inflorescence axillary, paniculate, dense, drooping, 10–20 cm long, densely short-hairy. Flowers bisexual, actinomorphic, on a 3–11 mm long pedicel; perianth tube shallow, tepals 6, in 2 whorls, imbricate, caducous, 3–3.5 mm long, greenish, yellow or purplish, puberulous outside; stamens without glands, in 4 whorls, in the outer 2 whorls staminodial and petaloid, 1.5 mm long, yellowish with a purple tip, ciliate, those of the third whorl fertile, thick, with minute red or white anthers with a pink hue, anther cells 4, in 1 horizontal row, the central 2 extrorse, the lateral 2 sublatrorse, stamens of the inner whorl staminodial, subulate, small; ovary superior, sessile, unilocular, with a single ovule, tapering into the subulate style; stigma small, discoid. Fruit drupaceous, on a thick



Eusideroxylon zwageri Teijsm. & Binnend. – 1, tree habit; 2, leaf; 3, inflorescence; 4, flower; 5, fruit; 6, seed.

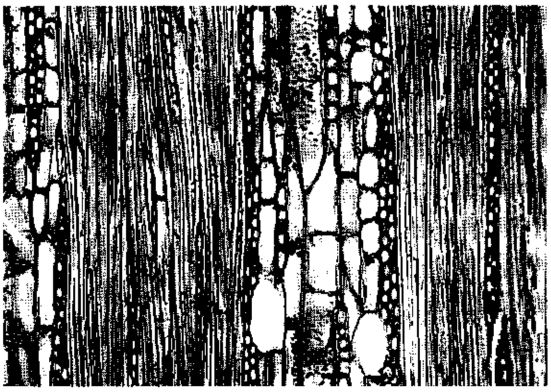
pedicel, 1 or 2 in each panicle, completely included in and adnate to the accrescent perianth tube, ellipsoid to ovoid or globular, 7–16 cm × 5–9 cm, glossy black at maturity, containing a single seed. Seed very large, seed-coat very hard, furrowed, brittle, pale bony; embryo very small. Seedling with hypogeal germination; cotyledons often partly fused, succulent but tough and long persistent; internodes sparsely adpressed pubescent; leaves all arranged spirally, conduplicate or induplicate when young, provided with a lateral branch in each axil.

Wood anatomy
– Macroscopic characters:
Heartwood dark yellowish-brown or reddish-brown with a greenish tinge, turning dark brown or chocolate brown on exposure, distinctly demarcated from the yellowish-brown sapwood. Grain straight or sometimes interlocked. Texture moderately coarse. Growth rings not distinct; tyloses visible to the naked eye.
– Microscopic characters:
Growth rings indistinct. Vessels diffuse, 5–10/mm^2, solitary and in radial multiples of 2–3, 150–300 μm in tangential diameter; perforations simple; intervessel pits alternate, bordered, 8–10 μm; vessel-ray and vessel-parenchyma pits simple or with reduced borders, enlarged, narrowly oval to scalariform; reddish contents present; tyloses abundant and sometimes sclerotic. Fibres 1.2–1.9 mm long, thick-walled (wall 5–12 μm thick), with minutely bordered to simple pits, confined to the radial walls. Parenchyma occasionally in apotracheal bands and diffuse, and aliform and confluent forming wavy tangential bands; oil cells frequent. Rays 8–10/mm, (1–)4-seriate, up to 2300 (–2800) μm high, homocellular and occasionally heterocellular, with one row of marginal square cells (Kribs type homogeneous to heterogeneous III), cells with reddish contents. Crystals and silica bodies absent.

Growth and development Seedlings and saplings demand some shade, but older saplings and young trees require plenty of light for vigorous growth. Mean annual diameter increment of young trees may be 9.5 mm under good conditions, but usually it is less. Trees can reach a height of 8 m in 8 years, and usually they are 9–14 m high after 16 years. The growth rate seems to be rather uniform during the life of a tree, but it will probably slow down slightly when the tree becomes older. The maximum diameter of 40-year-old trees is reportedly 36 cm, and probably trees need over 100 years to reach a diameter of 50 cm. This

transverse section (×25)

radial section (×75)



tangential section (×75)

Eusideroxylon zwageri

means that growth is slow, even under optimal conditions.

Trees may begin to flower at an age of 15–20 years. They bear fruits at irregular intervals, often every 2–3 years, sometimes annually. In southern Sumatra fruits are often found in July – August, in Kalimantan in October – November. Fruits ripen within 3 months after flowering. Seed dispersal is apparently often by water; rich pockets of ulin forest are often found at places where the fruits wash ashore in large quantities along rivers. Procupines may also disperse the seeds.

Other botanical information The second species of the genus often mentioned in literature, *Eusideroxylon melagangay* Sym., has been transferred to the monotypic genus *Potoxylon* (*Potoxylon melagangay* (Sym.) Kosterm.). The two genera constitute the subtribe *Eusideroxylineae* in the tribe *Cryptocaryeae*.

Several varieties can possibly be distinguished within ulin, based on the form and size of the fruits. In practice, 'bulian sirap', having wood suitable for the manufacture of shingles, is sometimes distinguished from 'bulian tanduk' or 'bulian daging', which is suitable only for the production of timber. However, the large variation in fruit shape does not seem to be correlated with the variation in wood properties. Smooth, grey- or white-barked trees are sometimes encountered. The abnormal bark formation is likely to be induced by external factors (fungi).

Ecology Ulin is a constituent of primary or old secondary tropical rain forest. It thrives in a climate with an average annual rainfall of 2500–4000 mm. It prefers well-drained soils in valleys or on hillsides or even low ridges when soil moisture is sufficient. It is found from sea-level up to 500(–625) m altitude. Ulin generally occurs on sandy soils of Tertiary origin, on clay-loam soils or on sandy silt-loam soils, but large specimens have also been found on limestone.

Ulin occurs scattered or gregarious and is often the dominant canopy species. It sometimes forms almost pure stands. In Sumatra the 'ironwood forest' is recognized as a distinct forest type characterized by an exceptionally low species diversity. Ulin occurs also in mixed dipterocarp forest and has been found associated with *Koompassia*, *Shorea*, and *Intsia* species.

Propagation and planting Ulin can be propagated by seed, but nursery-raised wildlings are also often used for planting. Seeds are often placed horizontally between two beds of grass, or they are covered with 2–5 cm of soil. Germination usually starts after about 2 weeks (but it may take 6–12 months) and the germination rate is approximately 40%. Scarification (cutting off the top of the seed or removing the whole outer shell) may improve the germination rate to 70%.

Nursery-raised seedlings or wildlings of about 40 cm tall, a height reached after 1–1.5 years, are planted into the field at a spacing of 3 m × 4 m and need shade. In experiments, seedlings of 10–15 mm diameter gave significantly higher survival and height growth than thinner ones (5–10 mm).

Silviculture and management In natural forest ulin is usually cut selectively with a diameter limit of 50 cm. Regeneration in logged-over forest is often not sufficient, although ulin may coppice freely and can be persistent. In South Kalimantan, for instance, seedlings of ulin often dominate the regeneration in virgin forest, together with meranti (*Shorea* spp.), but in logged-over forest regeneration of ulin is often considerably less prolific. In such situations, enrichment planting in strips or lines is advisable. Systems with poison-girdling of unwanted tree species can be successful as long as sufficient shade is maintained for the ulin seedlings and saplings. As the trees are slow growers, rotation should be adequately long. Ulin could be grown in pure plantations, but the plantations would require very long cutting cycles to provide larger dimensions of timber.

Diseases and pests No serious diseases and pests are reported, although deer and boars may damage seedlings and saplings, and seeds are often destroyed by porcupines. In East Kalimantan 45% of the unsound fruits proved to be attacked by insect borers.

Harvesting Since ulin is exploited separately from other species in forest concessions, just like ebony (*Diospyros celebica* Bakh.), harvesting is mostly done manually. Ulin logs sink in water. They are transported over land or rafted fastened to floater boles.

Yield The standing timber volume of ulin trees with a diameter of over 50 cm can be as much as 90 m^3/ha in natural forest in Sarawak or even more: 112 m^3/ha in Jambi, Sumatra.

Genetic resources Originally, ulin was a common species of primary forest, but over-exploitation for its valuable timber has caused a serious depletion of stands and many stands are in critical condition. Moreover, as ulin often occurs near rivers, places which are easily accessible, stands are also endangered by shifting cultivation. Control of exploitation and trade together with enrichment planting after logging is desirable.

Prospects Ulin is one of the most important timbers for local use, and future supplies should be guaranteed. Forests containing much ulin seem to be best suited for management under selective felling systems with enrichment planting. Long cutting cycles are probably needed to obtain a sustainable yield. More research on appropriate management systems and appropriate methods of propagation is needed. Ulin does not seem to be very suitable for large-scale plantation establishment, as it grows too slowly.

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Other selected sources 55, 57, 102, 159, 176, 183, 187, 318, 352, 359, 377, 379, 380, 448, 458, 460, 484, 514, 578, 667, 717, 723, 762, 782, 787.

A.J.G.H. Kostermans (general part),
B. Sunarno (general part),
A. Martawijaya (properties),
S. Sudo (wood anatomy)

Gmelina L.

Sp. pl.: 626 (1753), Gen. pl. ed. 5: 274 (1754).
VERBENACEAE
x = unknown; *G. arborea*: $2n = 36, 38$

Trade groups
- Yemane: lightweight hardwood, *Gmelina arborea* Roxb.
- White beech: lightweight hardwood, e.g. *G. moluccana* (Blume) Backer ex K. Heyne.

Vernacular names
- Yemane: gmelina, gumhar, Malay beechwood (En). Burma: yemani, mai saw. Thailand: so (northern), so-maeo (Narathiwat). Vietnam: l[ox]i th[oj], nghi[ees]n d[aas]t.
- White beech: grey teak, northern white beech (En).

Origin and geographic distribution *Gmelina* consists of about 33 species of trees and shrubs and is distributed from Pakistan and India, Sri Lanka and southern China through the Malesian Archipelago towards northern and western Australia, Fiji, New Zealand and New Caledonia. About 12 species occur in Malesia. *G. arborea* is the best known species of the genus. It has frequently been planted as a fast-growing plantation tree in South-East Asia as well as in India, tropical Africa and Brazil.

Uses Yemane wood is suitable for general utility purposes, especially light construction and structural work, general carpentry, packaging, carvings, utility furniture and decorative veneers with excellent woodworking properties. Additionally, the wood has been used in light flooring, for musical instruments, matches, particle board, as a mine timber, in vehicle bodies and ships. The usually poor form and tapering of the bole limit its use for sawn timber.

The wood of yemane produces good quality pulp. Unmixed semi-chemical pulp is only suitable for carton board or low grade writing paper, but kraft pulp of yemane wood is suitable for higher grades of writing paper.

White beech is used for a very wide variety of pur-

poses where light structural timber is needed. It is suitable for all purposes mentioned for yemane and, additionally, it is used for canoe-making.
Roots, bark, leaves, fruits and seeds of yemane are used in Hindu medicine. Both the fruit and bark have medicinal properties against bilious fever. Yemane is sometimes planted as avenue tree and is valuable in coffee and cocoa plantations to protect young trees and to suppress noxious grasses. The leaves are widely used as cattle fodder. Yemane is recommended for silkworm culture. Both wood ash and fruit yield a very persistent yellow dye. Outside South-East Asia the wood of yemane is used as firewood and for charcoal. Flowers of yemane produce abundant nectar from which a high-quality honey is produced.

Production and international trade The majority of yemane timber is consumed locally in South-East Asia, mainly for construction purposes and ship building. Until 1990 it was not exported much. Elsewhere other comparable timbers are usually available. This fast-growing and comparatively cheap timber can supply local markets when no special demands with regard to the wood are required.
The largest single plantation of yemane was at Jarilandia, Brazil.

Properties Yemane is a lightweight hardwood. The colour is uniformly cream to light yellowish-brown, turning reddish-brown with age. The wood has a high and silky lustre, and the odour and taste are not distinct. The density is 400–580 kg/m^3 at 15% moisture content. It has been found to increase gradually from the pith outwards in planted trees of 8 years old in Nigeria, and also upwards in the bole. Studies in Nigeria have shown that there is a high correlation between density and age. The grain is straight to interlocked, texture coarse.
At 15% moisture content, the modulus of rupture is 61–75(–82) N/mm^2, modulus of elasticity 8900–9600 N/mm^2, compression parallel to grain 28–39 N/mm^2, compression perpendicular to grain 2.5–3 N/mm^2, shear 7.5–9(–10.5) N/mm^2, cleavage 49 N/mm radial and 53 N/mm tangential, and Janka side hardness 2580–3440 N. Tests carried out with wood harvested in Malaysia, Burma and India have shown differences in strength properties. The modulus of elasticity, impact bending and hardness of the introduced trees in Malaysia are higher than those of trees tested in Burma and India.
The rates of shrinkage of yemane are low, from green to 15% moisture content only 0.5–0.6% radial and 1.1% tangential, from green to 12% moisture content 1.2–1.5% radial and 2.4–3.5% tangential, from green to oven dry 2.4% radial and 4.9% tangential. Seasoning is reported as either good and fairly rapid or slow with some warping. Air seasoning may take about 3.5 months for boards of 12.5 mm and about 11 months for boards of 38 mm thick. Slow drying is probably due to numerous knots in the wood. Kiln drying of the wood is satisfactory; the recommended temperature is 71°C for boards up to 38 mm. Higher temperatures are required for thicker boards and this may cause some darkening on the surface. It takes about 2 weeks to kiln dry boards of 25 mm thickness from green to 12% moisture content.
Yemane timber saws easily and has only slight blunting effects on tools. It planes to a smooth finish and polishes well. When knots are present in the wood, cutting angles should be reduced. The wood is too soft for satisfactory turning. Nailing is fairly easy, but pre-boring is recommended for screwing as the wood tends to split. Rotary peeling is easy even without pretreatment, and the veneers are easy to handle without a tendency to tear; they remain flat after drying. The gluing properties are reported as good. Yemane is in general very stable in service. Pulp of yemane is usually rather short-fibred, but the fibres are comparatively flexible. The quality of paper made from it can be improved by the addition of small amounts of long fibres.
The timber is non-durable, having an average life of 1.3 years when buried in the ground under tropical conditions, but the more dense heartwood is moderately durable. The resistance to termite and marine borer attack is variable, but the wood is usually classified as susceptible. The heartwood is difficult to treat with preservatives, probably due to the presence of numerous tyloses. Yemane was found to absorb only 32 kg/m^3 of creosote into the heartwood using the full-cell process, while the sapwood absorbed 112 kg/m^3 in the same test.
Results from various analyses of the chemical composition of the wood of yemane are fairly uniform. The lignin content is 27%, ash content 1% and extractives content 5%. The content of holocellulose is generally high and varies between 67% and 81%.
Yemane is not very suitable for firewood. The energy value is 20 150–20 750 kJ/kg. It burns quickly, and the charcoal burns well and without smoke, but leaves much ash.
White beech wood (from *G. moluccana*) has a density of about 465 kg/m^3 at 12% moisture content.

At the same moisture content, the modulus of rupture is 61 N/mm^2, modulus of elasticity 8830 N/mm^2, compression parallel to grain 36 N/mm^2, shear 7–8 N/mm^2, cleavage 45 N/mm tangential, and Janka side hardness 2000 N. Shrinkage and drying properties are comparable with yemane, but a large variation in moisture content of the fresh wood has been observed, being reflected in drying times. Within *G. moluccana* two forms are reported: white and red. The red wood often cracks during the drying process and is therefore used less often.

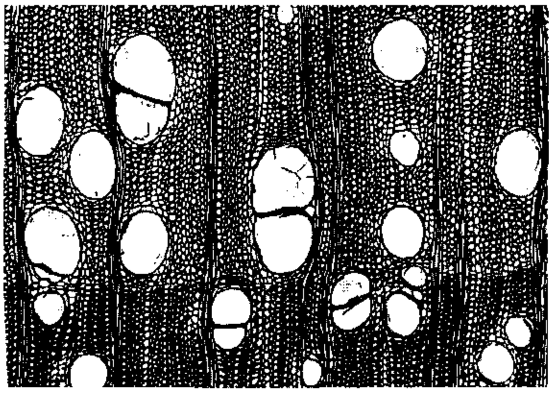
The working properties and durability of white beech are also comparable to yemane. However, sawdust may clog up sawteeth, and coated nails should be used because the wood has corrosive properties. The gluing properties are moderate due to a greasy surface. The heartwood is extremely difficult to treat with preservatives.

Description Small to medium-sized trees or shrubs, up to 30 m, rarely 40 m tall with cylindrical bole having a diameter of up to 100(–250) cm, without buttresses but sometimes flanged; bark smooth or scaly, pale brown to grey; twigs glabrous or pubescent, spinous or unarmed. Leaves opposite, simple, entire, toothed or lobed, often strongly varying in shape within the same plant, reticulately veined, lacking stipules. Inflorescence a terminal or axillary cymose raceme or panicle. Flowers zygomorphic, bisexual, with small bracts; calyx tubular or somewhat campanulate, with 4 or 5 teeth or subentire, generally with large glands; corolla with (4–)5 fused petals, tube slender below, ventricose upwards, more or less 2-lipped, hairy outside, yellow to orange or purplish; stamens 4, didynamous, alternate with the corolla-lobes, inserted in the lower part of the corolla-tube, filaments flat, filiform, often sparsely glandular, anthers 2-celled, dorsifixed, elliptical to oblong; ovary 4-locular, with one ovule in each cell, ovule attached to an axile placenta at or above the middle, style filiform, with two unequal stigmatic lobes. Fruit a succulent drupe, with hard and stony endocarp, usually 4-celled. Seed oblong. Seedling with epigeal germination; cotyledons somewhat fleshy.

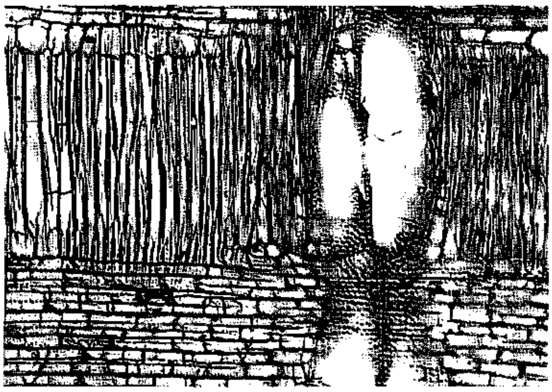
Wood anatomy

– Macroscopic characters:

Demarcation between heartwood and sapwood indistinct, heartwood light brown to yellowish-brown, sometimes with a pinkish tinge, sapwood whitish, sometimes with a greenish or yellowish tinge. Grain straight to interlocked. Texture coarse. Growth rings generally not distinct.



transverse section (×25)



radial section (×75)

tangential section (×75)

Gmelina arborea

– Microscopic characters:
Growth rings indistinct, if present, marked by smaller size of latewood pores. Vessels diffuse, 3–6(–12)/mm^2, solitary and in radial multiples of 2–4, occasionally with narrow vessels between the larger ones, 130–240 μm in tangential diameter; perforations simple; intervessel pits alternate, c. 8 μm; vessel-ray and vessel-parenchyma pits enlarged, reticulate or palisade-like, simple to half-bordered; tyloses abundant. Fibres 0.7–1.5 mm long, septate, with up to 5 septa per fibre, very thin-walled (walls in *G. arborea* 2–3.5 μm thick), with minutely bordered pits mainly confined to the radial walls. Parenchyma paratracheal, usually vasicentric and partly aliform, rarely confluent, and apotracheally diffuse. Rays 5–7/mm in *G. arborea*, 10–13/mm in *G. dalrympleana*, usually (1–)2–4 seriate, maximum height 420–550 μm, homocellular, often seemingly heterocellular in tangential section due to the presence of one row of taller marginal, procumbent cells. Crystals present in ray cells, small, acicular. Silica inclusions in fibres and/or axial parenchyma cells of *G. moluccana* only.
Species studied: *G. arborea, G. dalrympleana, G. moluccana.*

Growth and development Germination of yemane is epigeal with the stony endocarp opening by lateral valves. The radicle then appears, followed by the cotyledons. The primary root is long and slender at the initial stage but then thickens, producing a moderate number of lateral roots. The depth of the root system varies. Growth of yemane is very rapid during the first 6 years, but decreases sharply from the 7th year onwards. Yemane is a short-lived species which reaches an age of 30(–50) years. Under favourable conditions it can reach a height of 30 m and a diameter of 50 cm in 20 years. Growth is strongly site-dependent. Trees of 10 years old can vary in height from 5–31 m.
Trees of yemane are deciduous, shedding their leaves around January or February in all areas where it is planted. New leaves are produced in March to April. Flowering occurs when new leaves have just begun to develop, but intensity of flowering varies. Trees 3–4 years old are able to flower and fruit regularly. The fruit matures within 2–3 months, during which it changes colour from green to yellow and falls to the ground directly when ripe. Fruiting tends to be annual.
White beech has been found to flower and fruit in almost every month of the year. The mechanisms inducing flowering are still not known.

Other botanical information The genus *Gmelina* is closely related to the large genus *Vitex*, from which it is distinguished by its large and usually broadly bell-shaped corolla-tubes, and the well-shaped bole (in *Vitex* the corolla-tube is short and cylindrical, and the bole is usually poorly shaped).
Several varieties within *G. arborea* are sometimes distinguished. At least the typical variety (var. *arborea*) and a form with a glabrous lower leaf surface (var. *glaucescens* C.B. Clarke) are known to be cultivated in South-East Asia.

Ecology Yemane is rather common in its natural distribution area where it occurs in habitats varying from rain forest to drier deciduous forest. It reaches its maximum size in the more humid forests of Burma, especially in humid fertile valleys. It can grow up to 1300 m altitude but is then usually stunted. It thrives in climates with mean annual temperature of 21–28°C, with mean maximum temperature of the hottest month 24–35°C, and mean minimum temperature of the coldest month 18–24°C. In its natural range the annual rainfall varies from 750–5000 mm. Its optimum lies at an annual rainfall of 1800–2300 mm in areas with a dry period of 3–5 months and a relative humidity of at least 40%.
Although yemane can be found on a variety of soils it prefers deep moist soils with an ample supply of nutrients. When established under poor conditions the trees suffer dieback after 15 years and are also very sensitive to weed competition. Growth of yemane on leached acid soils is poor. In plantations it requires a well-drained fertile soil.
Yemane is an opportunist species in the rain forest and has been classified as a long-lived pioneer. It has a high light requirement. White beech is frequently found in primary or secondary, more open forests, along streams and on ridges. It often occurs in drier areas as compared to yemane, sometimes even in grasslands. It usually prefers well-drained, moist soils and occurs from sea-level to 1200 m altitude. It is a pioneer species, just like yemane, and may regenerate gregariously.

Propagation and planting The species is normally propagated by seed. The weight of 1000 seeds is approximately 400 g. Freshly collected seeds (stones) of yemane yield the best germination results. The germination rate is 65–80%. The fruit wall should still be yellow-green to yellow. Any dark coloured fruits should be discarded. Small amounts of fruits can be depulped by stepping on them to extract the stones. For large quantities, a modified coffee depulper can be used which may process 50 kg of fruits per minute.

About 400 kg of fresh fruits are needed for 50 kg of wet depulped seeds. Further washing is required to remove any remnants of the pulp which will otherwise cause rapid fungal infection during storage. After depulping the seed must be dried immediately, to prevent any loss in viability. Considerable loss in viability occurs within one year of storage at room temperature, often even within 6 months. Storage at 4°C reduces the loss but seeds stored for 3 years tend to be no longer viable. Stored seeds should be soaked in cold water for 1–2 days before sowing. Fresh seeds do not need soaking.

In the nursery the seeds are sown on germination beds, preferably in a mixture of sand and loam. The blunt end of the seed should be approximately level with the soil surface and the acute end should point downward. Spacing should be 2 cm × 5 cm and the seeds should be covered by a thin layer of sand. Germination occurs after 2–3 weeks. The seedlings are potted in polyethylene bags after the first pair of leaves has appeared. They can be planted in the field when they reach a height of 23–30 cm, which is usually after about 6 months. Balled seedlings are preferred to bare-rooted ones. Stumps have also been used in artificial regeneration. Mainly because of the high mortality rate (about 50% has been reported), stump planting is no longer practised in more recent plantation projects with yemane. Instead, direct sowing after extensive site preparation is used, for example at the JARI project in Brazil. The usual spacing ranges from 2.5 m × 2.5 m to 3.5 m × 3.5 m.

Silviculture and management It is important to balance the spacing with the development of good stem forms. Narrow spacing combined with early and regular thinnings improves the stem form and reduces heavy branching and forking. Pruning is essential to produce long clear boles. Cutting off all leaves of the sapling except for the upper 2–3 pairs has been recommended in order to get a straight bole. As yemane has a high light requirement and is sensitive to competition, good site preparation and clearing by weeding or fire is required to ensure good growth and establishment.

Rotations of 6 years are used for pulpwood purposes while for sawnwood the usual rotation is usually 10 years. The second rotation is produced by coppicing. Seedling or stump planting is employed for a third rotation. Weeding is carried out 3–4 times during the first 2 years. With 10-year rotations, the stands are thinned to 50% after 5 years and again after 7 years.

Studies have shown that extensive addition of fertilizer is required to maintain sufficient growth of yemane during the second cycle.

In dense plantations trees shade out weeds and it might be necessary to take measures on sloping ground before planting, to avoid erosion. Natural regeneration is usually not abundant in plantations as the seedling demands light.

Diseases and pests Serious fungal infestation has been observed in various locations. *Armillaria mellea, Ceratocystis fimbriata, Ganoderma colossum, Gnomonia* sp. and *Poria rhizomorpha* are some of the fungi found to cause serious damage to planted trees of yemane. Additionally, a parasitic plant, *Loranthus scurrula* L. can also cause damage. The latter is controlled by spraying herbicides.

Plantation trees of yemane tend to be attacked by the stem-boring beetle *Xylotrupes gideon*. Termites which damage the heartwood near the ground have been observed in Peninsular Malaysia but do not cause any serious problems in other regions. Plantations in India have been reported to be defoliated by the yemane leaf beetle (*Calopepla leayana*) which damages the leaves, buds and twigs, and the defoliator *Ozola minor* (*Lepidoptera, Geometridae*) occurs in the Philippines.

Yield Under favourable conditions yemane is capable of reaching an annual increment of 20–25 m^3/ha with impressive exceptions of over 30 m^3/ha with a maximum of 38 m^3/ha. On poor sandy soils a yield of only 84 m^3/ha after 12 years was reported, whereas on very favourable soils a production of 304 m^3/ha after 10 years can be reached.

Genetic resources and breeding The various species of *Gmelina* are usually widely distributed, and although they are not abundant (except on favourable sites), none of them seems to be threatened with extinction.

Owing to the introduction of yemane into plantation forestry, extensive breeding programmes have been carried out in the South-East Asian region, particularly Malaysia and Indonesia. An international provenance trial has been established in the region by the Danish International Development Agency (DANIDA). A major project was started on Kolombangara (the Solomon Islands).

Prospects Although yemane is extensively planted in industrial plantations, its success is still doubtful because of the problems encountered at the JARI plantation in Brazil. The main problem is that the species performs very differently on different soil types. Moreover, the need for additional nutrients makes the establishment of plantations expensive. Breeding might overcome this problem, as well as bringing about an improvement of the shape of the bole and tree.

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Selection of species

Gmelina arborea Roxb.

Hort. bengal.: 46 (1814).

Vernacular names Yemane (trade name).

Distribution Native from Pakistan south to Sri Lanka and east to Burma and extensively planted in South-East Asia, tropical Africa and Brazil.

Uses The wood is used mainly for light construction and for pulping. Several parts of the plant are used medicinally. Leaves are good cattle fodder.

Observations A medium-sized tree of up to 30(–40) m tall, bole with average diameter of 50 cm but sometimes reaching 140 cm; leaves usually more or less heart-shaped, 10–25 cm × 5–18 cm, merely glabrous or velvety beneath; corolla bright yellow, ovary glabrous. For more information see genus treatment and the table on wood properties.

Gmelina arborea Roxb. – 1, tree habit; 2, flowering twig; 3, flower; 4, fruits.

Selected sources 12, 25, 37, 38, 47, 53, 56, 78, 80, 90, 102, 104, 106, 126, 129, 133, 134, 142, 143, 144, 153, 154, 158, 159, 168, 172, 191, 197, 212, 213, 227, 246, 256, 271, 289, 290, 292, 293, 297, 310, 332, 359, 361, 390, 392, 397, 399, 400, 404, 412, 414, 417, 418, 441, 467, 468, 470, 490, 505, 531, 536, 537, 567, 578, 596, 616, 658, 689, 695, 697, 712, 764, 776, 779, 788, 798, 813, 817.

Gmelina dalrympleana (F. v. Mueller) H.J. Lam

Verben. Mal. Arch.: 223 (1919).

Synonyms *Gmelina macrophylla* (R.Br.) Benth. (1870), non Wallich.

Vernacular names Dalrymple's white beech, Queensland beech (En).

Distribution New Guinea and Australia (Queensland).

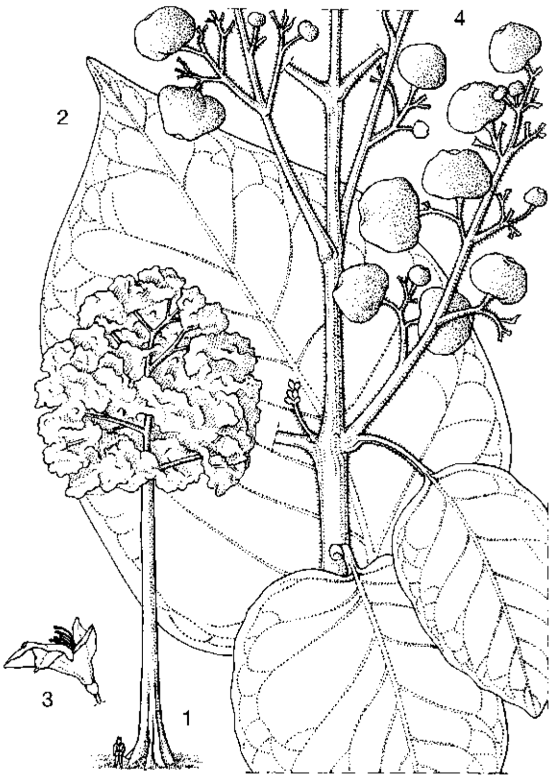
Uses The timber is used as white beech.

Observations A large shrub or small tree of 4–15(–25) m tall; leaves usually 10–25 cm × 7–15 cm, with a pair of glands at the base of the blade;

corolla purple-pink or blue with a yellow throat and mauve lower lip, ovary glabrous. *G. dalrympleana* occurs in both primary and secondary rain forest, preferably on moist, well-drained soils.
Selected sources 63, 114, 359, 494, 500.

Gmelina fasciculiflora Benth.

Benth. & F. v. Mueller, Fl. Austr. 5: 65 (1870).
Vernacular names Toeah (Queensland).
Distribution Native to northern Queensland; occasionally planted in Papua New Guinea.
Uses The timber is used as white beech.
Observations A medium-sized tree of 10–25 (–30) m tall; leaves 5–12(–16) cm × 4–7(–9) cm, glabrous; calyx without glands, corolla blue or mauve-purple with yellow markings on the lower lobe, ovary villous at the top. *G. fasciculiflora* occurs in primary rain forest as well as in shrub and secondary vegetations, preferably on moist, well-drained soils.
Selected sources 63, 114, 359, 494, 500.



Gmelina moluccana (Blume) Backer ex K. Heyne – 1, tree habit; 2, leaf; 3, flower; 4, fruiting twig.

Gmelina moluccana (Blume) Backer ex K. Heyne

Nutt. pl. Ned. Ind. 4: 118 (1917).
Synonyms *Gmelina glandulosa* H. Hallier (1918), *Gmelina salomonensis* Bakh. (1935).
Vernacular names Indonesia: kayu titi, arokoko, koko (Moluccas, Irian Jaya). Papua New Guinea: New Guinea white beech.
Distribution The Moluccas, New Guinea, New Britain and the Solomon Islands.
Uses The timber is used as white beech and is highly favoured by native people for canoes.
Observations A medium-sized to fairly large, probably non-deciduous tree, not seldom to 40 m tall, with a cylindrical bole branchless for up to 20 m; leaves 10–40 cm × 7–35 cm, pubescent beneath; corolla whitish-purple to blue or purple with a yellow throat, ovary densely hairy. The plants are aromatic. For more information see genus treatment and the table on wood properties.
Selected sources 66, 67, 240, 316, 359, 390, 494, 771.

S.K. Yap (general part, properties),
M.S.M. Sosef (general part, selection of species),
S. Sudo (wood anatomy)

Gonystylus Teijsm. & Binnend.

Bot. Zeitung (Berlin) 20: 265 (1862).
THYMELAEACEAE
x = unknown
Trade groups Ramin: lightweight to medium-weight hardwood, e.g. *Gonystylus affinis* Radlk., *G. bancanus* (Miq.) Kurz, *G. forbesii* Gilg, *G. macrophyllus* (Miq.) Airy Shaw, *G. maingayi* Hook.f., *G. velutinus* Airy Shaw.
Vernacular names Ramin. Indonesia: gaharu buaya (Sumatra, Kalimantan), medang keladi (Kalimantan). Malaysia: melawis (Peninsular), gaharu buaya (Sarawak). Philippines: lanutan-bagyo, anauan (general).
Origin and geographic distribution At present *Gonystylus* consists of about 30 species but this number will probably increase further because new species are regularly discovered. The species are distributed almost throughout the Malesian area with the exception of Central and East Java and the Lesser Sunda Islands. Eastward the distribution area extends towards the Solomon Islands, Nicobar and Fiji. The vast majority of species is found on Borneo (27), especially in Sarawak. Peninsular Malaysia and Sumatra

come second with 7 species each, and the Philippines possess 2 species. All other areas are occupied by a single species. The most widespread one is *G. macrophyllus*.

Uses The whitish timber of ramin is highly prized and popular as a decorative cabinet timber. More generally it is also suitable for furniture, interior decoration such as wall panelling, light flooring, toys, turnery, broom handles and other non-impact handles, Venetian blind slats, dowels, rulers, picture frames and drawing boards. Ramin is used for general light construction such as door and window frames, mouldings, skirtings, ceilings, partitions, stair treads and counter tops. Various other applications are planks, barrels, boxes and shipboards. Being highly susceptible to various attacks, the timber should always be used under cover. Ramin is very suitable for veneer, plywood and blockboard manufacture and can be made into a satisfactory quality of particle board.

The resin impregnated pathological heartwood of several species is well known as 'gaharu' or 'kayu garu' and is used as incense (just like *Aquilaria* spp.). The pounded fruits are sometimes used as a fish poison. A decoction of the roots of several species is administered after childbirth as a protective medicine.

Production and international trade Ramin is one of the major export timbers of South-East Asia. Indonesia is the most important exporter, followed by Sarawak and Peninsular Malaysia.

In 1983 the total volume of standing timber of ramin in Indonesia was estimated at 220 million m^3; trees over 50 cm diameter comprise 89 million m^3. The average production of ramin in Indonesia in 1991–1992 was 900 000 m^3/year. Major production areas are central and southern Sumatra, Riau, West Kalimantan and, particularly, Central Kalimantan (average annual production 550 000 m^3 in 1991–1992). In the early 1980s ramin was the most important species in Indonesia for sawnwood exports, accounting for 38% in volume and 46% in value. The average annual export was 598 000 m^3 with a value of US$ 119 million. In 1987 the export of sawn ramin was 299 000 m^3 (with a value of US$ 86 million) and in 1988 224 000 m^3 (with a value of US$ 74 million). On June 13, 1991 the export tax on ramin timber in Indonesia was increased from US$ 500/m^3 to US$ 1200/m^3.

The average log production in Sarawak was 509 000 m^3/year in the period 1981–1990; it was fairly constant over this period. Logging activities in Sarawak focus on ramin as one of the main timbers. In 1987, ramin accounted for 87% of the total sawn timber export from Sarawak. The export was 154 000 m^3 in 1987, and 175 000 m^3 in 1988. Logging activities in Sarawak are increasingly moving into hill dipterocarp forests, and supplies of ramin are expected to decline in future, once the virgin peat-swamp forests have all been logged for the first time. Sabah exports small amounts of sawn ramin timber; in 1992 exports amounted to 600 m^3 with a value of US$ 250 000.

The average production of ramin logs in Peninsular Malaysia in the period 1982–1990 was 37 000 m^3/year. The export of sawn ramin was 15 000 m^3 (worth US$ 2.3 million) in 1983, and decreased to 7000 m^3 (worth US$ 1.2 million) in 1986. In the period 1987–1990 the export was 14 000–15 000 m^3/year (worth US$ 3.7–4.3 million), but in 1991 there was a sudden increase to 25 000 m^3 (worth US$ 8.4 million). In 1992 it was 10 000 m^3 with a value of US$ 3.9 million.

European countries are the major importers of ramin from Sarawak, in order of importance: Italy, Britain, the Netherlands, Germany, Belgium and Spain. Japan is also an important importer, mainly from Indonesia.

Properties Ramin is a lightweight to moderately heavy hardwood. The heartwood is white to yellowish-white or yellow, sometimes weathering to straw-coloured, and not distinctly demarcated from the 3–6 cm thick sapwood. The density is 460–840 kg/m^3 at 15% moisture content. The grain is straight or shallowly interlocked, texture moderately fine to moderately coarse and even. The wood surface is slightly lustrous and lacks a conspicuous figure.

At 15% moisture content, the modulus of rupture is 84–105 N/mm^2, modulus of elasticity 13 600–16 300 N/mm^2, compression parallel to grain 47–58 N/mm^2, shear 6–10.5 N/mm^2, cleavage 34–50 N/mm radial and 44–58 N/mm tangential, and Janka side hardness 2970–5800 N.

The rates of shrinkage are moderately high, from green to 15% moisture content 1.3–2.6% radial and 3.7–5.2% tangential, and from green to oven dry about 4.4% radial and 9.6% tangential. Ramin dries fast, but it is slightly susceptible to end splitting, cupping and warping. The use of an end coating can minimize end splitting. The timber should be dipped in a preservative solution after sawing as it is prone to powder-post beetle attack and blue stain which may cause considerable discoloration. Air seasoning of 4 cm thick boards takes about 70 days. In Malaysia kiln-drying schedule C is advised, but kiln schedule B for boards thicker than 4 cm. Kiln drying of 2.5 cm thick boards to 12% moisture content takes approximately 7 days. Kiln-dried boards are usually free from serious defects, but cupping may occur, particularly in tangential boards.

Ramin is easy to work with hand tools as well as machines. It is easy to saw and plane in both green and dry condition. It can easily be worked into smooth mouldings. Turning gives quite good results, but boring produces rough surfaces. Mortising, shaping and sanding give good results. Ramin is prone to splitting when nailed, so that pre-boring is recommended. The wood can be stained and polished well, and glued with all types of glue. Good veneer can be produced at a peeling angle of 92°30' without pretreatment, but mild soaking in hot water renders peeling easier. The veneer should be handled with care as there is a tendency towards tearing along the grain. It dries well without serious defects. Gluing with urea-formaldehyde makes good plywood. Ramin is suitable for making hardboard, but the boards show a fairly high water absorption.

Ramin is non-durable. Graveyard tests with stakes showed an average life in contact with the ground under tropical conditions of only 6 months, and a maximum life of 1–2 years. The wood is susceptible to blue stain and ambrosia beetle attack, and the resistance to dry-wood termites and wood-rotting fungi is poor. Ramin is, however, easy to treat with preservatives. The inner bark contains numerous fine brittle fibres which may cause skin and eye irritation, and wood dust has been reported to cause occupational asthma. Fresh wood has an unpleasant smell.

Ramin wood contains 62% cellulose, 29.5% lignin, 19% pentosan, 0.5% ash and no silica. The solubility is 6.1% in alcohol-benzene, 1.1% in cold water, 3.4% in hot water and 11.5% in a 1% NaOH solution. The energy value is 19480 kJ/kg.

Description Small to medium-sized trees, up to 42 m tall, occasionally shrubs; bole cylindrical, straight, branchless for up to 21 m and up to 60(–120) cm in diameter, buttresses are thick if present, sometimes fluted at base; bark surface smooth to cracked, shallowly fissured or scaly, dull grey to red-brown or dark brown, occasionally with white patches, inner bark yellow, brown, pink or orange, laminated or fibrous, with glistening slightly irritating fibres on the cut surface; twigs striate, black or chocolate brown, pendulous, sometimes puberulous-velutinous when young but glabrescent. Leaves alternate, simple and entire, papery to thick-leathery, often sparsely hirsute below, especially on the midrib; petiole short, glabrous to velutinous, pellucid-punctate; stipules absent. Inflorescence usually terminal, paniculate, few-branched with short lateral branches; bracts minute, very early caducous. Flowers bisexual, actinomorphic, long-pedicelled; calyx more or less cupular, divided to about 1/4–1/3 in 5 petaloid thick tough lobes, densely setulose-hairy inside; corolla consisting of a ring of 7–40 small, more or less rudimentary petals, often shortly united at base; stamens about equal in number to the petals, rarely twice as many, anthers basifixed on short filaments and folded backwards; ovary sessile, globose, densely hispid-setulose, (2–)3–4(–8)-locular, style filiform, glabrous or pubescent, wiry, sinuate-contorted, stigma punctiform to capitate. Fruit a globose, or rarely lanceolate, woody, 2–5-valved and dehiscent capsule, 1–5-seeded. Seed large, up to 4 cm long, with a smooth softly coriaceous testa, partly enclosed in a thin aril, with thick horny cotyledons and lacking endosperm. Seedling with hypogeal germination, with a taproot emerging from one pole of the seed, the hypocotyl rupturing the testa and the shoot emerging through the slit; leaves arranged spirally, lower ones sometimes subopposite.

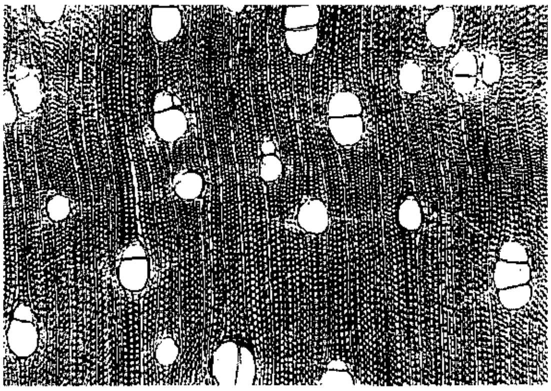
Wood anatomy

– Macroscopic characters:

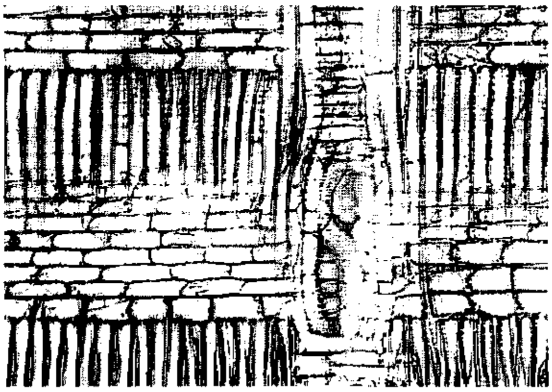
Heartwood white to light yellowish-white, not distinct from the sapwood. Grain straight to shallowly interlocked. Texture moderately fine and even. Growth rings indistinct.

– Microscopic characters:

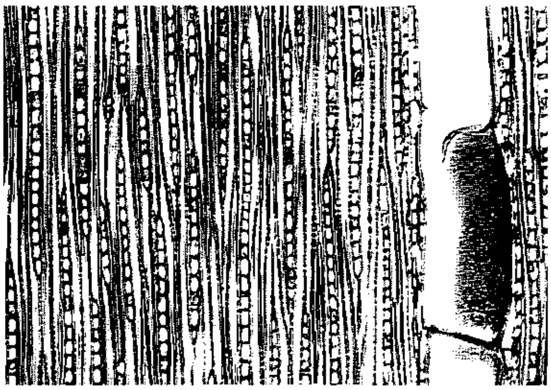
Growth rings indistinct. Vessels diffuse, usually 3–9/mm^2, solitary and in radial multiples of 2–3(–4), 110–190 μm in tangential diameter; perforations simple; intervessel pits alternate, round, 3–4 μm, apertures often coalescent; vessel-ray and vessel-parenchyma pits almost similar to intervessel pits; yellowish contents often present in perforation plate area. Fibres with distinct radial alignment, 1.2–1.9 mm long, thin-walled (wall 4–5 μm thick), with small, more or less distinctly bordered pits confined to the radial walls. Parenchyma paratracheal, winged-aliform to confluent, wings usually thin and long. Rays 9–11/mm, uniseriate, sometimes accompanied by biseriate rays or with frequent presence of biseriates (*G. macrophyllus*), 240–440 μm high, sometimes up to 2000 μm, homocellular (Kribs type homogeneous). Prismatic crystals and small styloids present; sometimes more than one crystal of various sizes in one cell of axial or ray parenchyma; crystals sporadic in some specimens.



transverse section (×25)



radial section (×75)



tangential section (×75)

Gonystylus bancanus

Species studied: *G. bancanus, G. macrophyllus.*

Growth and development Seedlings used for enrichment planting in Kalimantan showed an average growth in height of 12.5 cm/year. A mean annual diameter increment of young trees of 0.5–0.7 cm can be expected, attaining 1 cm under optimal conditions. Although seedlings can withstand a certain level of shade and competition, best growth is reported under light shade conditions and low density of weeds.

Flowering and fruiting of *G. bancanus* trees are at comparatively short but irregular intervals. In West Kalimantan the flowering time is August – October. Fruits ripen in about 2 months after flowering. In Sulawesi it has been demonstrated that seeds of *G. macrophyllus* are dispersed by the bat *Rousettus celebensis*; the fairly large seeds probably cannot be easily carried by the bats and may frequently be dropped.

Other botanical information The genus *Gonystylus* is treated here as a member of the family *Thymelaeaceae*. Together with the related small genera *Aetoxylon* and *Amyxa*, *Gonystylus* comprises a distinct subfamily (*Gonystyloideae*) within the *Thymelaeaceae*. This subfamily has sometimes been given the rank of family (*Gonystylaceae*); some authors place it next to the *Thymelaeaceae*, others regard it as more related to *Tiliaceae* or *Flacourtiaceae*. In dry condition the characteristic colours of the foliage can be used for species identification. The identification of saplings is often difficult because of the differences in habit of young and mature plants. The absence of resin canals precludes confusion with any dipterocarp timber.

Ecology The species of ramin are typically found in primary, non-inundated rain forest at low and medium elevations, reaching 1200 m altitude in Sumatra and 1500 m in Borneo and the Philippines. The ecology of the most important species *G. bancanus* differs, however, from most of the others. In Sarawak and Brunei it is an important, often gregarious component of the mainly coastal peat-swamp forest, where it occurs in both the peripheral mixed swamp forest and also in alan (*Shorea albida* Sym.) forest and 'padang paya' forest (pole-sized peat-swamp forest). It is also found in heath forest. In mixed swamp forest *G. bancanus* is often the most abundant large tree with up to 20 trees/ha with a diameter above 50 cm and is locally the single dominant species. It is principally associated with several *Shorea* species, *Copaifera palustris* (Sym.) de Wit and *Dactylocladus stenostachys* Oliver (jongkong). The latter may in some places be more abundant than *G. bancanus*. Other associates encountered are: *Dyera lowii* Hook.f. (jelutong), *Palaquium* spp. (nyatoh), *Cratoxylum arborescens* (Vahl) Blume (geronggang), *Agathis borneensis* Warb. (kauri), *Durio* spp. (durian), *Dipterocarpus* spp. (keruing) and *Dryobalanops* spp. (kapur). In alan swamp forest *G. bancanus* is much less abundant and usually occurs unevenly. It seems to prefer the fringes of this forest type and trees rarely exceed 85 cm in diameter. In the 'padang paya' forest *G. bancanus* is fairly common but rarely exceeds a diameter of 50 cm. In a few heath forests on podzol *G. bancanus* is often found in association with *Calophyllum* spp. (bintangor) and its diameter is usually less than 75 cm. *G. bancanus* prefers flat land without influence of tidal water and an acid, rather poorly drained soil. It is an evergreen tree, and young plants require shade, whereas moderately large trees will flourish in full sunlight. In Indonesia species of ramin grow on red-yellow podzolic soil, peat soil, alluvial soil and podzol at sea-level. *G. maingayi* is somewhat exceptional, growing on lithosol on steep hills up to 200 m altitude.

Propagation and planting Ramin (*G. bancanus*) can be planted using wildlings, nursery-raised seedlings and cuttings. In experiments with enrichment planting, nursery-raised seedlings showed good survival (67%) and height increment (12.4 cm/year) when compared with cuttings (44% and 5.5 cm/year, respectively) and wildlings (40% and 12.6 cm/year, respectively). Since seedlings and saplings require shade, the planting should be in the strip or line planting system in logged-over or secondary peat-swamp forest, with a spacing of 5 m × 5 m in logged-over forest and 3 m × 1 m in secondary forest. After 2–3 years the shade can be gradually removed to stimulate growth.

Silviculture and management In Indonesia, natural ramin peat-swamp forest is managed under the Indonesian selective felling and planting system, with a diameter limit of 35 cm and a cutting cycle of 35 years. At least 25 healthy trees/ha of over 15 cm diameter should be left as core trees. In planted ramin forest, the first thinning can be carried out at an age of 5 years, and from then on at intervals of 3 years up to the age of 20 years, and subsequently at intervals of 5 years up to the felling age.

In Sarawak large areas of logged-over mixed peat-swamp forest are regularly treated to stimulate regeneration and growth of ramin. The problem is that ramin is shade-loving and grows slower than other species in a regenerating forest.

Harvesting Access to the swamp forest where ramin grows is often very difficult because of the spongy soil, stagnating water and the presence of fallen branches and trees. In Kalimantan wood-slide tracks are laid out towards each felled tree so that personnel work out of the water. The trees are mostly harvested by hand but chain saws are used for felling and cross cutting and an engine pulls small trucks to the floating woodyard. Log beds and sleepers support the line on which rail is fixed for transport of logs above the water level (usually the water is 10–50 cm deep). Logs are hauled on wood sleds by manpower.

In depots the logs are sprayed with preservatives. This is necessary, as they are very susceptible to blue stain and insect attack. In Sarawak a mixture of benzene hexachloride, sodium pentachlorphenate, borax and water (5:1:2:10) is used for dipping, in West Kalimantan agrocide (1/3 kg/m^3), borax (1/3 kg/m^3) and sodium pentachlorphenyl (2 kg/m^3). The logs are transported by river. Ramin rafts are formed by lashing together logs of similar length (about 4 m), laid at right angles to the current; each unit consists of 200–300 logs, i.e. 150–250 m^3 volume. The logs are lashed together by rattan straps, and the rafts by nylon cables.

Yield In Indonesia, the productive ramin peat-swamp forest of West Kalimantan has an extent of 1 million ha with an average standing stock of 30 m^3/ha. In Central Kalimantan the ramin forest covers about 1.5 million ha with an average standing timber volume of 25 m^3/ha. The annual allowable cut was determined at 696 000 m^3/year for West Kalimantan with a potential of 480 000 m^3/year, and at 865 000 m^3/year with a potential of 600 000 m^3/year for Central Kalimantan. Merchantable logs of ramin constitute about 3 m^3 of timber.

In Sarawak the number of ramin trees over 20 cm in diameter is estimated at 2–20 trees/ha in mixed swamp forest. The standing stock of ramin may be as high as 35 m^3/ha in mixed peat-swamp forest and 17 m^3/ha in alan swamp forest.

Genetic resources *G. bancanus* occurs widely and is often dominant. The potential of swamp forest in Kalimantan, for instance, is 40–60 m^3/ha of timber, of which ramin constitutes 27–40 m^3/ha and other common timbers such as kauri (*Agathis* spp.), meranti (*Shorea* spp.) and keruing (*Dipterocarpus* spp.) only 1–3 m^3/ha each. Stands of *G. bancanus*, as the main source of ramin timber, have been heavily depleted. The species is vulnerable because of heavy exploitation and habitat loss. In Sarawak, where large stands occur, it has been heavily overcut for some decades, and in Kalimantan the pressure on natural populations is also very high. In Peninsular Malaysia large areas of peat-swamp forest have been cleared for agriculture, especially to establish oil-palm and pineapple plantations.

The large-scale exploitation of ramin is followed by replanting or promoting activities for natural regeneration only in Sarawak. The great majority of the populations of *G. bancanus* are outside nature reserves and lack protection. However, the species is not currently threatened with extinction as it also occurs on sites where commercial exploitation is not profitable, and in Sarawak natural regeneration is stimulated. Other *Gonystylus* species are often confined to a more restricted area and occur more scattered; they are probably more easily liable to genetic erosion when forests are converted into agricultural land.

At the beginning of 1992 ramin was proposed for inclusion in the CITES Appendix II, which would strictly regulate trade in order to avoid over-exploitation. Indonesia and Malaysia successfully protested against this proposal, arguing that the stable production figures show that it is not yet rare or threatened.

Prospects In order to halt the over exploitation of natural ramin forest, the amount of harvested and traded timber should be restricted. Logged-over forest should be regenerated by means of enrichment planting, and large areas of swamp forest should be designated as protected reserves. Information on silviculture of ramin is available from Sarawak only, and more research is badly needed. Some timbers are good substitutes for ramin, e.g. perupok (*Lophopetalum* spp.) which is particularly harvested in East Kalimantan. Rubberwood (*Hevea brasiliensis* (Willd. ex A.L. Juss.) Muell. Arg.) seems to be a promising substitute, as it can be planted easily, grows rapidly and has fairly similar wood properties; it is already planted on a large scale for the production of timber.

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Selection of species

Gonystylus affinis Radlk.

Sitzungsber. Math.-Phys. Kl. Bayer. Akad. Wiss. München 16: 329 (1887).

Synonyms *Gonystylus beccarianus* v. Tieghem (1893) p.p.

Vernacular names Indonesia: banit (West Kalimantan). Malaysia: ramin dara elok (Peninsular), poko batu pasir (Negeri Sembilan), pinang baik.

Distribution Peninsular Malaysia, south-western Sarawak and possibly in West Kalimantan.

Uses The timber is used as ramin, mainly for house construction.

Observations A small to medium-sized tree of up to 33 m tall, bole up to 90 cm in diameter, fluted, bark surface smooth to shallowly fissured and sloughing in square scales, reddish to brown, occasionally with white patches, inner bark pink; leaves elliptical to almost oblong, 9–19 cm × 3.5–8.5 cm, broadly cuneate to rounded at base, shortly caudate-acuminate at apex, margin markedly revolute, glabrous above, often rather persistently tomentellous below, especially on the midrib, petiole 10–15(–20) mm long; inflorescence

8–15 cm long, densely fulvous-tomentellous; petals about 20, filiform-subulate, glabrous; fruit globose, up to 4 cm in diameter. *G. affinis* occurs on plains, hillsides and ridges, in open rain forest, mixed dipterocarp forest and heath forest up to 330 m altitude. The density of the wood is about 730 kg/m^3 at 15% moisture content.

Selected sources 100, 620, 748, 779, 807.

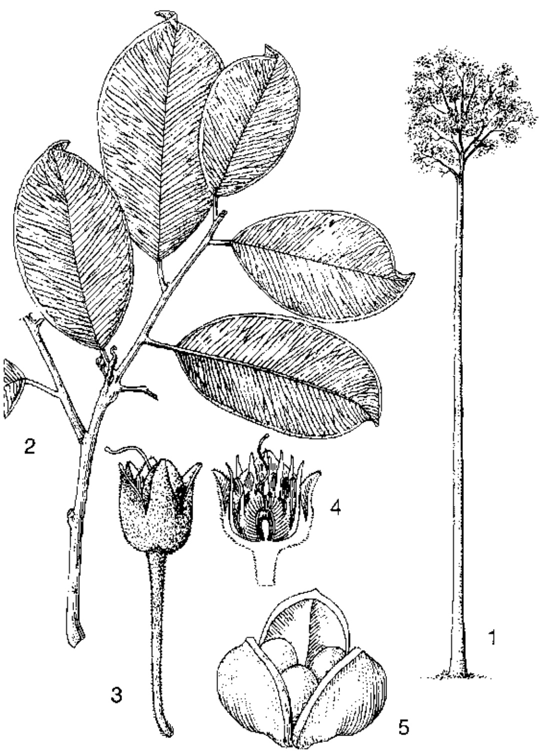
Gonystylus bancanus (Miq.) Kurz

Natuurk. Tijdsch. Ned. Ind. 27: 171, 240 (1864).

Vernacular names Brunei: ramin. Indonesia: ramin (general), gaharu buaya (Sumatra, Kalimantan), merang (Kalimantan). Malaysia: ramin melawis, melawis, ramin telur (Peninsular), garu buaja (Sarawak).

Distribution South-western Peninsular Malaysia, south-eastern Sumatra, Bangka and Borneo.

Uses *G. bancanus* is the most important source of ramin timber. The wood is suitable for general light construction, and numerous uses where a clean, whitish timber is desired. The heartwood is used for incense.



Gonystylus bancanus (Miq.) Kurz – 1, tree habit; 2, sterile twig; 3, flower; 4, sectioned flower; 5, dehisced fruit.

Observations A medium-sized to fairly large tree of up to 40(–45) m tall, bole cylindrical, up to 120 cm in diameter but usually less, sometimes slightly fluted at the base, with many knee-roots (pneumatophores), bark surface often cracked and fissured, greyish to red-brown, inner bark fibrous, orange-brown to red-brown, sapwood pale cream or white; leaves elliptical, shortly oblong-oblanceolate or obovate, (4–)5–8(–14.5) cm × (2–)3–5(–7) cm, often conduplicate, broadly cuneate to rounded at base, suddenly narrowed into an acuminate-cuspidate apex, quite glabrous, petiole 8–18 mm long; inflorescence up to 9 cm long, minutely adpressed ochraceo-puberulous; petals 13–20, narrowly lanceolate, glabrous; fruit subglobose, up to 4 cm in diameter. *G. bancanus* occurs gregariously in lowland freshwater swamp or peat-swamp forests outside the influence of tidal waters but often in broad belts along the coast. It occurs up to 100 m altitude and is occasionally found in pure stands (e.g. Sarawak). The density of the wood is (460–)540–750(–840) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 10, 14, 15, 89, 93, 100, 102, 146, 318, 323, 340, 406, 435, 456, 457, 461, 578, 620, 635, 639, 691, 748, 779, 785, 786, 807.

Gonystylus brunnescens Airy Shaw

Kew Bull.: 138 (1950).

Vernacular names Brunei: kelat. Indonesia: gerima, garu campaka (West Kalimantan). Malaysia: ramin daun tebal (Peninsular), paliu, nasinasi (Sabah).

Distribution Eastern Peninsular Malaysia and Borneo.

Uses The timber is used as ramin.

Observations A medium-sized to fairly large tree of up to 36(–45) m tall, bole fluted, up to 95 cm in diameter, bark surface fissured, roughly cracking to slightly scaly with elongated scales, brown, inner bark pink, sapwood yellow; leaves elliptical to oblong, 12–26 cm × 4–10 cm, cuneate to rounded at base, rounded or subacute at apex, glabrous, petiole 12–15 mm long; inflorescence 4–11 cm long, finely pubescent or ferrugineous-tomentellous; petals 25–30, subulate-filiform, glabrous outside, rather densely retrorse-hispid inside; fruit ovoid, up to 6 cm in diameter. *G. brunnescens* occurs in non-inundated rain forest on hills and low-lying land, often near the sea, up to 350(–1500) m altitude. The density of the wood is about 750 kg/m^3 at 15% moisture content.

Selected sources 100, 748, 779, 807.

Gonystylus confusus Airy Shaw

Kew Bull.: 10 (1947).

Vernacular names Indonesia: banitan, sitabai (Sumatra). Malaysia: (ramin) pinang muda (Peninsular), karu-karu (Selangor), gelugor tawar (Pahang).

Distribution Peninsular Malaysia and probably also in northern Sumatra.

Uses The timber is used as ramin.

Observations A small to medium-sized tree of up to 30 m tall, bole up to 70 cm in diameter, bark surface not fissured, with elongated, adherent scales, dull grey and green or dark brown, inner bark yellow and pink; leaves oblanceolate-oblong or rarely oblong, 8–27 cm × 2–9 cm, cuneate to rounded at base, cuspidate to shortly acuminate at apex, glabrous except for a few adpressed hairs near the midrib below, petiole 8–17 mm long; inflorescence 6–20 cm long; calyx lobes not reflexed, petals about 30, subulate-filiform, glabrous, ovary with 3 small abortive styles around the base of the functional style; fruit subglobose, 4–10 cm in diameter. *G. confusus* is fairly common in evergreen, non-inundated rain forest, and occurs on hills and low-lying land, up to 600 m altitude.

Selected sources 620, 748, 779, 807.

Gonystylus consanguineus Airy Shaw

Kew Bull. 17: 454 (1964).

Vernacular names Indonesia: melingkat pepah (Dayak, West Kalimantan), ngalin (East Kalimantan), tempe-eng (Bassap-Mapulu, East Kalimantan). Malaysia: bidaru (Sabah).

Distribution Borneo.

Uses The timber is used as ramin.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole branchless for up to 30 m, up to 80 cm in diameter, fluted at base and with small buttresses, bark surface not fissured, smooth or with elongated scales, red-brown to dark brown, inner bark laminated, cream to ochre, sapwood pale yellow; leaves elliptical to oblong, 10–25 cm × 5–9 cm, broadly cuneate at base, abruptly caudate-acuminate at apex, glabrous or sparsely hairy on the midrib below, petiole 7–12 mm long; inflorescence 10–13 cm long; calyx lobes finally reflexed, petals about 30, small, glabrous. *G. consanguineus* is locally common in primary or old secondary lowland (dipterocarp) forest on loamy or clayey soils or even limestone rocks, sometimes in periodically inundated locations, up to 400 m altitude.

Selected sources 9, 146.

Gonystylus forbesii Gilg

Engl. & Prantl, Nat. Pflanzenfam. Nachtr. 1: 232 (1897).

Synonyms *Gonystylus warburgianus* Gilg ex Domke (1932).

Vernacular names Indonesia: banitan nirang (Sumatra), sibutoh bulug (Siberut), paoh balang (South Kalimantan).

Distribution Sumatra, Siberut and Borneo.

Uses The timber is used as ramin; it is comparatively hard and heavy but only of minor importance.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole often rather poorly shaped, up to 85 cm in diameter, angular, usually fluted at the base but not buttressed, bark surface rather shaggy, dark brown, inner bark orange-yellow, sapwood white, often with faint longitudinal streaks; leaves elliptical, often almost rhomboid, 4–10(–11.5) cm × 2.5–5 cm, usually markedly cuneate at base, cuneate-acuminate or sometimes rounded and caudate at apex, glabrous or thinly puberulous below, petiole 9–11 mm long; inflorescence 5–15 cm long; calyx lobes reflexed, petals about 10, ovate-deltoid, tomentellous throughout and setulose inside; fruit oblong-ellipsoid, about 3 cm in diameter. *G. forbesii* is fairly common in evergreen swamp forest, especially near streams and in dryland rain forest and occurs scattered or in small groups, from sea-level up to 1200 m altitude. The density of the wood is 530–735 kg/m^3 at 15% moisture content.

Selected sources 89, 146, 748.

Gonystylus keithii Airy Shaw

Kew Bull.: 13 (1947).

Vernacular names Indonesia: bepisang, songkop (West Kalimantan), letung (East Kalimantan). Malaysia: mangriau, saukau, malindah (Sabah).

Distribution Borneo.

Uses The timber is used as ramin. Pounded fruits are mixed with ash and used as a fish poison.

Observations A shrub or small to medium-sized tree of up to 26 m tall, bole up to 90 cm in diameter; leaves elliptical-oblong to oblanceolate, 13–24 cm × 4–9 cm, cuneate at base and gradually narrowed at apex, practically glabrous throughout, petiole 1–1.5 cm long; inflorescence 8–13 cm long; calyx lobes strongly revolute, petals 20–22, subulate, retrorse-setulose inside. *G. keithii* occurs scattered in evergreen, non-inundated rain forest, mostly on sandy soils, up to 400 m altitude.

Selected sources 146, 748.

Gonystylus lucidulus Airy Shaw

Kew Bull. 17: 447 (1964).

Distribution North-eastern Sarawak and Brunei.

Uses The timber is used as ramin.

Observations A medium-sized to fairly large tree of up to 36 m tall, bole branchless for up to 27 m, up to 40 cm in diameter, fissured, bark surface scaly, dark brown, inner bark pale brown, sapwood pale yellow or yellow; leaves oblong to elliptical-oblong, 10–20 cm × 5–8 cm, rounded at base and broadly but abruptly caudate, glabrous, petiole 12–18 mm long; inflorescence up to 18 cm long; fruit lanceolate-ovoid, 1.7 cm in diameter. *G. lucidulus* occurs in primary lowland dipterocarp forest on low undulating hills, on yellow sandy soil, up to 300 m altitude.

Selected sources 9.

Gonystylus macrophyllus (Miq.) Airy Shaw

Kew Bull.: 9 (1947).

Synonyms *Gonystylus miquelianus* Teijsm. & Binnend. (1862), *Gonystylus philippinensis* Elmer (1915), *Gonystylus obovatus* Merr. (1917).

Vernacular names Indonesia: pinang bai (Sumatra), garu kapas (West Java), garu campaka (West Kalimantan). Malaysia: kelembak (Peninsular, Johor). Philippines: lanutan-bagyo, anauan, busilak (general).

Distribution Throughout the Malesian area and reaching the Solomon Islands, except for Central and East Java and the Lesser Sunda Islands, and on the Nicobar islands.

Uses The timber is an important source of ramin; it is often heavier than that of other species. The heartwood is used for incense.

Observations A medium-sized to large tree of up to 45 m tall, bole up to 100 cm in diameter; leaves exceedingly variable in size and shape, oblong, elliptical, obovate or sublanceolate, 2–40 cm × 2–15 cm, cuneate to rounded at base, acuminate to rounded or even retuse at apex, glabrous, petiole up to 25 mm long; inflorescence elongate, up to 20 cm long; calyx lobes not reflexed, petals 20–40, narrowly subulate, glabrous; fruit subglobose, up to 7 cm in diameter. *G. macrophyllus* occurs in primary forest at low and medium altitudes, ascending to 1200 m in Sumatra and to 1500 m in Sabah and the Philippines. It might well prove that the present concept of this species is too wide and that several distinct species can be recognized, especially from the eastern Malesian region. The density of the wood is about 550 kg/m^3 at 15% moisture content.

Selected sources 9, 35, 146, 175, 360, 748, 771.

Gonystylus maingayi Hook.f.

Fl. Brit. India 5: 200 (1886).

Vernacular names Brunei: bidaru. Indonesia: bemban-itam (Sumatra). Malaysia: ramin pipit, pinang muda, sepa petri (Peninsular).

Distribution Peninsular Malaysia, Sumatra and northern Borneo.

Uses The timber is used as ramin, especially for making planks and boards for domestic buildings. A decoction of the roots is administered after childbirth as a protective medicine.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole branchless for up to 31 m, up to 75 cm in diameter, sometimes with a fluted base, bark surface cracking to fissured and scaly, pale grey to dark brown or red-brown, inner bark orange; leaves elliptical-oblong, 7–12(–17) cm × 2.5–4.5(–6) cm, cuneate to rounded at base, narrowed and acuminate at apex, adult leaves glabrous but midrib thinly puberulous below, petiole 8–15 mm long; inflorescence about 20 cm long; calyx lobes revolute, petals 10–12, triangular-subulate to ovate-acuminate, glabrous; fruit ovoid to rounded, 2.5–3 cm in diameter. *G. maingayi* occurs in primary lowland rain forest and in peat-swamp forest up to 150(–200) m altitude. The density of the wood is 520–780 kg/m^3 at 15% moisture content.

Selected sources 9, 102, 146, 620, 748, 779, 807.

Gonystylus velutinus Airy Shaw

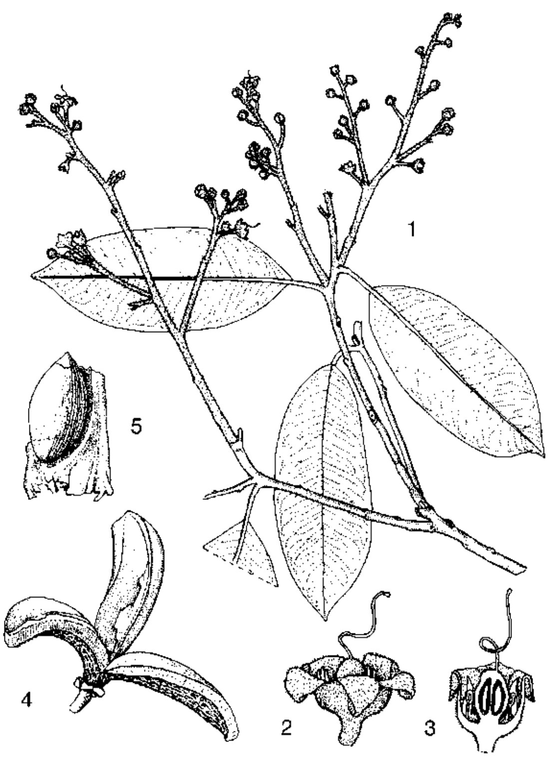
Kew Bull.: 140 (1950).

Vernacular names Indonesia: kayu minyak (Sumatra), menamang (Bangka), malam (Belitung). Malaysia: ramin telur melanau (Sarawak).

Distribution Sumatra, Bangka, Belitung; probably also on Borneo.

Uses The timber is used as ramin, for example for planks and house construction.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole up to 70 cm in diameter; leaves elliptical, oblong-elliptical or lanceolate-elliptical, 8–11(–13) cm × 3.5–5 cm, cuneate to subrotundate at base, shortly and narrowly cuspidate-acuminate at apex, usually more or less pubescent below, petiole 7–11 mm long; inflorescence 7–12 cm long; calyx lobes strongly revolute, petals 7–8, deltoid, acute; fruit lanceolate-oblong, 1.2–2.5 cm in diameter. *G. velutinus* occurs scattered and



Gonystylus velutinus Airy Shaw - 1, flowering twig; 2, flower; 3, sectioned flower; 4, dehisced fruit; 5, seed.

is locally common in primary rain forest, mostly on non-inundated sandy soils but also on clayey swampy soils near water courses at very low altitude. The sap is said to be irritant.

Selected sources 748.

Gonystylus xylocarpus Airy Shaw

Kew Bull.: 73 (1952).

Vernacular names Indonesia: medang belet (West Kalimantan). Malaysia: garu melitan (Iban, Sarawak).

Distribution Western Borneo (Sarawak and western Kalimantan).

Uses The timber is used as ramin, in Sarawak for cheap furniture.

Observations A medium-sized to fairly large tree of up to 36 m tall, bole cylindrical, up to 75 cm in diameter, fluted at base, bark surface flaky, dark to red-brown; leaves broadly elliptical, 10–17 cm × 4.5–9 cm, rounded at base and shortly subapiculate to rounded at apex, the midrib sparsely puberulous below; inflorescence up to 18 cm long; calyx lobes recurved, petals 35–40, narrowly subulate, glabrous; fruit globose, up to 7.5 cm in diameter. *G. xylocarpus* occurs in primary rain forest and heath forest up to 100 m altitude.

Selected sources 8, 9, 748.

I. Soerianegara (general part),
E.N. Sambas (general part),
A. Martawijaya (properties),
S. Sudo (wood anatomy),
L.E. Groen (selection of species)

Heritiera Aiton

Hort. kew. 3: 546 (1789).

STERCULIACEAE

x = unknown; *H. littoralis*: $2n$ = 20, 28, 38

Trade groups

- Mengkulang: medium-heavy hardwood, e.g. *Heritiera javanica* (Blume) Kosterm., *H. simplicifolia* (Masters) Kosterm.
- Dungun: heavy hardwood, e.g. *H. littoralis* Aiton, *H. sylvatica* S. Vidal.

Vernacular names

- Mengkulang: teralin (Fr). Brunei: kembang. Indonesia: palapi, teraling. Malaysia: kembang (Peninsular, Sabah). Philippines: lumbayau. Burma: kanazo. Laos: hao. Thailand: chumpraek (Trat).
- Dungun. Indonesia: dungon. Philippines: dungon, dungon late. Burma: kanazo, pinle-kanazo. Thailand: ngonkai-thale (central, Surat Thani), duhun (Trang). Vietnam: c[aa]y cui.

Origin and geographic distribution *Heritiera* consists of about 35 species and is distributed over a large area comprising tropical Africa (2 species), southern Asia from India to New Guinea (the majority of the species), Micronesia (1 species), and tropical Australia (3 species). About 20 species occur in Malesia. *H. littoralis* is the most widespread species, covering almost the entire area of the genus.

Uses Mengkulang is a very good general-purpose timber. It is not very durable, but is suitable for interior construction, flooring, furniture, ship masts and other ship constructions above the waterline. For the export market mengkulang is recommended for joinery, flooring and other purposes, as an alternative to red meranti (from *Shorea* spp.), niangon (from the African *Heritiera utilis* (Sprague) Sprague) and African mahogany (from the genus *Khaya*). Mengkulang is suitable for flooring subject to medium or light traffic, and also for purlins, ceiling joists, window frames, and

even foundation piling (but must then be treated with preservative). It is particularly suited for staircase construction. It makes high quality veneer for core and outer layers of plywood. The wood can be used to make strong and stable particle board.
Dungun wood is of good quality, but it is not used so commonly because of the often twisted and stunted form and low branching of the bole; moreover, the timber is difficult to work. It is particularly used for rice pounders and other domestic articles, but sometimes also for piling, bridges and ship building. In the Philippines it is recommended for steamed bentwork and when strength and durability are required. Dungun was formerly valued for bulletproof shields because of its toughness.
H. littoralis has several other uses, particularly for tanning and in traditional medicine. The wood is said to be suitable for making paper.

Production and international trade Mengkulang timber is locally commercially important, particularly in Malaysia. The export of sawn mengkulang timber from Peninsular Malaysia decreased from 1981 (44 000 m^3 with a value of US$ 7 million) to 1984 (17 600 m^3 with a value of US$ 2.9 million). From then on there was an increase to 1989 and 1990 (with an export volume of 39 700 m^3 and value of US$ 11.5 million, and 31 500 m^3 and value of US$ 9.9 million, respectively). In 1992 the export was 23 000 m^3 with a value of US$ 7.5 million. Mengkulang is also exported from Sarawak and Sabah, particularly to Japan. The export of round logs from Sabah was 15 000 m^3 (worth US$ 1.3 million) in 1987, and the 1992 export was 6000 m^3 of logs and 9000 m^3 of sawn timber with a total value of US$ 3.5 million.
In other countries mengkulang is not generally available in commercially important quantities for shipment as a separate timber. It is often traded in combination with dark red lauan from the Philippines and dark red meranti from Indonesia (both from *Shorea* spp.). Mengkulang is much exported from the Riau Archipelago to Singapore. In Papua New Guinea, the timber is ranked in MEP (Minimum Export Price) group 4, and fetched a minumum export price for saw logs of US$ 43/m^3 in 1992.
Dungun is of less commercial value and only locally important, e.g. in the Philippines.

Properties Mengkulang is a medium-weight and moderately hard wood. The heartwood is reddish-brown to dark brown, occasionally pinkish-brown, the sapwood pale yellow-brown to reddish. The density is (520–)640–820(–990) kg/m^3 at 15% moisture content. The grain is straight to shallowly interlocked, texture coarse and fairly even.
At 15% moisture content, the modulus of rupture is 70–100 N/mm^2, modulus of elasticity (7500–) 11 000–16 000 N/mm^2, compression parallel to grain 50–60(–72) N/mm^2, compression perpendicular to grain 4–6 N/mm^2, shear 7–12(–16) N/mm^2, cleavage 52 N/mm radial and 48 N/mm tangential, Janka side hardness 4000–4500(–5900) N and Janka end hardness 6430 N.
The rates of shrinkage of mengkulang are moderate to fairly high: from green to 15% moisture content 1.3–1.7% radial, and 3.0–3.8% tangential, from green to 12% moisture content up to 3% radial and 7% tangential. Mengkulang seasons rapidly, but it has a slight tendency to warp and to exhibit surface checking. Straining is recommended to reduce warping. It takes about 3 months to dry 4 cm thick boards to air-dry condition. Mild kiln schedules are required in drying. A temperature of 57–77°C and a corresponding relative humidity of 80% to 40% are recommended. In Malaysia kiln schedule D is considered suitable. Form stability is good when dry.
Mengkulang is somewhat difficult to work due to the high silica content, which is generally less than 0.5%. Blunting effects on tools are severe to moderately severe when sawing the timber. It is easy to polish. Care is needed when planing quarter-sawn timber in order to avoid the grain picking up, but a 20° cutting angle will produce a smooth finish. Mengkulang is moderately easy to turn and chisel. The nail-holding capacity is fairly good, but pre-boring is advised. Gluing gives no problems. Finishing with the usual treatments gives good results when the grain is properly filled. The wood is suitable for plywood. It can be peeled satisfactorily. Good veneer can be made at a peeling angle of 92° without pretreatment. The fibre is used in hardboard and superhardboard with good results.
Mengkulang is rated as non-durable; stake tests show an average service life in contact with the ground of only 2–2.5 years under tropical conditions, and 5–10 years under temperate conditions. It is rated as durable for interior work in the tropics and under dry conditions. It is prone to termite and marine borer attack, but is not particularly susceptible to powder-post beetle attack. The resistance to wood-rotting fungi varies greatly, even within one species. Mengkulang is moderately easy to treat with preservatives. Applying an open tank treatment using a creosote-diesel mixture,

an average absorption of 112 kg/m^3 was obtained in Malaysia.

Wood of *H. javanica* contains 50% cellulose, 17% lignin, 12.5% pentosan, 0.8% ash and 0.4% silica. The solubility is 4.6% in alcohol-benzene, 0.8% in cold water, 3.3% in hot water and 14.6% in a 1% NaOH solution. The energy value is about 18 800 kJ/kg.

Dungun is a heavier wood, with a density of 830–1040 kg/m^3 at 15% moisture content. It is hard and strong; at 12% moisture content the modulus of rupture is 132 N/mm^2, modulus of elasticity 18 000 N/mm^2, compression parallel to grain 72 N/mm^2, shear 14 N/mm^2, cleavage 62 N/mm radial and Janka side hardness 7600 N.

Dungun is a timber with high shrinkage: from green to 15% moisture content about 2% radial, and about 4.5% tangential. It is more difficult to season than mengkulang, and subject to considerable end splitting and surface checking. Dungun contains rather large amounts of silica which rapidly blunt edged tools. It turns fairly well and takes a good finish.

Dungun is moderately durable when exposed to the weather or in contact with the ground; a life of 3 years in contact with the ground under tropical conditions is probably as much as can be expected. The wood is not susceptible to powder-post beetles, and is reported to be resistant to marine borers, but not always to termites. Dungun is probably difficult to impregnate with preservative because gum-like deposits are present.

The bark of *H. littoralis* contains 12–15% tannin on dry weight basis. The ichthyotoxic activity of the roots of *H. littoralis* is due to the presence of heritol, heritianin and heritonin. These compounds have potential as natural pesticides as well.

Description Medium-sized to large monoecious trees, up to 50 m tall, with usually tall and straight bole (but often stunted and low-branched in *H. littoralis*), branchless up to 20 m, and up to 100(–135) cm in diameter; trunk with well-developed, but usually thin, buttresses; bark greyish to reddish-brown outside, shallowly fissured and scaly or spotted, inner bark generally pink to red, laminated; twigs usually slender and terete, usually with prominently raised leaf scars, often with clustered or stellate hairs, and scaly. Leaves alternate, principally compound with palmately arranged leaflets, but also unifoliolate, and then seemingly simple; petiole swollen at both ends; leaflets entire, usually finely scaly beneath. Inflorescence axillary, paniculate, pubescent at the base, scaly or stellate-hairy towards tip. Flowers unisexual, very small, with 4–5(–6)-lobed calyx and lacking corolla; male flowers much more numerous than female ones, having an androgynophore bearing 8–10 sessile anthers and with or without minute sterile ovaries; female flowers slightly larger than male ones, having 4–5(–6) sessile small ovaries with short styles, alternating with small groups of sterile anthers. Fruit an ellipsoid to globose (often oblique) nut with woody wall, provided with a ridge often apically enlarging into a wing (i.e. a samara). Seed with a fairly thin testa, lacking albumen. Seedling (of *H. littoralis*) with hypogeal germination; first 2 leaves opposite or subopposite, often scale-shaped, subsequent leaves arranged spirally.

Wood anatomy

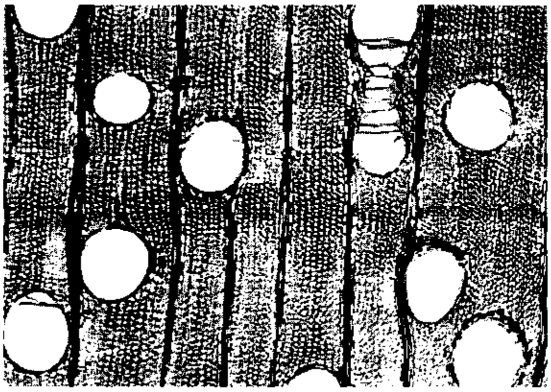
– Macroscopic characters:

Mengkulang: heartwood brown to various shades of red-brown, sometimes with dark streaks, distinctly or indistinctly demarcated from the lighter sapwood (pale brown-yellow to reddish). Grain straight to shallowly interlocked. Texture moderately coarse to coarse; fiddleback and ray figure present; wood more or less lustrous. Growth rings usually indistinct; vessels visible to the naked eye, and sometimes with reddish, yellow or white contents; parenchyma and rays usually not distinct without a lens (except larger rays in some species); faint to distinct ripple marks usually present.

Dungun differs especially in the darker colour of the heartwood (dark brown, usually with a chocolate or even purple tinge), the often strongly interlocked grain, and the finer texture without ray figure.

– Microscopic characters:

Mengkulang and dungun: growth rings, if present, marked by marginal parenchyma bands and/or slight differences of vessel frequency, spacing of tangential parenchyma lines, and/or fibre wall thickness on either side of the ring boundary. Vessels diffuse, 2–8(–25)/mm^2, solitary and in radial multiples of 2–5(–8), sometimes with narrow vessels in long radial tails or more rarely in clusters, round to oval, average tangential diameter 120–260 μm; perforations simple; intervessel pits alternate, round to polygonal, 4–6(–8) μm; vessel-ray and vessel-parenchyma pits similar but half-bordered; helical thickenings absent, but vessel walls sometimes with fine spiral grooves intergrading with coalescent apertures; dark-staining gum-like deposits present in heartwood; tyloses absent. Fibres (800–)850–1500(–2100) μm long,



transverse section (×25)

radial section (×75)

tangential section (×75)

Heritiera simplicifolia

non-septate, mostly medium thick-walled, but ranging from very thin-walled to thick-walled, variable within and between species (see also large wood density ranges), with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma scarce, vasicentric (rarely tending to aliform), diffuse-in-aggregates or in fine discontinuous lines, and occasionally in marginal bands, in 2–4(–5)-celled strands. Rays 4–8/mm, of 2 distinct sizes, 1(–2)-seriate and 3–5(–9)-seriate, broad rays up to 2 mm high in some species, but tallest rays less than 1 mm in several others, heterocellular with one row of upright marginal cells to homocellular (mostly Kribs type heterogeneous III); sheath cells usually present. Prismatic crystals often present in chambered axial parenchyma cells, less frequently also in non-chambered axial parenchyma and upright or procumbent ray cells; ray and parenchyma cells often with reddish-brown deposits. Silica inclusions recorded in axial and ray parenchyma. Traumatic gum ducts in concentric bands occasionally present. Axial parenchyma strands, vessel elements and part of the rays weakly to distinctly storied, or all elements non-storied.
Species studied: *H. aurea, H. borneensis, H. elata, H. javanica, H. littoralis, H. novoguineensis, H. simplicifolia, H. sumatrana, H. sylvatica.*

Growth and development The fruits are either dispersed by water (mangrove species) or by wind (inland forest species). The fruit of *H. littoralis* floats in water with the ridge upwards, and is impermeable to water. When washed up on a beach, the base of the fruit weakens, allowing moisture to penetrate. The thick, hard radicle opens the hard fruit wall and the primary root penetrates deeply into the soil. Fruits of other *Heritiera* species with large wings (e.g. *H. javanica, H. simplicifolia*) are wind-dispersed.
In *H. littoralis* the growth of the branches is rhythmic and the shoots are distinctly articulate. *H. simplicifolia* flowers at the beginning of the rainy season, but not every year. *H. littoralis* usually flowers at intervals throughout the year.

Other botanical information Kostermans has united the genera *Argyrodendron* and *Tarrietia* with *Heritiera*. According to several botanists, *Heritiera* in the sense of Kostermans is too heterogeneous in several aspects, and in their view *Tarrietia* s.s., including *Argyrodendron*, is distinct from *Heritiera* s.s. Identifying and collecting *Heritiera* species often gives much trouble. Leaves may vary enormously within species; in trees up to 20 m tall they are often still completely

different from those of mature trees. For instance, in young trees of *H. simplicifolia* the leaves may be palmately compound, whereas in old trees they are always simple. Many species are rare to very rare, plants are not easy to collect because of their habit (large trees with hard wood), they have very small flowers, and fruiting is often scanty.
The wood of *Heritiera utilis* (Sprague) Sprague and *H. densiflora* (Pellegr.) Kosterm. is exported from Africa. *H. fomes* Buch.-Ham. is extensively cut in India and Burma for its timber.

Ecology *H. littoralis* grows in mangrove swamps on rocky and sandy coasts, often in drier sites and in the transition zone from mangrove to freshwater swamp. It is typically a tree of the banks of tidal rivers. Sometimes *H. littoralis* may make up 40% of the total stand, e.g. in Sarawak. It is often accompanied by *Bruguiera parviflora* (Roxb.) Wight & Arn. ex Griffith, *Xylocarpus granatum* Koenig, and *Excoecaria agallocha* L. Like *H. littoralis*, *H. globosa* grows behind the tidal zone of the mangrove belt, whereas some other species, e.g. *H. novoguineensis*, apparently prefer sites inundated by fresh water. Other species are found in inland forests, usually scattered and at low and medium altitudes (up to 600 m) in mixed dipterocarp forest. The different wood types may partially be determined by ecological conditions: mengkulang comes from inland forest species, dungun generally from mangrove swamp species.

Propagation and planting *H. javanica* and *H. simplicifolia* can be propagated by sowing seeds in a nursery or by stump cuttings. Seedlings are transplanted into the field when 30–50 cm high. Spacing is 3 m × 4 m. The survival rate of planted stump cuttings is about 60%.

Silviculture and management Natural regeneration techniques as used in regular management of mixed dipterocarp forest may be successful, but pure stands are probably not a good management target. Moreover, natural regeneration is usually scanty, especially in the inland forest species. In Africa *H. utilis* is artificially regenerated by strip planting.

Diseases and pests Moth larvae and beetles of the families *Curculionidae* and *Scolytidae* may damage seeds of *H. littoralis*. High percentages of *H. littoralis* seeds may show evidence of borers. Research in Australia showed that very few seeds contain an intact embryo. There may be a significant amount of pre-dispersal predation by insects on developing seeds of *H. littoralis*. Moreover, crabs may damage seedlings.

Harvesting An occasional defect of the log is said to be its brittle heart, up to a core of 15 cm.

Genetic resources Many *Heritiera* species are apparently rare, and the more common species usually occur scattered in the forest, e.g. *H. simplicifolia* less than 1 tree/ha. As this makes these species liable to genetic erosion and possible extinction, steps should be taken to conserve and grow them.

Prospects Mengkulang is a valuable timber, but the scattered appearance of the species in natural forests hampers its commercialization and endangers its survival if cut without management precautions. Research on silvicultural aspects, in particular growth rates and methods of vegetative propagation, is urgently needed.
Dungun is less valuable, but it is used extensively locally. In many places its habitat, i.e. mangrove forest, is threatened by uncontrolled exploitation, and needs integral protection.

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Selection of species

Heritiera albiflora (Ridley) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 64 (1959). Also in: Reinwardtia 4: 527 (1959).

Synonyms *Tarrietia albiflora* Ridley (1938).

Distribution Borneo (Brunei, Sarawak, Kalimantan).

Uses The timber is occasionally used as mengkulang.

Observations A medium-sized tree, up to 30 m tall with branchless bole up to 17 m, and up to 50 cm in diameter, buttresses low and thin; leaves palmately trifoliolate, glabrous beneath, petioles (2–)5–7 cm long, rather slender; panicles comparatively narrow, up to 13 cm long; fruit with large wing, glabrous. *H. albiflora* occurs scattered (but locally abundant) in heath forest at low altitude, especially in subcoastal areas.

Selected sources 33, 378, 447.

Heritiera arafurensis Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 36 (1959). Also in: Reinwardtia 4: 499 (1959).

Vernacular names Indonesia: korumu (Halmaheira), rorum (Morotai).

Distribution The Lesser Sunda Islands from Lombok to Timor, the eastern Moluccas; possibly also Sulawesi and Irian Jaya.

Uses The timber is occasionally used as dungun.

Observations A large tree, up to 45 m tall with straight, and up to 20 m branchless bole, up to 50 cm in diameter, with large buttresses; leaves simple, densely scaly beneath, petioles 2–5 cm long, slender; fruit with a faint dorsal ridge and a small apical rudder-like wing, densely scaly.

Selected sources 378, 735.

Heritiera aurea Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 55 (1959). Also in: Reinwardtia 4: 518 (1959).

Vernacular names Indonesia: papungu merah (Kalimantan).

Distribution Borneo (Sarawak, Brunei, Kalimantan).

Uses The timber is used as mengkulang.

Observations A fairly large tree, up to 40 m tall with up to 20 m branchless bole, 80 cm in diameter, buttresses tall, up to 4.5 m; leaves simple, densely scaly beneath, petioles 3–5 cm long, stout; fruit with large wing, glabrous. *H. aurea* resembles *H. simplicifolia*, except for the indumentum of the leaves, and has been confused frequently with the latter species. The tree is locally common on leached loamy soil in mixed dipterocarp forest up to 500 m altitude.

Selected sources 33, 100, 378, 447.

Heritiera borneensis (Merr.) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 56 (1959). Also in: Reinwardtia 4: 519 (1959).

Synonyms *Tarrietia borneensis* Merr. (1918), *Tarrietia unifoliolata* Ridley (1920).

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo; possibly also Sulawesi.

Uses The timber is used as mengkulang.

Observations A medium-sized to large tree, up to 45 m tall with bole up to 75 cm in diameter, buttresses small or absent; leaves 1-3-foliolate, glabrous, petioles 2–6(–9) cm long, slender; panicles lax, up to 18 cm long; fruit with large wing, glabrous. *H. borneensis* resembles *H. javanica* but lacks the tufts of hairs in the axils of the veins, and often has simple leaves. This species is locally common, e.g. in Peninsular Malaysia, elsewhere apparently rare, e.g. in Sarawak and Sabah. It occurs scattered in mixed lowland dipterocarp forest.

Selected sources 33, 378, 447, 779.

Heritiera elata Ridley

Journ. Roy. As. Soc. Straits Br. 50: 112 (1908).

Vernacular names Brunei: dungun bukit. Thailand: thong suk, ngonkai-khao (Nakhon Si Thammarat), ngonkai-bok (Surat Thani).

Distribution Peninsular Malaysia, Singapore, Borneo; possibly also Thailand.

Uses The timber is occasionally used as mengkulang.

Observations A fairly large tree, up to 40 m tall with bole up to 75 cm in diameter and large buttresses; leaves simple, densely scaly beneath, petioles 0.5–2.5 cm long, stout; panicles lax, up to 10 cm long; fruit almond-shaped, with a fairly small apical wing, glabrous. *H. elata* is apparently rare and occurs in lowland forest, especially on ridges and slopes of hills.

Selected sources 33, 102, 146, 378, 779.

Heritiera globosa Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 22 (1959). Also in: Reinwardtia 4: 484 (1959).

Vernacular names Indonesia: dungun besar (Kalimantan).

Distribution Borneo.

Uses The timber is used as dungun; it is the main source of dungun in Borneo.

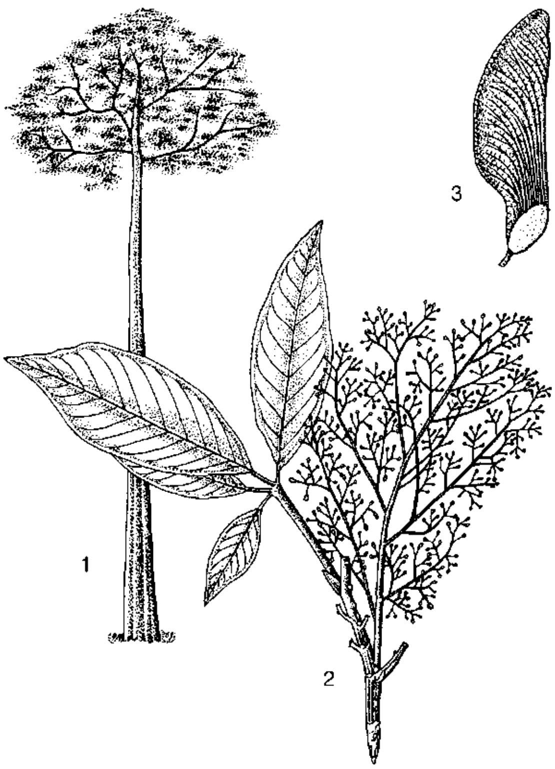
Observations A medium-sized to fairly large tree, up to 35 m tall with usually short bole up to 100 cm in diameter, with wavy buttresses extending far out; leaves simple, densely scaly beneath, petioles 2–4 cm long; panicles up to 10 cm long; fruit subglobose, with a small keel-like wing at apex, glabrous. Like *H. littoralis*, *H. globosa* usually grows behind the tidal zone of the mangrove belt. It can be distinguished from the latter species by its large size, the coppery (not silvery) lower leaf surface, and by the shape of the fruit. The wood has similar properties to that of *H. littoralis*. The density of the wood is 835–865 kg/m^3 at 15% moisture content.

Selected sources 33, 100, 378, 447, 703.

Heritiera javanica (Blume) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 58 (1959). Also in: Reinwardtia 4: 521 (1959).

Synonyms *Tarrietia javanica* Blume (1825).



Heritiera javanica (Blume) Kosterm. – 1, tree habit; 2, flowering twig; 3, fruit.

Vernacular names Indonesia, Malaysia: mengkulang jari. Laos: hao. Thailand: chum-phraek (Trat), thong suk (Trang), loma (Ranong, Surat Thani).

Distribution Indo-China, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, northern Sulawesi and the Philippines.

Uses The timber is used as mengkulang.

Observations A large tree, up to 45 m tall with columnar bole 20–25 m long and up to 100(–130) cm in diameter, buttresses thin; leaves palmately compound with (3–)5–7 leaflets, glabrescent but with characteristic tufts of hairs in the axils of secondary veins, petioles 5–10 cm long; panicles much-branched, up to 13 cm long; fruit with large wing, glabrous. *H. javanica* is one of the major species for mengkulang but less important than *H. simplicifolia*. It is widely distributed in lowland forest, mainly on ridges up to 600 m, and is locally common, e.g. in the Philippines (Mindanao, Basilan), where the species is co-dominant with dipterocarp species. The wood is slightly less heavy, less hard and less strong than that of *H. simplicifolia*. The density of the wood is 635–850 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 10, 35, 100, 175, 190, 274, 359, 378, 443, 447, 461, 484, 486, 579, 779, 795.

Heritiera littoralis Aiton

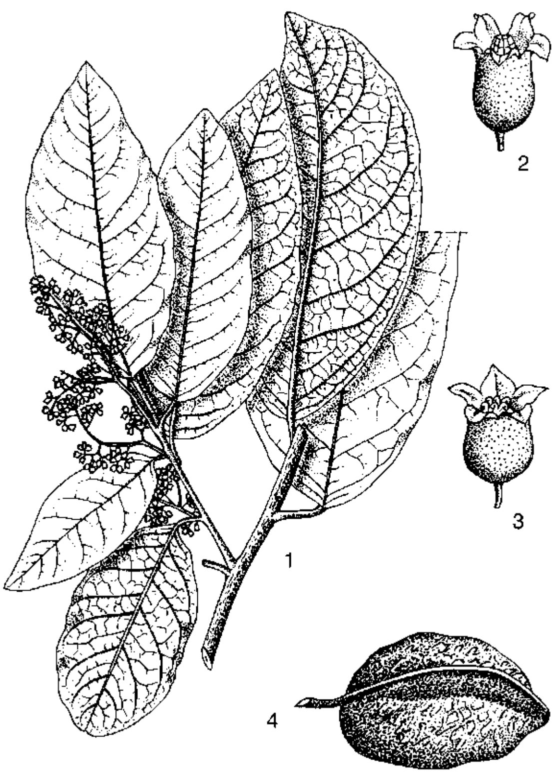
Hort. kew. 3: 546 (1789).

Synonyms *Heritiera minor* (Gaertner) Lamk (1797).

Vernacular names Looking-glass tree (En). Brunei: itik-itikan. Indonesia: dungon (general), dungun kecil (Kalimantan). Malaysia: dungun (general), dungut laut (Sabah). Philippines: dungon-late (Pilipino). Burma: pinle-kanazo. Cambodia: khleay. Thailand: khai khwai (Krabi), duhun (Trang), ngonkai-thale (central, Surat Thani). Vietnam: c[aa]y cui, cui bien.

Distribution Eastern Africa, southern Asia from India to southern China and to tropical Australia, Hawaii and New Caledonia; throughout Malesia.

Uses The timber is used as dungun. It is excellent firewood, having a high energy value. Moreover, the wood is suitable for the production of wrapping, writing, and printing paper. The bark contains tannin and is used for toughening fishing nets. An extract from the seeds is used medicinally in cases of diarrhoea and dysentery. The seeds are occasionally eaten. In the Philippines the roots are used as a fish poison.



Heritiera littoralis Aiton – 1, flowering twig; 2, male flower; 3, female flower; 4, fruit.

Observations A medium-sized evergreen tree, up to 25 m tall, but usually much less, with usually twisted and stunted bole up to 40(–60) cm in diameter, buttresses thin, wavy, extending far out; leaves simple, silvery scaly beneath, petioles 0.5–1(–2) cm long, stout; panicles lax, up to 18 cm long; fruit ellipsoid, with a rudder-like ridge, glabrous and glossy. *H. littoralis* grows in the inland zone of mangrove swamps, and it is common in many places. The wood often smells like leather. The density of the wood is 830–1040 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 33, 35, 48, 67, 89, 100, 119, 146, 175, 190, 378, 385, 438, 484, 486, 579, 703, 735, 779.

Heritiera novoguineensis Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 25 (1959). Also in: Reinwardtia 4: 488 (1959).

Distribution New Guinea.

Uses Local people sometimes use the timber like dungun, for building.

Observations A medium-sized tree, up to 30 m tall with bole up to 60 cm in diameter; leaves simple, densely and minutely scaly beneath, petioles 2.5–4 cm long; fruit subglobular to elongate and depressed, with short apical wing, minutely scaly. *H. novoguineensis* occurs in riverine forests of tidal rivers.

Selected sources 378, 735.

Heritiera simplicifolia (Masters) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 52 (1959). Also in: Reinwardtia 4: 514 (1959).

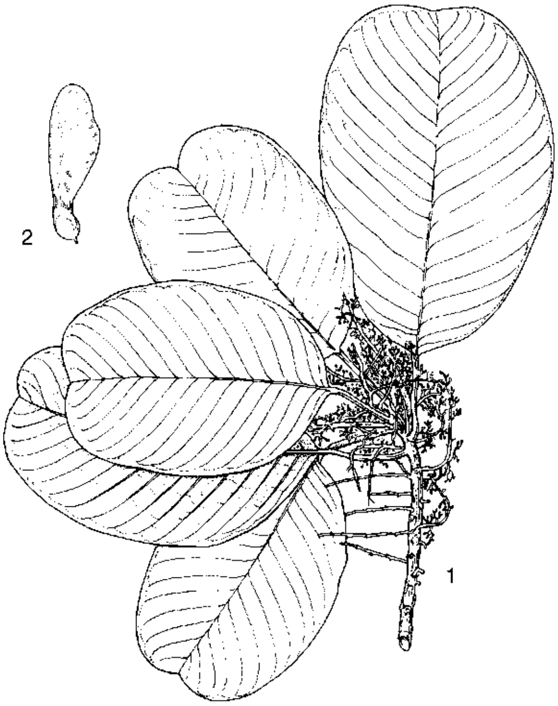
Synonyms *Tarrietia simplicifolia* Masters (1874).

Vernacular names Indonesia: teraling (Sumatra). Malaysia: mengkulang siku keluang (Peninsular).

Distribution Peninsular Malaysia, Sumatra, Borneo.

Uses The timber is commonly used as mengkulang, also for export.

Observations A large tree, up to 50 m tall with straight and columnar bole up to 135 cm in diameter, buttresses large; leaves simple, densely scaly beneath, petioles 2.5–6 cm long; panicles up to 9



Heritiera simplicifolia (Masters) Kosterm. – 1, flowering twig; 2, fruit.

cm long; fruit with large wing, glabrous. *H. simplicifolia* is the most important species of mengkulang timber. It is widely distributed but always occurs scattered in lowland mixed dipterocarp forest on flat or undulating terrain with well-drained clay soils, up to 300 m altitude. The wood is often traded together with *Shorea* spp. (dark red meranti). The mechanical properties of the wood are close to those of teak, but the wood is stiffer and tougher. The density of the wood is 520–890(–990) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 10, 33, 89, 100, 146, 159, 190, 226, 252, 260, 359, 378, 443, 447, 461, 758, 779, 786.

Heritiera sumatrana (Miq.) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 61 (1959). Also in: Reinwardtia 4: 524 (1959).

Synonyms *Tarrietia sumatrana* Miq. (1860), *Tarrietia curtisii* King (1891), *Tarrietia perakensis* King (1891).

Vernacular names Malaysia: mengkulang jari bulu. Thailand: chum-phraek khaao (Trat), seesiat cho (Surat Thani), siat khang (Yala).

Distribution Thailand, Peninsular Malaysia, Sumatra, Borneo.

Uses The timber is used as mengkulang.

Observations A medium-sized to large tree, sometimes up to 45 m tall but usually up to 30 m tall, bole up to 70(–100) cm in diameter, with large, thin buttresses; leaves palmately compound with 3–7 leaflets, sparsely hairy beneath, petioles 2–7(–11) cm long; panicles with slender ramifications, up to 15 cm long; fruit dorsally and ventrally flattened, nut ovoid-ellipsoid, wing large, glabrous. *H. sumatrana* resembles *H. javanica* but lacks the characteristic tufts of hairs in the axils of the veins of the latter species, and can be distinguished also by the blunter terminal buds, and by the much larger nut. This species is widely distributed, especially in Peninsular Malaysia. In most of the area of distribution it occurs scattered in mixed dipterocarp forest on undulating land up to 800 m altitude.

Selected sources 33, 100, 146, 378, 779.

Heritiera sylvatica S. Vidal

Revis. pl. vasc. filip.: 66 (1886).

Synonyms *Tarrietia sylvatica* (S. Vidal) Merr. (1903).

Vernacular names Philippines: dungon.

Distribution The Philippines; possibly also in Sulawesi and Irian Jaya.

Uses The timber is used as dungun in the Philippines.

Observations A large tree, up to 45 m tall, with columnar bole of 12–18 m long and up to 100 cm in diameter, buttressed; leaves simple, silvery scaly beneath, petioles 1–5 cm long, slender; panicles lax, up to 13 cm long; fruit with fairly large wing, scaly. *H. sylvatica* grows in dry primary forests at low and medium altitudes, and is locally abundant in the Philippines. The wood is very similar to that of *H. littoralis* and, just like that species, smells like leather. The density of the wood is about 945 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 378, 486, 579, 735.

Heritiera trifoliolata (F. v. Mueller) Kosterm.

Penerb. Madj. Ilmu Peng. Indon. 1: 65 (1959). Also in: Reinwardtia 4: 528 (1959).

Synonyms *Tarrietia argyrodendron* Benth. (1863) p.p., *Tarrietia trifoliolata* F. v. Mueller (1875).

Vernacular names Crowfoot elm, common stave wood (En). Indonesia: rumo (Sulawesi).

Distribution Eastern Malesia (from Sulawesi to New Guinea) and tropical Australia.

Uses The timber may be used as a substitute for European beech (*Fagus sylvatica* L.).

Observations A medium-sized tree, up to 30 m tall with bole up to 18 m long and 100 cm in diameter, buttressed; leaves (1–)3-5-foliolate, densely coppery or silvery scaly beneath, petioles 2–7 cm long, slender; panicles lax, up to 15 cm long; fruit with very large wing, coppery scaly. *H. trifoliolata* grows in primary forests up to 2000 m altitude, sometimes along rivers. The species is widespread, but apparently not common, except in Australia. The wood is pale, close-grained, tough and firm.

Selected sources 378, 735.

R.H.M.J. Lemmens (general part, selection of species),
I. Soerianegara (general part),
S.I. Wiselius (properties),
P. Baas (wood anatomy)

Hopea Roxb. (merawan)

Pl. Coromandel 3: 7 (1811).
DIPTEROCARPACEAE
$x = 7$; *Hopea beccariana*: $2n = 20$–22, *H. latifolia*:

$2n = 21$, *H. nervosa*: $2n = 14$, *H. odorata*: $2n = 14$, 20–22, *H. sangal*: $2n = 14$

Trade groups Merawan: lightweight to medium-heavy hardwood, e.g. *Hopea beccariana* Burck, *H. dryobalanoides* Miq., *H. mengarawan* Miq., *H. odorata* Roxb., *H. sangal* Korth.

Timber of *H. sangal* is sometimes traded separately in Indonesia as 'cengal'.

Vernacular names Merawan: light hopea (En). Brunei: selangan, damar kemantok, luis. Indonesia: damar mata kucing (Sumatra), gagil (Kalimantan). Malaysia: gagil, selangan, mang (Sarawak, Sabah) luis (Sarawak). Papua New Guinea: light hopea. Philippines: manggachapui. Burma: thingan. Cambodia: kôki:(r). Laos: kh'è:n. Thailand: takhian-thong (central). Vietnam: sao den.

Origin and geographic distribution *Hopea* consists of some 102 species. The section *Dryobalanoides* (Miq.) Burck, to which most of the merawan timbers belong, comprises about half of the total number of species and is distributed from mainland South-East Asia towards Peninsular Malaysia, Sumatra, Borneo, the Philippines and New Guinea. The oldest fossil wood belonging to the genus *Hopea* was found on the east coast of southern India and dates from the Miocene.

Within South-East Asia several species (especially *H. odorata* and *H. mengarawan*) are being used for reforestation.

Uses Merawan is a very useful general-purpose timber for light and medium-heavy construction; some of the heavier species are even suitable for heavy construction under cover. Its generally good working properties make it suitable not only for house construction, where it is e.g. used for joists, rafters, beams, columns, boards, stairs and door and window frames, but also for general joinery and turnery, although not for high-class furniture. Its comparatively high resistance to fungal attack makes merawan superior to e.g. meranti for uses such as weatherboarding and tiling battens. Merawan, especially wood of *H. odorata*, is often used for light- or medium-traffic flooring or for light industrial floors. Its generally high durability, including in contact with water, makes it suitable for boat and ship building and water barrels. It is satisfactory for the manufacture of plywood, veneer and particle board.

Several species yield a clear resin known as 'damar mata kucing' which is used to manufacture varnish and locally for torches and caulking boats. This resin was formerly used as a medicine applied to sores and wounds. The bark sometimes contains tannin which gives good results when applied to tan leather and is used for the manufacture of tannin-formaldehyde adhesive. The bark is also used for walls and partitions of local houses.

Production and international trade Merawan timber is usuallly not available in large quantities and large sizes. Therefore, it is rarely traded separately in Malaysia and Indonesia. Small quantities are sometimes mixed with timber of *Shorea* spp. and sold as meranti (Peninsular Malaysia, Indonesia) or selangan (Sabah). However, merawan is exported separately (as 'gagil') from Sabah and in 1987 the export of round logs was 118 000 m^3 with a value of US$ 7.6 million (US$ 64/m^3). In 1992 the export of merawan logs from Sabah was 16 000 m^3 and of sawn timber 15 500 m^3, with a total value of US$ 3.7 million. In the Philippines merawan ('manggachapui') occurs locally abundantly, but no export figures are available. *Hopea* (both heavy and light) is one of the more important export timbers in Papua New Guinea, and it is ranked in the MEP (Minimum Export Price) group 3 and fetched a minimum export price of US$ 50/m^3 for saw logs in 1992. However, it constitutes less than 1% of the total amount of timber imported in Japan from Papua New Guinea.

Properties Merawan is a light to medium-heavy hardwood. The sapwood is light yellow and distinct from the usually yellowish-brown heartwood (sometimes olive-brown or reddish-brown); on exposure the heartwood often darkens to dark brown. The density is (420–)490–980(–1155) kg/m^3 at 15% moisture content. Planed surfaces are glossy and the radial surface often shows a stripe figure. The grain of the wood is interlocked, texture moderately fine and even.

Tests of merawan wood in green condition in Indonesia, Malaysia, Papua New Guinea and the Philippines showed the following mechanical properties: modulus of rupture (64–)77–110 N/mm^2, modulus of elasticity 12 000–15 500 N/mm^2, compression parallel to grain (33–)42–51 N/mm^2, compression perpendicular to grain 5–9 N/mm^2, shear (4–)5–11 N/mm^2, cleavage 35–65 N/mm radial and 44–84 N/mm tangential, Janka side hardness 3010–5525 N and Janka end hardness (2710–) 3910–6110 N.

Tests in Indonesia at 15% moisture content gave the following results: modulus of rupture 94–117 N/mm^2, modulus of elasticity 13 000–14 000 N/mm^2, compression parallel to grain (46–)51–58 N/mm^2, shear 4–12 N/mm^2, cleavage 26–43 N/mm radial and 31–66 N/mm tangential, Janka side

hardness (2200–)3800–4870 N and Janka end hardness (4200–)5150–6180 N.
The rates of shrinkage are small to moderate, from green to 15% moisture content 0.9–1.3% radial and 2.2–3.3% tangential, and from green to oven dry 2.7–3.6% radial and 6.1–7.5% tangential. Merawan air dries comparatively slowly, but rarely develops serious seasoning defects except for slight cupping; sometimes end and surface checks and warping occur, especially on wide boards. Boards of 15 mm and 40 mm thick of *H. sulcata* wood take respectively 4 months and 6 months to air dry. In Malaysia kiln-drying schedule H is recommended. It takes 5 days for 25 mm thick boards to kiln dry from 50% to 10% moisture content.
Merawan is usually easy to resaw and cross cut. Planing is also easy, giving a smooth finish. Boring is recorded as slightly difficult for *H. nervosa*, but easy for *H. mengarawan* and *H. sulcata*, and the surface produced is usually smooth. Turning is easy and the finish is smooth. *H. sulcata* is rated as very poor in resistance to splitting when nailed. Merawan is suitable to be peeled for veneer. Veneer 1.5 mm thick can be made satisfactorily with a peeling angle of 91°. Gluing with urea formaldehyde extended with 20% wheat flour produces good-quality plywood. The pulping and paper-making properties of merawan are rated as satisfactory; the paper is suitable for writing, printing and wrapping.
Merawan is moderately durable under exposed conditions. Graveyard tests with stakes in Malaysia showed an average life in contact with the ground of 3–3.5 years, but in Indonesia up to 7.5 years (*H. mengarawan*) or even 10 years (*H. dasyrrhachis*). The wood is resistant to fungal infection under normal conditions but some species are very susceptible to damage by ambrosia beetles. The sapwood is susceptible to severe damage by termite and (in damp situations) fungal attack. Most species are immune to powder-post beetle attack. The wood is not resistant to marine borer attack. It is difficult to treat with preservatives. When the open tank process is used, the wood absorbs only 32–48 kg/m^3 of a mixture of creosote and diesel fuel, and under heavy pressure in the full-cell process absorption will be about 80 kg/m^3. However, in spite of the low absorption, treated wood is very durable in exposed conditions or in contact with the ground.
Merawan wood contains 54–60% cellulose, 27–29% lignin, 13–13.5% pentosan, 0.6–0.8% ash and about 0.2% silica. The solubility is 5.2–7.1% in alcohol-benzene, about 1% in cold water, 2.1–4.5% in hot water and 13.3–13.4% in a 1% NaOH solution. The energy value of *H. mengarawan* wood is 19 600 kJ/kg.

Description Small to fairly large, occasionally large, trees of up to 40(–60) m tall; bole usually tapering, frequently branching low but sometimes branchless for up to 20(–30) m, with a diameter of up to 100(–180) cm, often exuding a pale or white clear dammar, sometimes in globular or stalactitic masses; buttresses present, often small but sharp and stilted, sometimes with adventituous stilt roots; bark surface regularly, closely, rather deeply fissured, or comparatively smooth at maturity, sometimes irregularly fissured or cracked with age, dark chocolate-brown with greenish-yellow areas, inner bark pink, dull sandy-brown or dull light brown tinged pink, close-textured; crown in small trees lanceolate, monopodial with slender, more or less horizontal and pendant branches, in large trees becoming hemispherical, with many small straight branches radiating from the bole apex. Leaves alternate, simple, small or medium-sized, sometimes large and narrowly oblong, usually with domatia on lower surface; secondary veins sometimes comparatively few with scalariform tertiary venation (*H. nervosa, H. papuana* and *H. sublanceolata*), more often numerous and of varying length, more or less indistinct and with indistinct tertiary venation ('dryobalanoid'), superficially resembling *Dryobalanops*, or intermediate between these two types ('subdryobalanoid'); petiole never geniculate; stipules linear, fugacious (subpersistent in saplings). Inflorescence paniculate, regularly branched with short branchlets, terminal or axillary, many-flowered, slender; bracts fugacious or subpersistent. Flower buds small, ovoid or rarely globose; flowers secund or distichous, bisexual, actinomorphic, 5-merous, pale or dark coloured, scented; sepals imbricate, 2 outer ones ovate, more or less obtuse, thickened, 3 inner ones suborbicular, frequently mucronate, thin at margins; petals oblong, connate at base and falling in a rosette, often persistently pubescent on the parts exposed in bud; stamens 10 or 15 (rarely up to 38), in 1–3 verticils or irregular, filaments broad and compressed at base, tapering medially and filiform apically, anthers usually subglobose, with 4 pollen sacs, the outer pair somewhat larger, appendage to connective slender, usually at least twice as long as the anther, glabrous or minutely glandular tuberculate; ovary ovoid, glabrous or tomentose, without or with a distinct stylopodium and then pear-shaped or truncate, style long or short, glabrous, with a minute stigma. Fruit comparatively small, 2 outer fruit calyx lobes prolonged, spatulate, 3 inner ones short, sometimes all 5 fruit calyx lobes short and subequal, all lobes thickened and saccate at base; nut ovoid, usually glabrous, with a distinct apical stylopodium if present in the flower; pericarp splitting irregularly at germination. Seedling with epigeal germination; cotyledons subequal; first pair of leaves opposite, followed by spiral leaves or an initial whorl of 3.

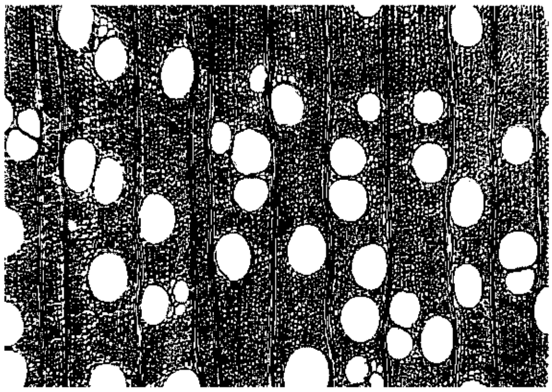
Wood anatomy

– Macroscopic characters:

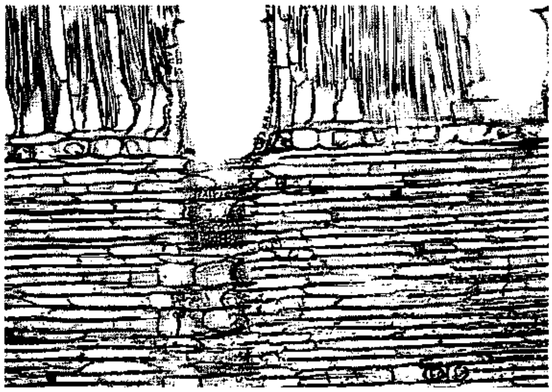
Heartwood yellowish-brown, usually with a greenish tinge, but *H. sangal* wood with a pinkish tinge and *H. nervosa* wood reddish-brown with darker streaks, darkening to brown with a greenish tinge or dark reddish-brown on exposure, distinctly demarcated from the yellowish-white sapwood. Grain shallowly or deeply interlocked, sometimes wavy. Texture moderately fine; irregularly spaced, light-coloured concentric lines surrounding white dots visible to the naked eye, usually less clearly than in giam. Growth rings not distinct.

– Microscopic characters:

Growth rings indistinct. Vessels diffuse, usually 10–20/mm^2, mostly solitary, with a small number of radial multiples of 2(–3), usually 140–200 μm in tangential diameter; perforations simple; intervessel pits alternate, vestured, round, usually 5–10 μm; vessel-ray and vessel-parenchyma pits round to oval, simple to half-bordered; tyloses often abundant. Fibres 1.2–2.2 mm long, c. 25 μm in diameter, non-septate, thin- to thick-walled, much thinner-walled than fibres of giam (walls c. 2.5 μm thick in *H. sangal*), with infrequent, small, simple to minutely bordered pits confined to the radial walls. Parenchyma vasicentric, aliform and short confluent, and also often apotracheally diffuse-in-aggregates, partly forming a reticulate pattern (*H. acuminata, H. odorata, H. sangal*), and in irregularly spaced tangential bands surrounding the intercellular canals. Rays 5–7/mm, 1–4-seriate (*H. acuminata*) or 1–7-seriate (*H. odorata*), mostly 1000–2000 μm high, the multiseriate part of some species (e.g. *H. acuminata, H. odorata*) often heterocellular, with 1 and/or 2–4 rows of square and/or upright marginal cells (Kribs type heterogeneous III and II). Prismatic crystals present in axial parenchyma cells, in long chains (*H. ferruginea*), or absent (*H. mengarawan, H. sangal*); druses present in addition in *H. ferruginea*; prismatic crystals generally present in ray-parenchyma cells, often alligned radially. Axial intercellular



transverse section (×25)



radial section (×75)

tangential section (×75)

Hopea sangal (merawan)

canals of the concentric type surrounded by tangential parenchyma bands, with whitish contents. Species studied: *H. acuminata, H. ferruginea, H. mengarawan, H. nervosa, H. odorata, H. sangal.*
Merawan differs from giam by its larger vessels, thinner-walled fibres and fewer rays.

Growth and development The growth of seedlings is enhanced by inoculation with ectomycorrhizae. The fungi significantly promote the uptake of macronutrients in the tissues of seedlings. For *H. odorata*, inoculation with *Scleroderma* sp. gives better results than inoculation with *Russula* and *Boletus* sp. Most species regenerate prolifically under natural conditions. In natural forest in Malaysia, 75% of the seedlings of *H. pedicellata* survived 2 years after germination. Mortality was highest among seedlings 10–20 cm tall. Seedlings of *H. foxworthyi* are shade tolerant; they have a survival rate of 85% a few months after germination when growing under heavy shade. On the other hand, seedlings of *H. sangal* survive remarkably well when planted in full sunshine. The sapling branches mainly at the apex of the leader shoot at the initiation of each growth period; this gives the sapling a pagoda-like appearance.
Growth rates of trees vary considerably between species. At an age of 40 years, *H. mengarawan* and *H. myrtifolia* are reported to reach a maximum diameter of 60 cm, *H. beccariana, H. ferruginea* and *H. latifolia* reach 50 cm, *H. nervosa* 42 cm, and *H. pubescens* only 26 cm, whereas *H. sangal* trees may reportedly reach a maximum diameter of 40–70 cm. *H. odorata* is reported to reach a diameter of 53 cm in 25 years. In East Kalimantan *H. dryobalanoides* showed a mean annual height increment of 1.3 m and mean annual diameter increment of 1.0 cm, in a 4-year period. Data from three 20-year-old plantations of *H. mengarawan* in Indonesia show corresponding values of 1.1 m and 1.0–1.3 cm.
Merawan trees flower at more or less regular intervals. The flowering periodicity of the various species is unknown. *H. odorata*, planted at the Forest Research Institute Malaysia (Kepong) flowers and fruits almost regularly every 2 years. Many *Hopea* spp. are pollinated by thrips (*Thysanoptera*). The period between anthesis and maturity of the fruit is about 3 months. Even though the fruits have 2 long wings and thus seem adapted to dispersal by wind, they generally fall directly below the mother tree in the aseasonal, almost windless rain forest. This is evident from the abundance of regeneration of *Hopea* seedlings below mother trees.
Polyembryony has been reported in *H. odorata*. This species has found to be triploid, effectively confirming that it is apomictic.

Other botanical information The genus *Hopea* belongs to the tribe *Shoreae* and is very closely related to the genus *Shorea*. The two genera are distinguished by a single character. In *Hopea* the two outer sepals are slightly or markedly thicker than the inner three and only they develop into wings in fruit. In *Shorea* the three outer sepals are thicker than the inner two and they normally develop into the large wings (or lobes) in fruit. In both genera species with only short and subequal fruit sepals occur and these are assigned to one of the two genera by comparison of other floral characters. All but a few *Shorea* species are emergent trees, whereas all but a few *Hopea* species are main canopy or understorey trees.
The groups distinguished commercially, the giam timbers and the more variable merawan timbers, correspond to some degree to the botanical division of the genus *Hopea*. Most giam timbers belong to the section *Hopea*, most merawan timbers (except *H. acuminata, H. dasyrrhachis, H. glaucescens, H. odorata, H. papuana, H. philippinensis, H. sangal*) to the section *Dryobalanoides* (Miq.) Burck. The latter is characterized by dryobalanoid or subdryobalanoid venation (scalariform in *H. nervosa* and *H. sublanceolata*), smooth, fissured or cracked, not evenly flaky bark, bole often stilt-rooted and wood with numerous chambered parenchyma strands and not markedly heterogeneous rays.
There are some *Hopea* species that cannot be assigned to either of the two commercial groups. Since they all belong to the section *Hopea*, they are treated under the giam timber. The density range of the wood of *H. pierrii* is very wide, making it a heavy merawan or giam.
In Malaysia, the scaly-barked species all belong to the giam group, those with smooth or fissured bark belong to merawan. These field characters can probably also be applied to *Hopea* species growing outside Malaysia.

Ecology Merawan is found from sea-level to 1650 m altitude. It occurs as a main canopy or understorey, rarely as an emergent tree in evergreen or seasonal, semi-evergreen forest. The semi-evergreen forest accommodates more *Hopea* species, often narrow endemics. The different species occur in a wide variety of forest types, ranging from mixed dipterocarp forest to heath forest and swamp forest. Consequently, merawan occurs on a wide variety of soil types, often on well-drained clayey soils but also on sandy, alluvial soils, podzols or on limestone. Few species extend their range towards swampy or inundated habitats. Merawan is usually not dominant, but some species occur markedly gregariously, especially in Papua New Guinea, with comparatively large gaps between the groups.

Propagation and planting It is recommended to begin collecting seed as soon as the seed-wings start turning brown. The weight of 1000 seeds of *H. mengarawan* is about 155 g, that of *H. odorata* is about 130 g. Merawan seeds exhibit no dormancy and germinate quickly after maturation. Seeds of *H. odorata* from Thailand have a high moisture content (about 50%); they die quickly through dehydration and lose their viability within 5 days when kept in the open air at 20°C. However, seeds of *H. odorata* dried at 35°C to 33% moisture content could be kept viable in Malaysia for 1–2 months at 15°C, maintaining a germination rate of over 60%. Long-term storage of seeds at 21°C in closed polyethylene bags proved possible for some species (e.g. *H. nervosa*); after almost one year the germination rate may still be 20% provided that fungal infection is prevented. Seeds of *H. latifolia*, *H. odorata* and *H. nervosa* survive at 4°C in sealed polyethylene bags for various periods, but not exceeding 3 months.

In Indonesia seedlings are planted into the field when they are 30–40 cm high. They are planted in cleared strips (1–2 m wide) in the forest at a distance of 5 m within the strip and 6–8 m between strips. For enrichment planting, wildlings are also used (e.g. of *H. mengarawan*). The application of naphthalene acetic acid (125 ppm) stimulates root growth in wildlings. Bare-root transplanting of *H. odorata* results in almost 100% survival if pruned seedlings are used. The pruned seedlings can be stored in polyethylene bags at 25°C for long periods; viability is over 50% after 7 months.

Merawan can be propagated vegetatively, though often with a low success rate. Experiments with stem cuttings taken from vertical axes of 3–4-year-old saplings treated with growth hormones (e.g. indole acetic acid and/or indole-3-butyric acid) showed successful rooting in only up to 40% of the cuttings. Stump planting of *H. beccariana* and *H. nervosa* shows high mortality. *H. foxworthyi* has been propagated by air layering, but only 20% of the branches developed roots.

Silviculture and management In a 30-year-old plantation in Indonesia trees of *H. mengarawan* planted at a density of 600 trees/ha produced 760 000 seedlings/ha. In Malaysia the survival rate of planted trees of *H. vesquei* after 15 years was 91%, whereas that of *H. andersonii* was 80%. Because of its good prospects *H. mengarawan* is recommended in Indonesia for reforestation programmes.

Diseases and pests The fungus *Cylindrocarpon destructans* causes brown leaf-spots and defoliation of seedlings of *H. mengarawan*. Seeds of *H. odorata* are reported to be attacked by the weevil *Nanophyes shoreae*.

Harvesting Logs should be removed rapidly from logging areas as they are sometimes very susceptible to attack by ambrosia beetles and blue stain infection (particularly the sapwood). Fresh logs often sink in water (e.g. *H. nervosa*) and cannot be transported by river. Large logs are often hollow.

Yield Yields are usually not high. Merawan trees are often scattered in the forest, and stands with 10–13 trees over 40 cm in diameter per ha occur only very locally.

Genetic resources *Hopea* is a large genus, and some of the species occur commonly and widespread, but others are scattered or rare. Large-scale logging without identification of species, as it is commonly practised, could easily endanger the less common species.

Prospects More research on propagation and silviculture of merawan is desirable. The establishment of large-scale plantations could be profitable, as some species grow quickly (e.g. *H. mengarawan, H. odorata, H. sangal*) and the durability of the wood is often superior to meranti.

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Selection of species

Hopea acuminata Merr.

Philipp. Govt. Lab. Bur. Bull. 29: 30 (1905).

Synonyms *Hopea maquilingensis* Foxw. (1918).

Vernacular names Philippines: manggachapui (general), dalingdingan (Tagalog, Samar-Leyte Bisaya), manggasinoro (Tagalog).

Distribution The Philippines.

Uses The timber is a lightweight merawan, generally used for bridges, ship building and rough construction, especially doors, sills and flooring board. The bark contains tannin which can be used in the production of leather. It is also used in the manufacture of tannin-formaldehyde adhesive.

Observations A medium-sized to fairly large tree up to 35 m tall, bole often branching low, with a diameter of up to 90 cm, bark surface flaky, with distinct ridges forming a network, ridges brown to nearly black, furrows light brown to yellowish, inner bark light yellowish; leaves elliptical-falcate to ovate-lanceolate, 4.5–12 cm × 2–4.5 cm, thin leathery, base unequal, cuneate, acumen slender, tapering, up to 1 cm long, venation scalariform, midrib applanate above, 9–11 pairs of secondary veins, arched at 45–65°; stamens 10, equal, anthers oblong, ovary and stylopodium broadly cylindrical, truncate, slightly tapering, densely pubescent; 2 longer fruit calyx lobes up to 5.5 cm × 1 cm, 3 shorter ones up to 3 mm × 2 mm, elliptical. *H. acuminata* is widespread and common in evergreen and semi-evergreen forest at (100–)300–800 m altitude. The density of the wood is 625–725 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 175, 258, 449, 579, 593, 748.

Hopea altocollina P. Ashton

Gard. Bull. Sing. 22: 271, pl. 16 (1967).

Vernacular names Brunei: luis gunong.

Distribution North-western Borneo.

Uses The wood is used as merawan and is suitable for door and window frames, particle board and, when treated, railway sleepers.

Observations A large tree of up to 50 m tall, bole straight, cylindrical, with a diameter up to 165 cm, buttresses prominent, branching, thin, up to 4 m tall, bark surface pale fawn-brown, shallowly longitudinally irregularly flaking, inner bark pale yellow-brown, sapwood cream, turning to a pale coffee-brown heartwood; plant glabrous, except sepals and petals sericeous outside; leaves lanceolate, 7–10 cm × 3–4.5 cm, base obtuse, appearing cuneate owing to the prominently revolute margin, acumen slender, up to 1 cm long, venation dryobalanoid, midrib slightly elevated above, secondary veins about 16 pairs, more or less indistinct; stamens 15, ovary and stylopodium cylindrical, style short; 2 longer fruit calyx lobes up to 4.5 cm × 0.8 cm, 3 shorter ones up to 4 mm × 4 mm, suborbicular, obtuse, shorter than the nut. *H. altocollina* is locally frequent on clay-rich soils, hillsides and spurs at 800–1000 m altitude. The density of the wood is 735–835 kg/m³ at 15% moisture content.

Selected sources 31, 258, 359, 748.

Hopea beccariana Burck

Ann. Jard. Bot. Buitenzorg 6: 240 (1887).

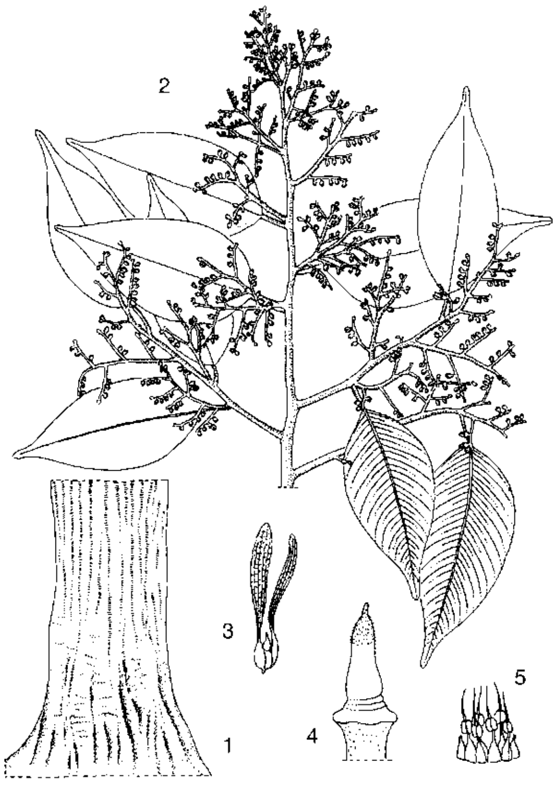
Synonyms *Hopea intermedia* King (1893), *Balanocarpus ovalifolius* Ridley (1920).

Vernacular names Brunei: selangan hijau, garang buaya daun kechil (Malay), chengai pasir (Iban). Indonesia: amang jankar (West Kalimantan), lempong mit (East Kalimantan), nuas nyerakat hitam (south-eastern Kalimantan). Malaysia: merawan batu, jangkang, (Peninsular), selangan penak (Sabah, Sarawak).

Distribution Peninsular Thailand, Peninsular Malaysia, eastern Sumatra and Borneo.

Uses *H. beccariana* is an important source of heavy merawan timber. It is used locally for house supports and boat hulls. The tree is an important source of dammar ('damar mata kucing') in Peninsular Malaysia.

Observations A medium-sized to large tree up to 45 m tall, bole straight, cylindical, branchless to a considerable height and with a diameter of up to 110 cm, buttresses sharp, usually slightly, sometimes markedly, stilted, bark surface fissured, the ridges dark brown, inner bark light brown tinged



Hopea beccariana Burck – 1, trunk base; 2, flowering twig; 3, fruit; 4, ovary; 5, stamens.

pink, sapwood pale yellow-ochre, exuding a clear dammar; young twigs, buds and petioles waxy glaucescent; leaves ovate, 5–8 cm × 2–4.5 cm, thin leathery, base cuneate, frequently subequal, acumen slender, up to 1.5 cm long, margin not revolute, venation dryobalanoid, midrib slightly raised above, secondary veins about 8 pairs, indistinct, main secondaries almost reaching the margin; stamens 15, anthers broadly oblong, ovary and stylopodium hour-glass-shaped, tapering into the short style; 2 longer fruit calyx lobes up to 3.5 cm × 1 cm, twisted, 3 shorter ones up to 7 mm long, acute. *H. beccariana* is widespread on coastal hills and on deep soils on inland ridges (especially in Peninsular Malaysia), occasionally up to 1200 m altitude. The density of the wood is 620–1000 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 102, 253, 258, 318, 324, 476, 514, 677, 748.

Hopea bracteata Burck

Ann. Jard. Bot. Buitenzorg 6: 239 (1887).

Synonyms *Balanocarpus curtisii* King (1893), *Balanocarpus bracteatus* (Burck) Merr. (1921), *Hopea minima* Sym. (1939).

Vernacular names Brunei: merawan padi. Indonesia: merawan mas (general), bangkirai amas (South Kalimantan), nyerakat (East Kalimantan). Malaysia: merawan ungu, damar mata kucing, tempunai (Peninsular).

Distribution Peninsular Malaysia and Borneo (Sarawak, Brunei, Sabah, south-eastern Kalimantan).

Uses The timber is used as merawan and is suitable for door and window frames, particle board and, when treated, railway sleepers. A dark resin can be obtained from the tree.

Observations Small, occasionally medium-sized tree of up to 30 m tall, bole straight, cylindrical, frequently hollow, occasionally with smears of dammar, with a diameter of up to 90 cm and prominent stilt roots or thin buttresses of up to 70 cm tall, bark surface, dark brown and grey mottled, hoop-marked, inner bark pale yellow-brown, sapwood cream gradually changing to pale brown, heartwood soft; young parts shortly persistently puberulent; leaves narrowly ovate, 2.5–6 cm × 0.7–2 cm, thin, base cuneate, acumen up to 1.5 cm long, venation subdryobalanoid, midrib depressed above, secondary veins about 11 pairs, slender, with slightly less distinct secondaries in between, strongly curved, at 55–65°; stamens 15, ovary and stylopodium glabrous, cylindrical, truncate, style short; fruit calyx lobes up to 5 mm × 5 mm, subequal, broadly ovate, obtuse, incrassate at base. *H. bracteata* is locally abundant on spurs and ridges below 650 m altitude. The density of the wood is 525–945 kg/m^3 at 15% moisture content.

Selected sources 30, 102, 253, 258, 321, 359, 476, 677, 748.

Hopea cernua Teijsm. & Binnend.

Natuurk. Tijdschr. Ned. Ind. 29: 252 (1867).

Synonyms *Hopea argentea* Meijer (1963).

Vernacular names Indonesia: temang jankar, damar putih, (Kalimantan). Malaysia: selangan urat (Sabah), mang besi, luis timbul (Sarawak).

Distribution Bangka, northern and eastern Borneo and possibly Sumatra.

Uses The timber is a comparatively heavy merawan.

Observations A medium-sized to large tree of up to 50 m tall, bole with a diameter of up to 125 cm, buttresses up to 4 m tall, frequently branched, with small stilt roots and flying buttresses, outer bark dark chocolate brown, pale within, inner bark pale brown, sapwood pale yellow, heartwood chocolate brown, hard; young parts caducous grey-brown pubescent; leaves elliptical to ovate, 5–15 cm × 2–5 cm, thin leathery, base cuneate, equal, acumen up to 6 mm long, more or less distinctly silvery lepidote beneath, venation dryobalanoid, midrib slightly raised above, secondary veins 10–12 pairs, slender but distinctly elevated and prominent beneath; stamens 15–18, in 3 unequal verticils, ovary ovoid, glabrous, style about 1.5 times the length of ovary, sometimes slightly swollen in the villous basal third; 2 longer fruit calyx lobes up to 6.5 cm × 1.2 cm, 3 shorter ones up to 1.5 cm long, lanceolate, acute. *H. cernua* occurs locally in mixed dipterocarp forest on fertile soils, especially on neutral and basic igneous rocks and limestone, up to 1650 m altitude. The density of the wood is 650–960 kg/m^3 at 15% moisture content.

Selected sources 31, 100, 258, 476, 557, 748.

Hopea dasyrrhachis v. Slooten

Bull. Bot. Gard. Buitenzorg, ser. 3, 17: 130, f. 18 (1941).

Vernacular names Indonesia: damar puteh (South Kalimantan), tekam ayer, tekam rayap (West Kalimantan).

Distribution South and West Kalimantan.

Uses The timber is used as merawan. It is used for poles and small beams. The tree yields a dammar which is used locally.

Observations A small to medium-sized tree of up to 32 m tall, bark surface dark; twig apices and panicles buff pubescent; leaves ovate-falcate, 7–15 cm × 2.5–8 cm, somewhat leathery, base cuneate, acumen up to 1.5 cm long, venation scalariform, midrib raised above, secondary veins 12–14 pairs, arched at 50–60°, slender; stamens 10, in a single verticil, ovary and stylopodium subcylindrical, terminating in a short truncate style; 2 longer fruit calyx lobes suborbicular, up to 4 cm × 3.5 cm, chartaceous, frequently subauriculate, 3 shorter ones suborbicular, up to 6 mm × 7 mm, saccate. *H. dasyrrhachis* is locally very common, even semi-gregarious, on sandy or clayey soil on river banks, up to 800 m altitude. The density of the wood is 580–960 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 258, 461, 741, 748.

Hopea dryobalanoides Miq.

Fl. Ind. Bat., Suppl. 1 (Prodr. Fl. Sum.): 492 (1861).

Synonyms *Hopea borneensis* Heim (1891), *Hopea sarawakensis* Heim (1891), *Hopea micrantha* King (1893) non Hook.f.

Vernacular names Brunei: mata kucing hitam. Indonesia: merawan seluai (Sumatra, Kalimantan), bayang gunong (western Sumatra), (emang) berjangkar (South Kalimantan). Malaysia: mata kucing hitam (Peninsular), luis hitam (Sarawak), selangan daun kapur (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as merawan. The tree was formerly a valuable source of dammar ('damar mata kucing').

Observations A medium-sized to large tree of up to 55 m tall, bole straight, cylindrical, with a diameter of up to 110 cm, buttresses sharp and stilted, adventitious roots often present, dammar in tear-like stalactitic exudations, colourless or pale yellow, bark surface dark brown, inner bark dull pale brown tinged pink, slightly layered, sapwood pale yellow, heartwood pale brown; young parts shortly densely greyish-brown fugacious pubescent; leaves ovate-lanceolate, 5–12 cm × 1.5–4.5 cm, thin leathery, base cuneate, equal or subequal, acumen narrow, up to 2 cm long, venation dryobalanoid, midrib raised above, secondary veins 8–12 pairs, slender but distinct beneath, curved; stamens 15, in 3 whorls, ovary ovoid, glabrous, without distinct stylopodium, style as long as ovary, setose in the basal half; 2 longer fruit calyx lobes up to 6.5 cm × 1.5 cm, subacute, pronouncedly twisted, 3 shorter ones up to 8 mm × 6 mm, broadly ovate, shorter than the nut, obtuse or subacute. *H. dryobalanoides* occurs widespread and is locally frequent on clay-rich fertile soils on undulating or well-drained flat land, or ridges below 600 m altitude; also common on basalt and neutral igneous and volcanic rocks on slopes and ridges. The density of the wood is 480–980 kg/m^3 at 15% moisture content.

Selected sources 30, 75, 89, 100, 253, 258, 324, 344, 461, 476, 677, 748.

Hopea dyeri Heim

Bull. Mens. Soc. Linn. Paris 2: 972 (1891).

Synonyms *Hopea intermedia* King (1893) p.p., *Hopea micrantha* Burck (1887) non Hook.f. p.p., *Hopea pierrei* Brandis (1895) non Hance.

Vernacular names Indonesia: bangkirai tanduk (South Kalimantan), omang terubuk, emang besi (West Kalimantan). Malaysia: merawan palit (Peninsular), selangan kechil (Sabah), selangan palit (Sarawak).

Distribution Peninsular Malaysia and Borneo.

Uses The timber is used as merawan. The tree is also a source of dammar.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole straight, tapering, with a diameter of up to 60 cm and thin, low buttresses and stilt roots, bark surface flaky with a red layer beneath, inner bark homogeneous pale pink-brown to yellowish-brown, sapwood pale yellow, heartwood brown; younger parts grey-brown pubescent; leaves ovate-lanceolate, 2.5–7 cm × 1.2–2.5 cm, somewhat leathery, base cuneate, subequal, acumen narrow, up to 1.5 cm long, margin frequently slightly revolute, frequently lepidote beneath, venation dryobalanoid, midrib raised on both surfaces, secondary veins 8–12 pairs, slender, slightly raised, with many distinct smaller veins; stamens 15, in 3 whorls, ovary and stylopodium pear-shaped, apex puberulent, style short; 2 longer fruit calyx lobes up to 2.5 cm × 1 cm, narrowly obtuse, 3 shorter ones up to 7 mm × 4 mm, ovate, acuminate. *H. dyeri* is locally abundant and occurs on well-drained soils on low hills and ridges up to 1000 m altitude. The density of the wood is 575–915 kg/m³ at 15% moisture content.

Selected sources 30, 76, 89, 100, 102, 253, 258, 318, 476, 677, 748.

Hopea ferruginea Parijs

Feddes Repert. 33: 243 (1933).

Synonyms *Hopea micrantha* Dyer (1874) non Hook.f. p.p.

Vernacular names Indonesia: merawan dasal (Sumatra, Kalimantan), bangkirai emang (south-eastern Kalimantan), chengal lempong (western Sumatra). Malaysia: (merawan) mata kucing merah (Peninsular), selangan mata kucing (Sabah), luis merah (Sarawak).

Distribution Peninsular Malaysia, the Riau Archipelago, eastern and central Sumatra and eastern Borneo.

Uses The timber is used as merawan. *H. ferruginea* is a minor source of dammar.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole branchless for up to 25 m, with a diameter of up to 75 cm and stilt roots and flying buttresses, frequently with globular exudations of clear dammar, bark surface flaky, light grey-brown, inner bark dull pink, grading to pale yellow, sapwood pale; young parts densely persistently greyish puberulent; leaves ovate to lanceolate, 4.5–7 cm × 1.5–4 cm, subleathery, base cuneate, shortly decurrent, acumen slender, up to 1.5 cm long, venation dryobalanoid, midrib raised and puberulent above, secondary veins about 14 pairs with many subequal smaller veins in between, distinct; stamens 15, unequal, ovary ovoid, stylopodium absent, style columnar, somewhat longer than the ovary, villous towards base; 2 longer fruit calyx lobes up to 3 cm × 0.5 cm, narrowly obtuse, 3 shorter ones up to 8 mm × 4 mm, ovate-acuminate, closely enveloping the nut. *H. ferruginea* is locally frequent in mixed dipterocarp forest on deep fertile soils up to 750 m altitude. The density of the wood is 520–930 kg/m³ at 15% moisture content.

Selected sources 75, 89, 100, 253, 258, 461, 476, 514, 677, 748.

Hopea fluvialis P. Ashton

Gard. Bull. Sing. 19: 254, pl. 1 (1962).

Vernacular names Brunei: merawan ayer. Malaysia: merawan ayer (Sarawak).

Distribution South-eastern Kalimantan, south-eastern Sabah, north-eastern Sarawak and Brunei.

Uses The timber is used as merawan, but because of the often crooked shape of the bole, not of great commercial interest.

Observations A small to medium-sized tree of up to 25 m tall, bole often of poor shape, with a diameter of up to 70 cm and small buttresses, flying buttresses present, stilt roots absent, bark surface smooth, inner bark brown to cream, sapwood pale yellow, medium hard, with a gradual transition to the pale brown heartwood; young parts shortly densely pale grey-brown tomentose; leaves lanceolate to ovate, 7–12 cm × 3–5 cm, chartaceous to thin leathery, base narrowly or broadly cuneate, subequal, acumen slender, up to 1.5 cm long, venation dryobalanoid, midrib raised above, secondary veins about 10 pairs with long smaller veins in between, slender, arched at 60–80°, the basal pair continuing as intramarginal veins to one-third up the margin, tertiaries reticulate, indistinct; stamens 15, ovary ovoid, glabrous, style filiform, tapering, as long as the ovary; 2 longer fruit calyx lobes up to 5.5 cm × 1 cm, tapering into an expanded but unthickened and hardly saccate base, 3 shorter ones unequal, 1–2.5 cm long, acute, cupped and enveloping the nut. *H. fluvialis* is locally abundant on rich clayey river banks up to 300 m altitude.

Selected sources 30, 31, 258, 748.

Hopea foxworthyi Elmer

Leafl. Philipp. Bot. 4: 1469 (1912).

Synonyms *Hopea glutinosa* Elmer (1912), *Hopea pierrei* Foxw. (1911) non Hance p.p.

Vernacular names Philippines: Foxworthy dalindingan (general), dalingdingan (Bikol, Dumagat, Tagalog), malungai (Bisaya), manggachapui-tagokan (Sibuyan).

Distribution The Philippines (Sibuyan).

Uses The timber is used as merawan for general house construction, posts, and bridges.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole with a diameter of up to 65 cm and narrow buttresses, bark surface smooth; young parts fugacious puberulent; leaves lanceolate, 2.5–6.5 cm × 1–2.5 cm, thin leathery, base more or less equal, cuneate, acumen slender, up to 1.5 cm long, margin subrevolute, lustrous, venation dryobalanoid, midrib depressed above, secondary veins about 10 pairs, very slender and more or less indistinct on both surfaces, ascending, arched, with a few shorter obscure veins in between; stamens 15, ovary ovoid, without stylopodium, fugacious puberulent, style filiform, about twice as long as ovary, tapering; 2 longer fruit calyx lobes up to 3.5 cm × 1 cm, tapering at base, 3 shorter ones up to 5 mm × 5 mm, broadly ovate, acute. *H. foxworthyi* is locally common in seasonal evergreen forest on red sticky volcanic soil along ridges up to 700 m altitude. The density of the wood is 540–730 kg/m^3 at 15% moisture content.

Selected sources 175, 258, 579, 593, 674, 748, 815.

Hopea glaucescens Sym.

Journ. Mal. Br. Roy. As. Soc. 19: 142, pl. 2 (1941).

Vernacular names Malaysia: merawan kelabu (Peninsular, general), merawan galor (Pahang), merawan jangkang (Perak).

Distribution Peninsular Malaysia.

Uses The timber is used as merawan.

Observations A medium-sized tree, bole with a diameter of up to 60 cm, with short buttresses or stilt-rooted, bark surface smooth; young parts puberulent; leaves elliptical, 9–18 cm × 3.5–9 cm, leathery, base cuneate, acumen slender, up to 1 cm long, glaucescent beneath in mature trees, venation scalariform, midrib distinctly elevated on both surfaces, secondary veins 12–15 pairs, slender but relatively prominent beneath, obscure above, with many distinct short veins in between; petals outside densely golden pubescent; stamens 15, ovary and stylopodium hour-glass-shaped, the ovary slightly broader, style short, tapering; 2 longer fruit calyx lobes up to 7 cm × 1.5 cm, 3 shorter ones up to 20 mm × 5 mm, linear-lorate, completely enclosing nut. *H. glaucescens* occurs in mixed dipterocarp forest below 500 m altitude. The density of the wood is 755–850 kg/m^3 at 15% moisture content.

Selected sources 258, 677, 748.

Hopea griffithii Kurz

Journ. As. Soc. Beng. 42(2): 60 (1873).

Synonyms *Hancea griffithii* (Kurz) Pierre (1891).

Vernacular names Indonesia: emang, mang (West Kalimantan). Malaysia: merawan jantan, pengerawan bunga (Peninsular), luis jantan (Sarawak).

Distribution Southern Burma, Peninsular Malaysia and Borneo.

Uses The wood is used as merawan and is especially suitable for door and window frames, particle board and railway sleepers.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole straight, cylindrical, with a diameter of up to 70 cm, thin buttresses and a few stilt roots, exuding a clear dammar drying cream, bark surface smooth, becoming fissured with age, chocolate brown, inner bark pink-brown, becoming paler at the cambium, sapwood cream; leaves ovate to lanceolate, 4–9 cm × 1.7–4.5 cm, leathery, base narrowly or broadly cuneate, acumen slender, up to 1.5 cm long, margin frequently subrevolute, venation dryobalanoid, midrib depressed above, secondary veins about 9 pairs, hardly raised beneath; stamens 15, in 3 unequal verticils, anthers broadly ellipsoid, ovary and stylopodium stoutly pyriform, papillose towards apex, style short, columnar; 2 longer fruit calyx lobes up to 3 cm × 0.5 cm, 3 shorter ones up to 8 mm × 1 mm, linear. *H. griffithii* is locally common on leached soils in mixed dipterocarp forest on low hills. The density of the wood is 505–835 kg/m^3 at 15% moisture content.

Selected sources 31, 258, 359, 557, 628, 677, 748.

Hopea johorensis Sym.

Journ. Mal. Br. Roy. As. Soc. 19, 2: 139, pl. 1B (1941).

Vernacular names Malaysia: mata kucing pipit (Peninsular).

Distribution Peninsular Malaysia (eastern Johor).

Uses The timber is used as merawan. The tree yields dammar.

Observations A medium-sized tree, bole poorly shaped, with a diameter of up to 50 cm, with sharp stilt roots, bark surface dull purple-brown, powdery, inner bark dull brown, tinged pink, or light red-brown grading to almost colourless at the cambium, sapwood pale yellow, usually with ripple marks; young parts persistently or caducously greyish-buff pubescent; leaves ovate, 3–7 cm × 1.5–3.5 cm, leathery, base more or less abruptly cuneate, subequal, acumen slender, up to 12 mm long, venation dryobalanoid, midrib raised above, secondary veins abouts 16 pairs, with many subequal smaller veins in between, very slender and hardly elevated beneath; stamens 15; 2 longer fruit calyx lobes up to 4 cm × 0.8 cm, subacute, tapering to base, 3 shorter ones up to 3 mm × 3 mm, ovate, subacuminate. *H. johorensis* is locally common on hill ridges. The density of the wood is 595–690 kg/m^3 at 15% moisture content.

Selected sources 258, 359, 677, 748.

Hopea latifolia Sym.

Gard. Bull. Str. Settl. 10: 360 (1939).

Vernacular names Brunei: merawan daun bulat. Indonesia: rasak tunjang (Sumatra). Malaysia: merawan daun bulat, merawan jangkang, chengal mata kucing (Peninsular). Thailand: khian-rak (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and north-western Borneo (Brunei, Sarawak).

Uses The timber is used as merawan.

Observations A medium-sized tree, bole straight, up to 70 cm in diameter, with small thin buttresses and stilt roots, exuding a white dammar, bark surface smooth, hoop-marked, pale grey-brown, inner bark pale brown to cream at the cambium, sapwood yellow, hard, heartwood dark brown; young twigs and buds waxy glaucescent; leaves ovate, 5–8 cm × 2–4.5 cm, thin leathery, base cuneate, frequently subequal, acumen slender, up to 1.5 cm long, margin not revolute, venation dryobalanoid, midrib slightly raised above, secondary veins about 8 pairs, indistinct; stamens 15, in 3 whorls, ovary ovoid, glabrous, stylopodium indistinct, style as long as the ovary, filiform, villous towards the base; 2 longer fruit calyx lobes up to 6 cm × 1.4 cm, narrowly obtuse, tapering to base, 3 shorter ones up to 9 mm × 7 mm, ovate, acute, saccate, thickened, frequently hiding the nut. *H. latifolia* is locally frequent in mixed dipterocarp forest on low-lying land. The density of the wood is 625–930 kg/m^3 at 15% moisture content.

Selected sources 30, 258, 514, 601, 628, 677, 748.

Hopea mengarawan Miq.

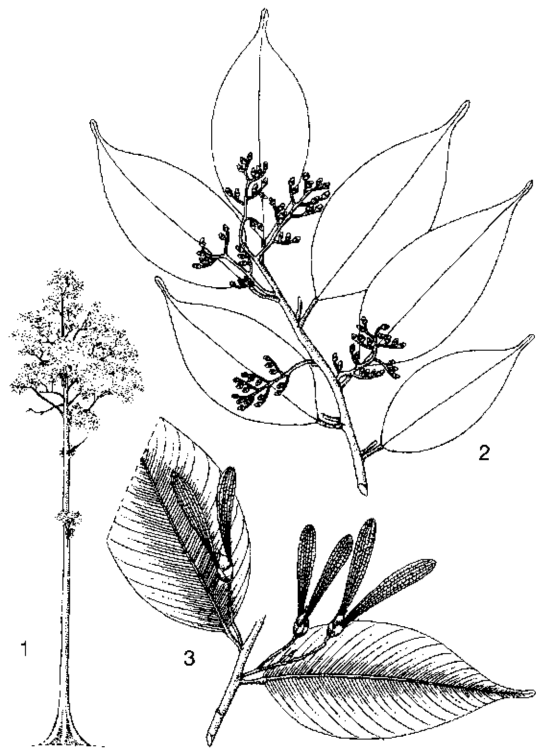
Fl. Ind. Bat., Suppl. 1 (Prodr. Fl. Sum.): 491, 192 (1861).

Vernacular names Indonesia: damar mata kucing (general), merawan benar (Sumatra, Kalimantan), chengal bulu (Sumatra), bangkirai telor (East Kalimantan). Malaysia: merawan penak (Peninsular, Sarawak), merawan hitam, pengerawan penak (Peninsular).

Distribution Peninsular Malaysia, Sumatra, Belitung, Bangka and Borneo.

Uses *H. mengarawan* is an important source of merawan timber. It produces a dammar which is considered of good quality in Sumatra and Peninsular Malaysia. The bark is used for roofing traditional houses.

Observations A medium-sized to large tree of up to 40(–60) m tall, bole branchless for up to 25 m, sometimes more, with a diameter of up to 90 cm and prominently buttressed, exuding a clear, yellow resin, bark surface fissured, chocolate coloured, inner bark pale yellow tinged pink, sapwood pale yellow, hard, heartwood brown, hard; twigs, petioles and leaves beneath caducous lepidote; leaves lanceolate, 6–12 cm × 2.5–5 cm, thick



Hopea mengarawan Miq. – 1, tree habit; 2, flowering twig; 3, fruiting twig.

leathery, base cuneate, acumen slender, up to 1.5 cm long, venation dryobalanoid, midrib raised above, secondary veins about 15 pairs, slender but prominent beneath, with many short to subequal veins in between; stamens 15, in 3 unequal verticils, ovary ovoid, style about 2 times the length of ovary, villous in the basal third; 2 longer fruit calyx lobes up to 7 cm × 1.2 cm, narrowly obtuse, 3 shorter ones up to 6 mm × 5 mm, ovate, acute, saccate. *H. mengarawan* occurs locally, scattered or sometimes gregariously on low-lying, often swampy or periodically inundated land and also on low hills up to 500 m altitude. The density of the wood is 510–910 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 75, 102, 204, 253, 258, 305, 318, 324, 461, 514, 526, 560, 677, 748.

Hopea montana Sym.

Journ. Mal. Br. Roy. As. Soc. 19, 2: 141, pl. 1A (1941).

Vernacular names Malaysia: merawan gunong (Peninsular), selangan bukit (Sabah).

Distribution Peninsular Malaysia, central Sumatra and Sabah.

Uses The timber is used as merawan.

Observations A medium-sized tree, bole often poorly shaped with a diameter of up to 60 cm and prominent buttresses, tending to be stilted, bark surface smooth, chocolate brown, inner bark dull brown tinged pink, sapwood pale yellow; tree entirely glabrous; leaves ovate-lanceolate, cuspidate, 6.5–9 cm × 2–4 cm, thin leathery, base abruptly cuneate, acumen up to 1 cm long, venation subdryobalanoid, midrib obscurely depressed above, secondary veins about 14 pairs, arched, ascending, with many shorter veins in between; flowers unknown; 2 longer fruit calyx lobes up to 5 cm × 1.2 cm, subacute, tapering to base, 3 shorter ones up to 10 mm × 3 mm, ovate, frequently shortly winged apically. *H. montana* is rare and occurs on hill slopes in dipterocarp forest up to 1200 m altitude. The density of the wood is 785–915 kg/m^3 at 15% moisture content.

Selected sources 100, 258, 476, 677, 748.

Hopea myrtifolia Miq.

Fl. Ind. Bat., Suppl. 1 (Prodr. Fl. Sum.): 493, 192 (1861).

Vernacular names Indonesia: luis tunjang (East Kalimantan), mahanamun (South Kalimantan), lampengwea (south-eastern Kalimantan). Malaysia: merawan mata kucing beludu, merawan jangkang (Peninsular).

Distribution Peninsular Malaysia, southern Sumatra, and south-eastern and western Borneo.

Uses The timber is used as merawan. The tree produces a clear dammar, apparently of good quality.

Observations A medium-sized, sometimes large tree, bole slightly fluted, with a diameter of up to 80 cm, having stilt roots and thin buttresses, commonly with small exudations of clear dammar, bark surface smooth, with a green layer beneath, inner bark pink-brown, grading to almost colourless at the cambium, sapwood pale yellow; young parts more or less persistently tawny puberulent; leaves lanceolate, (4.5–)6–12 cm × 2–5 cm, leathery, base broadly cuneate, subequal, acumen up to 1.8 cm long, prominent, venation dryobalanoid, midrib raised above, secondary veins about 13 pairs, with many shorter veins in between, slender but prominent beneath; stamens 15, ovary and stylopodium narrowly subcylindrical, style shorter than stylopodium and ovary; 2 longer fruit calyx lobes up to 5.5 cm × 1.2 cm, tapering to base, 3 shorter ones up to 4 mm × 3 mm, ovate, saccate, thickened. *H. myrtifolia* occurs on low-lying, flat, but well-drained land with deep fertile soil. The density of the wood is 640–925 kg/m^3 at 15% moisture content.

Selected sources 76, 258, 514, 556, 677, 748.

Hopea nervosa King

Journ. As. Soc. Beng. 62(2): 124 (1893).

Vernacular names Brunei: merawan jangkang. Indonesia: selangan puteh, selangan bertunjang, damar jangkar (south-eastern Kalimantan). Malaysia: merawan jangkang, chengal rawan (Peninsular), selangan jangkang (Sabah).

Distribution Peninsular Malaysia and Borneo.

Uses The timber is used as merawan.

Observations A medium-sized tree of up to 30 m tall, bole small, cylindrical, frequently crooked, with a diameter of up to 75 cm, buttresses usually prominent and stilted, exuding a white dammar, bark surface smooth, inner bark thin, soft, pale cream-brown, sapwood white, becoming pale brown within, soft; young parts and midrib of leaves on both surfaces caducous puberulent; leaves narrowly ovate to lanceolate, 9–18 cm × 4–7 cm, thin leathery, base broadly cuneate, acumen narrow, up to 1.4 cm long, venation scalariform, midrib slightly depressed above, secondary veins 13–15 pairs, dense, slender, prominent beneath, ascending at 40–60°, with or without short slender veins in between; stamens 15, ovary and stylopodium broadly cylindrical, truncate, style short;

2 longer fruit calyx lobes up to 12 cm × 1.8 cm, thin leathery, narrowly obtuse, 3 shorter ones up to 1.5 cm long, acute, closely adpressed to the nut. *H. nervosa* is locally frequent on low-lying flat land and hill slopes on clay-rich fertile soils up to 600 m altitude. The density of the wood is 605–895 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 100, 102, 258, 297, 324, 358, 417, 476, 514, 601, 677, 748.

Hopea odorata Roxb.

Pl. Coromandel 3: 7, t. 210 (1819).

Vernacular names Malaysia: merawan siput jantan, chengal pasir, chengal mas (Peninsular). Burma: thingan, net, sauchi. Cambodia: kôki:(r) mosau, kôki:(r) thmâr:(r). Laos: (maiz) kh'è:n, kh'èn h'üa. Thailand: takhian-thong, takhian-yai (general), khaen (north-eastern). Vietnam: sao den, sao b[ax] m[is]a, sao c[as]t.

Distribution Bangladesh, Burma, Laos, southern Vietnam, Cambodia, Thailand, the Andaman Islands and northern Peninsular Malaysia.

Hopea odorata Roxb. – 1, habit of young tree; 2, flowering twig; 3, flower; 4, fruit; 5, nut.

Uses The timber is used as merawan. The wood is suitable for rollers in the textile industry, piles, and bridge construction and as an alternative to maple for shoe and boot lasts. *H. odorata* is sometimes used as a shade tree. The bark has a high tannin content, and is suitable for tanning leather; it also produces an inferior quality dammar ('rock dammar'). The Burmese use this dammar as a varnish over paint, and associate it with paint in pictures; they are said to mix it with ink. It is also used to caulk boats. The dammar is medicinally applied to sores and wounds. In Indo-China the bark has been used as a masticatory.

Observations A medium-sized to large tree of up to 45 m tall, bole straight, cylindrical, branchless for up to 25 m, with a diameter of up to 120 cm and prominent buttresses, bark surface scaly, dark brown, outer bark rather thick, inner bark dull yellow, tinged green at the cambium, sapwood resinous; young parts sparsely pale buff puberulent; leaves ovate-lanceolate, 7–14 cm × 3–7 cm, falcate, base broadly cuneate, unequal, acumen broad, up to 1.5 cm long, venation scalariform, midrib applanate to slightly channelled above, secondary veins 9–12 pairs, prominent beneath, arched, with prominent saccate axillary domatia; stamens 15, anthers narrowly ellipsoid, ovary ovoid, punctate or glabrous, surmounted by an equally tall columnar style; 2 longer fruit calyx lobes up to 5.5 cm × 2 cm, broadly spatulate, saccate, 3 shorter ones up to 4 mm × 4 mm, ovate, subacuminate. *H. odorata* is a riparian species and usually occurs on deep rich soils up to 600 m altitude. The density of the wood is 620–930 kg/m^3 at 15% moisture content.

Selected sources 102, 150, 235, 253, 258, 324, 358, 359, 503, 599, 600, 601, 628, 677, 685, 748.

Hopea papuana Diels

Bot. Jahrb. Syst. 57: 461 (1922).

Vernacular names Papua New Guinea: light hopea.

Distribution New Guinea.

Uses The timber is used as merawan, especially for staircases, window and door frames, and marine constructions.

Observations A small or medium-sized tree of up to 30 m tall, bole branchless for up to 18 m, with a diameter of up to 90 cm, with or without buttresses, bark surface deeply fissured, dark purplish-brown or blackish, inner bark red and green, sapwood pale straw-coloured, heartwood brown; young parts persistently rufous scabrid tomentose; leaves oblong, 11–28 cm × 4–10 cm, leathery, base unequal, cordate, acumen tapering, up to 2.5 cm long, venation scalariform, midrib raised above, secondary veins 16–24 pairs, arched at 70–80°, slender but prominent above, without domatia; stamens 15; 2 longer fruit calyx lobes up to 5.5 cm × 1.8 cm, broadly spatulate, obtuse, 3 shorter ones up to 9 mm × 6 mm, ovate, subacute, similarly saccate. *H. papuana* is locally abundant on alluvial soils, on low hills and on river banks up to 620 m altitude. The density of the wood is 630–730 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 67, 87, 258, 359, 735, 748.

Hopea pedicellata (Brandis) Sym.

Gard. Bull. Str. Settl. 9: 327, pl. 19 (1938).

Synonyms *Hopea siamensis* Heim (1902), *Hopea pierrei* Ridley (1922) non Hance p.p.

Vernacular names Malaysia: mata kucing bukit (general), merawan mata kucing (Peninsular). Thailand: takhian-khao (general), sarayaa dam (peninsular). Vietnam: ki[eef]n ki[eef]n g[aa]n n[oor]i.

Distribution Southern Indo-China, peninsular Thailand, Peninsular Malaysia and Borneo.

Uses The timber is used as merawan. *H. pedicellata* is also a minor source of dammar ('damar mata kucing').

Observations A medium-sized to fairly large tree of up to 40 m tall, bole frequently crooked, with a diameter of up to 55 cm and thin, sometimes stilted buttresses, bark surface flaky, outer bark dark brown, with red inner layer, inner bark pink grading to a pale translucent layer at the cambium, sapwood pale yellow, rather hard, grading to the brown-pink heartwood; young parts and domatia grey-brown puberulent; leaves ovate-lanceolate, 4–9 cm × 1–3.5 cm, base cuneate, acumen slender, up to 1.5 cm long, venation dryobalanoid, midrib raised above, secondary veins 8–12 pairs, with subequal veins in between, indistinct, slender, hardly raised below; stamens 15, unequal, ovary with stylopodium, cylindrical-conical, truncate, punctate in the distal half, style short; 2 longer fruit calyx lobes up to 3 cm × 0.5 cm, 3 shorter ones up to 3 mm × 4 mm, ovate, saccate, adpressed to the nut. *H. siamensis* is sometimes kept separate from *H. pedicellata* differing in the shape and indumentum of the ovary and stylopodium; it is confined to south-eastern Thailand and southern Vietnam. *H. pedicellata* occurs in hill forest up to 750 m altitude. The density of the wood is 755–880 kg/m³ at 15% moisture content.

Selected sources 31, 258, 278, 623, 677, 748.

Hopea philippinensis Dyer

Journ. Bot. 16: 100 (1878).

Vernacular names Philippines: gisok-gisok (general), makatayring (Tagalog), baguatsa (Bikol).

Distribution The Philippines.

Uses The wood is a heavy-grade merawan, but owing to the small size of the bole used only locally for house posts and temporary railway ties.

Observations A small to medium-sized tree of up to 30 m tall, bole with diameter to 40 cm, frequently crooked and branching low, with a few stilt roots, dammar exudations cream-brown, bark surface smooth, red-brown to fawn mottled, inner bark hard, pale brown, sapwood pale yellow, grading to pale brown heartwood; young parts densely pale tawny pubescent; leaves narrowly elliptical-oblong to lanceolate, (7–)12–25 cm × (2.5–)4–7 cm, thin leathery, base unequal, acumen slender, up to 2 cm long, venation scalariform, midrib raised above, secondary veins 17–22 pairs, slender but prominent beneath, obscurely depressed above, arched at 50–60°; stamens 15, ovary and stylopodium hour-glass-shaped, the ovary slightly broader, style short but distinct; 2 longer fruit calyx lobes up to 12 cm × 3 cm, 3 shorter ones up to 7 mm × 8 mm, broadly ovate, mucronate, shorter than nut. *H. philippinensis* is a widespread and common species of evergreen non-seasonal forest on hills up to 500 m altitude. The density of the wood is 705–950 kg/m³ at 15% moisture content.

Selected sources 175, 258, 579, 593, 748.

Hopea pierrei Hance

Journ. Bot. 15: 308 (1876).

Vernacular names Malaysia: merawan palong (Peninsular). Cambodia: kôki:(r) khsach. Laos: (maiz) kh'èn hin. Thailand: takhian-rak (general), takhian-sai, khaen-hak-yong. Vietnam: ki[eef]n ki[eef]n.

Distribution Laos, Cambodia, Vietnam, south-eastern Thailand, Peninsular Malaysia and western Sumatra.

Uses The timber is used as merawan (light-weight wood) or as giam (heavy wood). It is valued in Cambodia for construction. In Vietnam the pale yellow dammar is used for torches and for caulking boats and is also used in powder form thrown upon burning charcoal to give a representation of gunfire in theatrical performances.

Observations A small to medium-sized tree of up to 25 m tall, bole often twisted and of poor shape, with a diameter of up to 50 cm and thin buttresses or stilt roots, bark surface smooth, dark with light patches, inner bark light brown, tinged pink, sapwood pale yellow-brown; twigs fugacious puberulent; leaves lanceolate, 4–8 cm × 1.5–4 cm, thin leathery, base abruptly broadly cuneate, acumen slender, up to 1.2 cm long, venation dryobalanoid, midrib obscurely depressed above, secondary veins about 18 pairs with many, more or less equal veins in between; stamens 15, ovary and stylopodium hour-glass-shaped, equal, tapering into the short style; 2 longer fruit calyx lobes up to 27 mm × 7 mm, spatulate, obtuse, 3 shorter ones up to 3 mm × 2 mm, ovate. *H. pierrei* occurs in lowland evergreen rain forest on sandy soils or in heath forest in Indo-China up to about 1000 m altitude; in Malaysia on ridges at 300–700 m altitude, sometimes locally gregarious. The density of the wood is 760–1155 kg/m^3 at 15% moisture content.

Selected sources 102, 235, 258, 628, 677, 748.

Hopea pubescens Ridley

Fl. Mal. Pen. 1: 239 (1922).

Vernacular names Malaysia: merawan bunga, merawan pipit, pengarawan bunga (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as merawan, especially for planking. The tree produces an oleo-resin, but this does not seem to be used. The bark is used for walls and partitions of traditional houses.

Observations A medium-sized to fairly large tree of up to 37 m tall, bole branchless for up to 21 m, with a diameter of up to 55 cm and small more or less stilted buttresses, bark surface fissured, dark brown or yellowish on top of the ridges, inner bark light brown tinged pink, sapwood pale yellow ochre; young parts and midrib above densely persistently tawny puberulent; leaves lanceolate, 2.5–6 cm × 1.3–2.8 cm, leathery, base broadly abruptly cuneate, acumen slender, up to 1 cm long, venation dryobalanoid, midrib depressed above, secondary veins about 12 pairs, with shorter veins in between, hardly prominent beneath, indistinct above; stamens 15, ovary ovoid, style somewhat longer than the ovary, columnar; 2 longer fruit calyx lobes up to 3.0 cm × 0.6 cm, 3 shorter ones up to 3 mm × 2 mm, ovate, acuminate. *H. pubescens* is frequent, sometimes abundant, on well-drained flat land and low hills. The density of the wood is 530–645 kg/m^3 at 15% moisture content.

Selected sources 102, 253, 258, 514, 677, 748.

Hopea sangal Korth.

Temminck, Verh. Natuurl. Gesch. Ned. Overz. Bez., Botanie, Kruidk.: 75 (1841).

Synonyms *Hopea sericea* (Korth.) Blume (1852), *Hopea curtisii* King (1893), *Hopea globosa* Brandis (1895), *Hopea lowii* Dyer ex Brandis (1895).

Vernacular names Brunei: gagil (Malay), selima (Iban). Indonesia: cengal (general), merawan jankar (Kalimantan), merawan telor (Sumatra). Malaysia: mersiput, chengal mata kucing (Peninsular), gagil (Sabah, Sarawak). Thailand: kalo samo, takhian-kaeo.

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, West Java, the Lesser Sunda Islands and Borneo.

Uses *H. sangal* is an important source of merawan timber. An inferior quality dammar is collected for illumination. The bark is locally added to palm wine to prevent acidification.

Observations A medium-sized to large tree of up to 50 m tall, bole often of good shape, with a diameter of up to 180 cm, with opaque white resin exudate and prominent buttresses, bark surface flaky, shallowly fissured, blackish, cork cambium orange-brown, inner bark cream, changing to dull greenish cambium, sapwood yellow-brown, heartwood pale coffee-brown; young parts and midrib above more or less sparsely pale grey-brown pubescent; leaves ovate, 5.5–10 cm × 3.5–5 cm, thin, base broadly cuneate, acumen slender, up to 1.2 cm long, venation scalariform, midrib applanate above, secondary veins 10–12 pairs, slender, prominent beneath, slightly curved, ascending at 50–60°; stamens 10, anthers oblong, ovary and stylopodium short, broadly cylindrical, truncate, puberulent at apex, style two-thirds the length of the ovary and stylopodium, filiform; 2 longer fruit calyx lobes up to 7 cm × 1.5 cm, tapering to base, 3 shorter ones up to 7 mm × 4 mm. *H. sangal* is locally common but scattered on clay-rich soils on river banks or hillsides up to 500 m altitude. The density of the wood is 510–890 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 10, 30, 75, 89, 100, 258, 318, 324, 359, 462, 476, 514, 677, 748.

Hopea sublanceolata Sym.

Gard. Bull. Str. Settl. 10: 341 (1939).

Vernacular names Malaysia: merawan jeruai (Peninsular, general), chengal karang (Perak), pau yang (Kelantan, Pahang).

Distribution Peninsular Malaysia.

Uses The timber is used as merawan.

Observations A medium-sized, sometimes large tree of up to 45 m tall, bole with a diameter of up to 90 cm, bark surface reddish-brown, inner bark yellow-brown tinged pink, with a pale yellow pellucid layer at the cambium, sapwood pale; young parts puberulent; leaves elliptical-lanceolate, 6.5–15 cm × 3.5–6.5 cm, subleathery, base cuneate, typically shortly decurrent, acumen up to 1.5 cm long, venation scalariform, midrib depressed above, secondary veins 13–18 pairs, arched, slender but prominent beneath; corolla dark red, stamens 15, ovary and stylopodium truncate, with a slight median constriction, style short, stout; 2 longer fruit calyx lobes up to 11.5 cm × 2 cm, 3 shorter ones up to 17 mm × 12 mm, ovate-acuminate, appressed to the nut and enclosing it except at apex. *H. sublanceolata* is locally common on undulating land and low spurs up to 150 m altitude. The density of the wood is 610–720 kg/m^3 at 15% moisture content.

Selected sources 253, 258, 324, 677, 748.

Hopea sulcata Sym.

Gard. Bull. Str. Settl. 10: 358, pl. 20 (1939).

Vernacular names Malaysia: merawan meranti, pengerawan bukit (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as merawan.

Observations A medium-sized tree of up to 30 m tall, bole straight, branchless for up to 15 m, with a diameter of up to 95 cm, at first with stilt roots, later on with small buttresses, bark surface fissured, dark brown or yellowish on top of the ridges, inner bark light brown tinged pink, sapwood pale yellow-ochre, exuding clear dammar; young parts silvery lepidote, domatia and petioles cream pubescent; leaves ovate to lanceolate, 4–10 cm × 1.7–4 cm, falcate, base cuneate, shortly decurrent, subequal, acumen slender, up to 2 cm long, venation dryobalanoid, midrib raised above, secondary veins about 10 pairs with many shorter unequal veins in between, arched, more or less distinctly elevated beneath; stamens 15, ovary ovoid, tapering into an equally long filiform style; 2 longer fruit calyx lobes up to 5.5 cm × 1.2 cm, base broadly subauriculate, 3 shorter ones up to 20 mm × 7 mm, similarly subauriculate, completely enclosing the nut. *H. sulcata* is locally abundant and gregarious on ridges, at 100–400 m altitude. The density of the wood is 530–850 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 253, 258, 297, 324, 417, 677, 748.

Hopea treubii Heim

Bull. Mens. Soc. Linn. Paris 2: 955 (1891).

Vernacular names Brunei: merawan daun tebal. Indonesia: gerik kecil daun (Kalimantan). Malaysia: merawan daun tebal (Sarawak), marakka (Sabah).

Distribution Borneo.

Uses The timber is used as merawan.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole more or less strongly tapering, with a diameter of up to 80 cm and low flying buttresses, bark surface fissured, deep reddish rust-brown, inner bark hard, yellow-brown, cambium yellowish, sapwood hard, yellow-brown, with an abrupt transition to dark rust-brown heartwood; tree glabrous except for the petals and stylopodium; leaves broadly elliptical to obovate, 5–8 cm × 3–5.5 cm, leathery, base cuneate, acumen broad, up to 5 mm long, margin subrevolute, venation dryobalanoid, midrib slightly raised above, secondary veins about 7 pairs, strongly curved, ascending at 60–70°, with smaller veins in between running almost to margin; stamens 10, subequal, in a single row, anthers broadly oblong, subequal, ovary and stylopodium cylindrical, subtruncate, style short; 2 longer fruit calyx lobes up to 3.5 cm × 7 cm, base narrow saccate, 3 shorter ones up to 8 mm × 2 mm, similar at base. *H. treubii* occurs locally on deep yellow sandy soils in mixed dipterocarp forest on coastal hills and ridges. The density of the wood is 630–830 kg/m^3 at 15% moisture content.

Selected sources 30, 258, 556, 748.

Hopea vesquei Heim

Bull. Mens. Soc. Linn. Paris 2: 971 (1891).

Vernacular names Brunei: selangan bukit. Malaysia: selangan bukit (Sarawak), selangan daun kecil, luis tebal (Sabah).

Distribution North-western Borneo.

Uses The timber is used as merawan, but is of minor importance.

Observations A medium-sized tree of up to 30 m tall, bole straight, cylindrical or sometimes cracked and fluted, with a diameter of up to 35 cm and thin buttresses, exuding white opaque dammar, bark surface patchily cracked, rust-brown and grey mottled, inner bark pale red-brown to cream at the cambium, sapwood yellow, heartwood medium hard, olive-brown; young parts more or less caducous grey-brown puberulent; leaves broadly ovate, 3.5–6 cm × 1.5–3.5 cm, leathery, base cuneate to obtuse, acumen slender, up to 1 cm long, venation dryobalanoid, midrib slightly raised above, secondary veins about 10–13 pairs, slender, hardly raised, with shorter veins in between; stamens 15, the inner 5 taller than the other ones, ovary ovoid, glabrous, style about 1.5 times the length of the ovary, columnar; 2 longer fruit calyx lobes up to 3.4 cm × 0.8 cm, sparsely setose in the basal half, 3 shorter ones up to 4 mm × 4 mm, ovate, saccate. *H. vesquei* is locally abundant on leached yellow sandy soils in mixed dipterocarp forest on coastal hills. The density of the wood is 680–735 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 100, 258, 476, 748.

K.M. Kochummen (general part, selection of species),
W.C. Wong (properties),
S. Sudo (wood anatomy),
F.T. Frietema (selection of species)

Hopea Roxb. (giam)

Pl. Coromandel 3: 7 (1811).
DIPTEROCARPACEAE
$x = 7$; *Hopea nutans*: $2n = 28$

Trade groups Giam: heavy hardwood, e.g. *Hopea ferrea* Lanessan, *H. forbesii* (Brandis) v. Slooten, *H. helferi* (Dyer) Brandis.
In Indonesia the wood of several species of *Hopea* is traded as 'balau' because it closely resembles the wood of the heavy species of *Shorea*. In Indonesia the name 'giam' is used for the wood of *Cotylelobium* spp. The wood of *H. ferrea* is sometimes traded separately and called 'malut'.

Vernacular names Giam: heavy hopea (En). Brunei: luis (Iban). Indonesia: balau (partly). Malaysia: selangan (Sabah, Sarawak). Papua New Guinea: heavy hopea. Philippines: yakal. Burma: thingyan. Cambodia: kôki:(r). Thailand: takhian-hin (peninsular), takhian-rak (peninsular), krabok-krang (Nan). Vietnam: s[aw]ng d[af]o, sao xanh.

Origin and geographic distribution *Hopea* consists of some 102 species. The section *Hopea*, to which most of the giam timbers belong, comprises about half of the total number of species and is distributed from Sri Lanka and southern and eastern India through mainland South-East Asia towards Malesia, where it occurs on all islands except for the Lesser Sunda Islands. The oldest fossil wood belonging to the genus *Hopea* was found on the east coast of southern India and dates from the Miocene.

Uses Giam is a useful general-purpose timber for heavy construction. Its durability both in contact with the ground as well as in contact with water makes it suitable for purposes such as bridges, piers, wharves, piling, posts and electricity poles, beams and railway sleepers; it is in demand for boat building, specifically for boat keels. Giam is suitable for heavy-duty, industrial flooring. Other general applications of the timber are for vehicle bodies, furniture, wall plates and other interior finish, window and door frames and heavy-duty laboratory benches. Due to its hardness giam is generally not suitable for plywood or veneer nor for particle board.
Several species yield a clear crystalline resin known as 'damar mata kucing' which is used for varnish manufacture and locally for torches and caulking boats.

Production and international trade Giam is not an important export timber in Malaysia, Indonesia and the Philippines. It is probably mostly used locally, but small amounts may be exported mixed with other heavy hardwoods such as balau (from *Shorea* spp.). However, *Hopea* timber (both heavy and light) is one of the more important export timbers in Papua New Guinea; it is ranked in the MEP (Minimum Export Price) group 3 and fetched a minimum export price of US$ 50/m^3 for saw logs in 1992.

Properties Giam is a heavy hardwood. The yellowish-white sapwood is generally distinct from the yellowish-brown heartwood, sometimes with a greenish tinge, darkening to dark brown on exposure. The density is 875-1220 kg/m^3 at 15% moisture content. Planed surfaces are usually not particularly lustrous; a stripe figure may be present. The grain of the wood is interlocked, texture fine and even.
When green, the modulus of rupture is 103–124 N/mm^2, modulus of elasticity 14600–22000 N/mm^2, compression parallel to grain 42–70 N/mm^2, compression perpendicular to grain 10–17 N/mm^2, shear 13–14 N/mm^2, cleavage 58-98 N/mm radial and 75–116 N/mm tangential, Janka side hardness 8700–9750 N and Janka end hardness 8100–8410 N.
The rates of shrinkage are moderate to fairly high, from green to 15% moisture content 1.4–2.0% radial and 2.6–4.4% tangential. Giam timber air dries slowly, often with slight end and surface checks and splits. Boards of 15 mm thick take about 6 months to air dry. Kiln-drying characteristics have not been assessed but in Malaysia kiln schedule B is recommended.
Giam is easy to difficult to resaw and cross cut.

The sawteeth may become clogged with resinous sawdust. Planing is easy, giving a smooth finish. Boring is easy to slightly difficult but the finish is always smooth. Turning is difficult and the quality of finish ranges from smooth to rough. The resistance to splitting when nailed is rated as very poor.

Giam is very durable, even under exposed conditions. Test stakes in Malaysia showed an average service life in contact with the ground of over 10 years. The wood is resistant to pinhole borer and powder-post beetle attack, and probably also to marine borer attack. The heartwood of giam is very resistant to preservative treatment, but it has great natural durability. The sapwood absorbs preservatives fairly well, and the life of the sapwood in poles can be prolonged by preservative treatment.

Description Small to fairly large trees of up to 48 m tall; bole usually tapering, frequently branching low with a diameter of up to 160 cm, exuding a pale clear dammar; buttresses usually thin, sometimes thick, bole sometimes stilt-rooted or with flying buttresses; bark surface usually flaky when mature, chocolate and grey mottled, hoop-marked, inner bark pink or greenish-yellow, close textured; crown of the smaller trees lanceolate, monopodial with slender, more or less horizontal and pendant branches, in large trees becoming hemispherical with many small straight branches radiating from the bole apex. Leaves alternate, simple, small or medium-sized, sometimes large and narrowly oblong, usually with domatia on the lower surface, usually with scalariform tertiary venation, but venation sometimes 'dryobalanoid', i.e. secondary veins numerous and of varying length, more or less indistinct and with indistinct tertiary venation; petioles never geniculate; stipules linear, fugacious (subpersistent in saplings). Inflorescence paniculate, rarely fascicled, irregularly branched, terminal or axillary, many-flowered, slender, generally tomentose. Flower buds small, ovoid or rarely globose; flowers secund or distichous, bisexual, actinomorphic, 5-merous, pale, scented; sepals imbricate, 2 outer ones ovate, more or less obtuse, thickened, 3 inner ones suborbicular, frequently mucronate, thin at margins; petals oblong, connate at base and shed as a rosette, often persistently pubescent on the parts exposed in bud; stamens 10 or 15, in 1–3 verticils or irregular, filaments broad and compressed at base, tapering medially and filiform apically, anthers subglobose, with 4 pollen sacs, the outer pair somewhat larger, appendage to connective slender, usually at least twice as long as the anther, glabrous or minutely glandular tuberculate; ovary ovoid, glabrous or tomentose, a distinct stylopodium sometimes present and then pear-shaped to cylindrical, style long or short, glabrous, with a minute stigma (except *H. ferrea*). Fruit comparatively small, 2 outer fruit calyx lobes prolonged, spatulate, 3 inner ones short, sometimes all 5 lobes short and subequal, lobes thickened and saccate at base; nut ovoid, usually glabrous, with a distinct apical stylopodium if present in the flower; pericarp splitting irregularly at germination (rarely into 3 valves). Seedling with epigeal germination; cotyledons subequal; first pair of leaves opposite, followed by spiral leaves or an initial whorl of 3.

Wood anatomy

– Macroscopic characters:

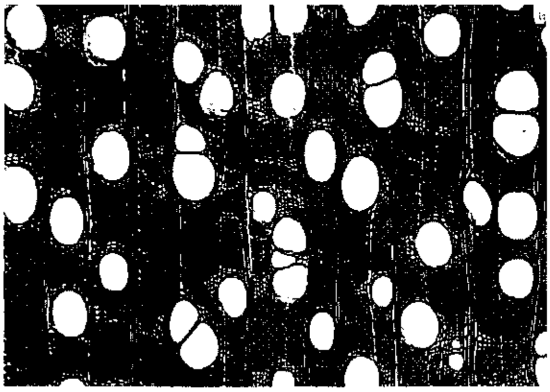
Heartwood yellowish-brown, often with a green tinge, turning dark yellowish-brown or red-brown upon exposure, usually distinctly demarcated from the yellowish-white sapwood. Grain shallowly to strongly interlocked. Texture fairly fine to fine; concentric lines composed of white dots and lighter coloured parenchyma distinct to indistinct. Growth rings usually not distinct.

– Microscopic characters:

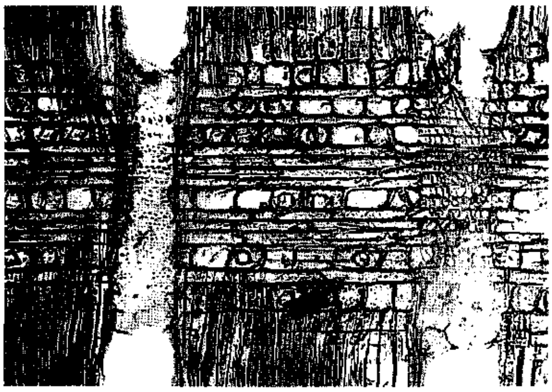
Growth rings indistinct. Vessels diffuse, usually 10–20/mm², mostly solitary, with a small number of radial multiples of 2(–3), less than 150 μm in tangential diameter; perforations simple; intervessel pits alternate, vestured, round, usually 5–8 μm; vessel-ray and vessel-parenchyma pits round to oval, simple to half-bordered; tyloses often abundant. Fibres 1.2–2.2 mm long, 18–25 μm in diameter, non-septate, usually thick-walled, with infrequent, small simple pits confined to the radial walls. Parenchyma vasicentric, aliform, short confluent and in tangential bands surrounding the intercellular canals. Rays 8–11/mm, 1–5-seriate, mostly 1000–2000 μm high, usually heterocellular, mostly with 1 and/or 2–4 rows of upright and/or square marginal cells (Kribs type heterogeneous III and II). Prismatic crystals sporadic or absent in axial parenchyma, usually found in ray parenchyma cells. Axial intercellular canals of the concentric type, with whitish contents, surrounded by tangential parenchyma bands.

Species studied: *H. nutans*, *H. semicuneata*.

Giam differs from balau (heavy *Shorea* timber), particularly in having more numerous vessels, narrower rays and a finer texture. Macroscopic identification is often difficult, and giam and balau are often not separated in trade.



transverse section (×25)



radial section (×75)

tangential section (×75)

Hopea nutans (giam)

Growth and development Seedlings need ectomycorrhizal infection for optimal growth. Most species regenerate prolifically under natural conditions and are shade-tolerant. Plagiotropic branching of *Hopea* saplings is mainly at the apex of the leader shoot at the initiation of each growth period; hence, the sapling has a pagoda-like appearance.

Giam trees usually grow slower than merawan (*Hopea* species with lighter wood) trees. *H. andersonii* is reported to reach a maximum diameter of 39 cm at an age of 40 years, *H. nutans* of 35 cm. However, for 40-year-old planted trees of *H. helferi* an astonishingly large maximum diameter of 82 cm has been reported in Malaysia.

The flowering periodicity of the various giam species is not known. Thrips are pollinators of many *Hopea* species. The interval between anthesis and mature fruits is about 3 months. The abundance of seedlings below trees indicates that most fruits fall directly beneath the mother tree.

Other botanical information The genus *Hopea* belongs to the tribe *Shoreae* and is very closely related to *Shorea*. The distinction is made by a single character: in *Hopea* the two outer sepals are slightly or markedly thicker than the three inner ones, and only they develop into wings in fruit. In *Shorea* the three outer sepals are thicker and larger than the two inner ones, and normally develop into fruit wings (or lobes). In both genera species with only short and subequal fruit sepals occur and these are assigned to one of the two by comparison of other floral characters. All but a few *Shorea* species are emergent trees, whereas all but a few *Hopea* species are main canopy or understorey trees.

The groups distinguished commercially, the giam timbers and the more variable merawan timbers, correspond to some degree to the botanical subdivision of the genus *Hopea*. Most giam timbers (except *H. coriacea* and *H. malibato*) belong to section *Hopea*, most merawan timbers to section *Dryobalanoides* (Miq.) Burck. Section *Hopea* is characterized by its scalariform leaf venation, smooth or evenly flaky bark, bole usually without stilt roots and wood with markedly heterogeneous rays and usually without chambered parenchyma strands.

Some *Hopea* species (*H. depressinerva* and *H. glabrifolia*) cannot be assigned to either of the two commercial groups. Since they belong to section *Hopea*, it seems justifiable to deal with these species under giam.

Ecology Giam is found in lowland and hill forest from sea-level up to 1000 m altitude. It occurs as a main canopy or understorey, rarely as an emergent tree in evergreen or seasonal, semi-evergreen forest. The semi-evergreen forest accommodates the majority of the species, often narrow endemics. The different species occur in a wide variety of forest types ranging from mixed dipterocarp forest to heath forest and mixed peat-swamp forest and, consequently, on a wide variety of soil types, including limestone. Some species occur markedly gregariously with comparatively large gaps between the groups.

Propagation and planting The viability of seeds under natural conditions is short. Seeds of *H. helferi* show a germination rate of over 90% at temperatures between 5°C and 35°C; the germination rate drops sharply above 40°C. The weight of 1000 seeds of *H. helferi* is about 125 g. When *H. helferi* seeds are dried at 35°C to 25% moisture content, they can be kept viable in sealed polyethylene bags for 2 months at 15°C. Seeds of *H. ferrea* can also be stored, but survival at 4°C does not exceed 3 months. *H. plagata* can be vegetatively propagated by air layering; in tests 15% of the branches developed roots.

Yield Yields are generally low. The trees often occur scattered in the forest, and very locally there may be 10–13 trees of over 40 cm diameter per ha.

Genetic resources *Hopea* is a large genus, and some of the species are common and widespread, but others are scattered or rare. Large-scale logging without identification of species, as commonly practised, could easily endanger the less common species.

Prospects Few timbers are as strong and durable as giam. The establishment of plantations is desirable, but more research is needed on propagation techniques and silvicultural aspects, since information about giam is scarce. The growth rates, gathered from the few data available, seem to be acceptable for such a heavy timber. *H. helferi* has been recommended for planting in Peninsular Malaysia.

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Selection of species

Hopea andersonii P. Ashton

Gard. Bull. Sing. 22: 272, pl. 17 (1968).

Vernacular names Malaysia: luis somit (Sarawak).

Distribution Sabah, Sarawak and south-eastern Kalimantan.

Uses The timber is used as giam, e.g. for poles and small beams in industries.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole frequently twisted and crooked, often branching low, with a diameter of up to 80 cm and prominent but rather narrow buttresses of up to 2 m tall and 80 cm long, bark surface chocolate-brown (subsp. *andersonii*) or coppery (subsp. *basalticola* P. Ashton), inner bark thick, pale pink-brown to cream-brown, sapwood yellow, heartwood dark chocolate-brown; twigs glabrous; leaves lanceolate-falcate to elliptical, 5–14 cm × 2–6 cm, leathery, base distinctly unequal, acumen slender, frequently falcate, up to 2 cm long, venation scalariform, midrib not or slightly raised above, secondary veins 9–12 pairs, arched at 65–75°, not prominently raised; stamens 15, in 3 unequal verticils, ovary and stylopodium cylindrical, very slightly constricted, style short; 2 longer fruit calyx lobes up to 6 cm × 2 cm, obtuse, 3 shorter ones up to 4 mm × 3 mm, obtuse, saccate.

H. andersonii is common on the lower slopes of limestone hills (subsp. *andersonii*) or in mixed dipterocarp forest on rich clay soils, especially on basic volcanic rocks (subsp. *basalticola*) up to 400 m altitude. The density of the wood is 895–1000 kg/m³ at 15% moisture content.

Selected sources 31, 258, 514, 748.

Hopea basilanica Foxw.

Philipp. Journ. Sc., Bot. 6: 260, pl. 42 (1911).

Vernacular names Philippines: basilan yakal (general), dalindingan (Sulu), yakal (Sulu, Yakan).

Distribution The Philippines (Basilan, Mindanao).

Uses The timber is used as giam for construction works requiring strong and durable wood, such as bridges and wharves.

Observations A large tree up to 60 m tall, with bole up to 65 cm in diameter, bark surface flaky, grey-brown to brown, inner bark yellowish when fresh and turning brown when dry, sapwood slightly paler than the yellowish to light brown heartwood; young twigs, petioles and panicles greyish sericeous; leaves oblanceolate or elliptical, (7.5–)10–14 cm × (2.5–)3.5–5 cm, thickly leathery, cuneate and unequal at base, acumen slender, up to 1.5 cm long, venation scalariform, midrib applanate above, secondary veins (9–)10–13 pairs, slender but prominent beneath, the basal pairs with axillary domatia; stamens 15, in 3 unequal verticils, ovary and stylopodium together hourglass-shaped with a distinct median constriction, style as long as ovary; 2 longer fruit calyx lobes up to 4.5 cm × 1.5 cm, obtuse, 3 shorter ones up to 7 mm × 5 mm, acute. *H. basilanica* occurs in primary forest on undulating land and low hills below 70 m altitude; it is not common. The density of the wood is about 920 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 175, 258, 579, 599, 748.

Hopea cagayanensis (Foxw.) v. Slooten

Reinwardtia 3: 318 (1956).

Synonyms *Balanocarpus cagayanensis* Foxw. (1918).

Vernacular names Philippines: narek (Ibanag), narig (Negrito, Ibanag), narik (Ibanag, Iloko).

Distribution The Philippines (north-eastern Luzon).

Uses The timber is used as giam, especially for poles and piles and house construction.

Observations A medium-sized tree, bole generally branchless for 8–15 m and with a diameter of 25–50(–70) cm, without prominent buttresses; young parts and domatia densely persistently tawny pubescent; leaves lanceolate, 8–10 cm × 2.5–4 cm, thin leathery, base unequal, acumen slender, up to 1.5 cm long, venation scalariform, midrib distinctly elevated above, secondary veins 9–12 pairs, arched at 55–65°, slender but prominent beneath; stamens 15, shorter than the style, in 3 more or less unequal verticils, ovary small, ovoid, tapering into an equally long somewhat narrower stylopodium, style short, columnar; fruit sepals short, subequal, 2 outer up to 9 mm × 7 mm, incrassate, 3 inner up to 10 mm × 10 mm, obtuse. *H. cagayanensis* occurs locally abundantly in semi-evergreen forest at low altitude. The density of the wood is about 920 kg/m³ at 15% moisture content.

Selected sources 175, 258, 579, 599, 748.

Hopea celebica Burck

Ann. Jard. Bot. Buitenzorg 6: 237 (1887).

Synonyms *Hopea dolosa* v. Slooten (1952).

Vernacular names Indonesia: balau mata kucing, dama dere itam, hulo dereh (Sulawesi).

Distribution Sulawesi (central and south-western).

Uses The timber is traded as giam (sometimes as balau), and used for construction of houses, bridges, ships, for railway sleepers, telegraph poles and furniture.

Observations A medium-sized, scaly-barked tree; twig apices, petioles, panicles and calyx outside caducous buff pubescent; leaves ovate-lanceolate, (5.5–)8–22 cm × (2.2–)2.5–8 cm, leathery, more or less lustrous, base subequal, acumen tapering, up to 1.5 cm long, margin more or less revolute, venation subscalariform, midrib distinctly elevated above, secondary veins 8–11 pairs, arched at 45–55° except at base, slender but prominent beneath; 2 outer sepals long, narrowly deltoid-lanceolate, 3 inner broadly ovate, distinctly acuminate, stamens 15, in 3 subequal verticils, ovary and stylopodium stoutly pyriform, stylopodium punctate, style short but distinct; mature fruits unknown. *H. celebica* is locally common in semi-evergreen forest up to 500 m altitude. The density of the wood is 890–1260 kg/m³ at 15% moisture content.

Selected sources 258, 318, 555, 748.

Hopea coriacea Burck

Ann. Jard. Bot. Buitenzorg 6: 237 (1887).

Synonyms *Hopea kelantanensis* Sym. (1941), *Hopea garangbuaya* P. Ashton (1962).

Vernacular names Brunei: garang buaya (Kedayan), arang bayar (Iban). Indonesia: damar melapi (Kalimantan). Malaysia: giam hantu (Peninsular).

Distribution Peninsular Malaysia (eastern coast), Borneo (West Kalimantan, Sarawak, Brunei).

Uses The timber is used as giam; it is locally in great demand for house supports and boat hulls.

Observations A medium-sized to large tree of up to 45 m tall, bole tapering in lower half, cylindrical, straight, with a diameter of up to 160 cm and prominent, thin, flying buttresses, bark surface flaky or fissured, outer bark hard, chocolate-brown outside, pale fawn within, inner bark rust-brown, sapwood rich orange-brown, heartwood rust-brown; all parts except petals glabrous; leaves broadly ovate, 11–16 cm × 6–10 cm, thick leathery, base obtuse, acumen narrow, up to 1.2 cm long, margin slightly revolute, venation dryobalanoid, midrib slightly raised above, secondary veins 8–11 pairs, arched at 60–70°, relatively prominent, tertiary veins rather distinct, densely scalariform; stamens 15, in 3 whorls, ovary ovoid, glabrous at base, tapering gradually into the long and filiform style, stylopodium indistinct; 2 longer fruit calyx lobes up to 7 cm × 1.5 cm, spatulate, auriculate and shallowly saccate at base, 3 shorter ones up to 2 cm × 1.2 cm, acute, similar at base. *H. coriacea* occurs scattered on well-drained yellow sandy clay soils, on ridges and hill-sides, up to 200 m altitude.

Selected sources 30, 258, 677, 748.

Hopea depressinerva P. Ashton

Gard. Bull. Sing. 22: 275, pl. 20 (1967).

Distribution Borneo (western Sarawak).

Uses The timber is used as giam, but is probably only of local value.

Observations A medium-sized tree of up to 25 m tall, bole with a diameter of up to 50 cm, bark surface slightly cracked, inner bark pale yellowish-brown; young parts glabrescent; leaves lanceolate to narrowly elliptical, 5–13 cm × 2–5 cm, leathery, base cuneate, acumen slender, up to 1.5 cm long, venation scalariform, midrib slightly depressed above, secondary veins 6–8 pairs, ascending at 40–50°, slender but raised beneath, depressed above; calyx densely buff sericeous, lobes ovate, acute, the outer 2 somewhat longer and comparatively narrower than the inner 3, stamens 10, equal, forming a ring around the ovary, ovary and stylopodium glabrous, cylindrical, truncate, surmounted by a short style; mature fruits unknown. *H. depressinerva* is confined to granodiorite hill slopes, where it appears to occur locally gregariously in mixed dipterocarp forest below 500 m altitude.

Selected sources 31, 258, 748.

Hopea ferrea Lanessan

Pl. util. colon. franç. 1: 300 (1886).

Synonyms *Balanocarpus anomalus* King (1893), *Hopea anomala* (King) Foxw. (1927).

Vernacular names Malaysia: malut (general), chengal laki, chengal batu (Peninsular). Cambodia: kôki:(r) thmâ:(r). Laos: chik cha:d, kh'è:n hin. Thailand: takhian-hin, kian-sai (peninsular), takhian-nuu (eastern). Vietnam: s[aw]ng d[af]o, sao t[is]a.

Distribution Laos, Cambodia, southern Vietnam, Thailand and north-western Peninsular Malaysia.

Uses *H. ferrea* is a commercially important source of giam timber, which is sometimes traded separately and called 'malut'. It also yields a very fragrant dammar, which is collected in Indo-China.

Observations A small, medium-sized or occasionally stout and fairly large tree of up to 35 m tall, bole often twisted and gnarled and with a diameter of up to 145 cm and inconspicuous buttresses, bark surface shaggy, flaking in thin scales, dark brown, inner bark dull orange-yellow tinged salmon, sapwood thin, yellow or brownish-yellow, heartwood distinctly darker, sometimes showing a brownish-red colour; plant glabrous except for densely buff puberulent inflorescences, petals and sepals, young leaves brilliant red; leaves ovate, 4–10 cm × 2–5.5 cm, base broadly cuneate, or rarely obtuse, acumen slender, up to 2 cm long, venation scalariform, midrib evident above, secondary veins (6–)8(–9) pairs, arched, slender but distinctly raised beneath; stamens 15, ovary together with stylopodium pear-shaped, glabrous, style short, obscure; 2 longer fruit calyx lobes up to 4 cm × 1 cm, broadly spatulate, obtuse, 3 shorter lobes up to 5 mm × 1 mm, lanceolate-acicular, thickened, saccate. *H. ferrea* is locally abundant in evergreen forest on rocky ridges and slopes, especially on limestone but also on granite and sandstone formations. The density of the wood is 870–1170 kg/m^3 at 15% moisture content.

Selected sources 102, 235, 258, 601, 628, 677, 748.

Hopea forbesii (Brandis) v. Slooten

Reinwardtia 5: 477 (1961).

Synonyms *Shorea forbesii* Brandis (1895).

Distribution Papua New Guinea.

Uses The timber is mainly used for window sills, staircases, window and door frames, and marine constructions.

Observations A medium-sized tree of up to 32 m tall, bole with a diameter of up to 100 cm; young parts densely buff pubescent, leaf undersurface and calyx sparsely so; leaves lanceolate, 5.5–11(–13) cm × 2–4 cm, thin leathery, base obtuse, more or less equal, acumen slender, up to 1.3 cm long, margin subrevolute, venation scalariform, midrib depressed above, secondary veins (11–)13–15 pairs, dense, slender but prominent beneath, without domatia; stamens (15–)16–19, shorter than style, ovary small, tapering into a stout columnar stylopodium, style short; 2 longer fruit calyx lobes up to 6.5 cm × 1.0 cm, spatulate, obtuse, 3 shorter ones up to 12 mm × 8 mm, ovate, mucronate, one however sometimes longer and spatulate. *H. forbesii* is locally common in lowland seasonal semi-evergreen forest up to 100 m altitude, sometimes dominant, especially on ridges.

Selected sources 258, 359, 735, 748.

Hopea glabrifolia C.T. White

Proc. Roy. Soc. Queensl. 43: 49 (1932).

Distribution Papua New Guinea and the Louisiade Archipelago.

Uses The timber is used as giam, mainly for wharf and bridge building, window framing, billiard-cue butts and external cladding.

Observations A medium-sized to large tree of up to 42 m tall, bole cylindrical with a diameter of up to 100 cm and prominent buttresses, bark surface flaky, inner bark green and fibrous, sapwood pale straw-coloured, heartwood brown; young parts and panicle greyish puberulent, glabrescent; leaves lanceolate, 18–19 cm × 2–5.5 cm, falcate, leathery, lustrous, base distinctly unequal, acumen broad, tapering, up to 1.5 cm long, margin narrowly subrevolute, venation scalariform, midrib raised above, secondary veins 9–12 pairs, arched, ascending at 45–50°, slender but prominent beneath, narrowly depressed above; stamens 15, ovary ovoid, surmounted by a cylindrical stylopodium twice the length of the ovary and a very short style, glabrous; 2 longer fruit calyx lobes up to 7 cm × 1.3 cm, spatulate, obtuse, 3 shorter ones up to 9 mm × 7 mm, ovate, acute. *H. glabrifolia* is locally abundant in semi-evergreen seasonal forest up to 350 m altitude.

Selected sources 258, 359, 735, 748.

Hopea gregaria v. Slooten

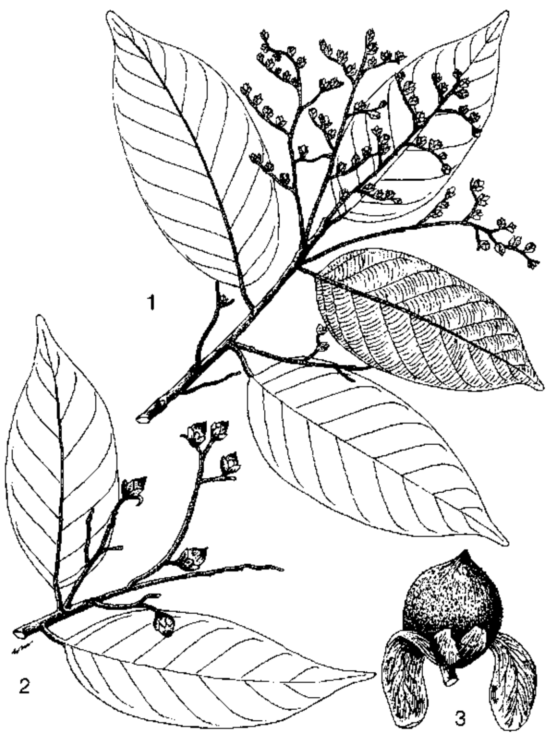
Reinwardtia 2: 21, f. 7 (1952).

Vernacular names Indonesia: pooti (Sulawesi), mandonor (Biak), kamura (Aru).

Distribution South-eastern Sulawesi, possibly also on the Aru Islands and on Japen Island.

Uses The timber is used as giam (sometimes traded as balau). Small quantities of a clear, white or yellow resin are produced by the tree and used locally.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole straight and with small buttresses; young parts buff caducous puberulent, more or less persistently on panicles, calyx and parts of petals exposed in bud; leaves lanceolate-falcate to ovate, 6–13 cm × 2.5–6.5 cm, thin leathery, with dull, minutely stellate undersurface, base cuneate, unequal, acumen slender, tapering, up to 1.5 cm long, venation scalariform, midrib slightly raised above, secondary veins 7–10



Hopea gregaria v. Slooten – 1, flowering twig; 2, fruiting twig; 3, fruit.

pairs, slender but distinctly elevated beneath; stamens 15, in 3 subequal verticils, ovary and stylopodium broadly pear-shaped, somewhat abruptly tapering to the short columnar style; fruit calyx lobes unequal but the 2 longer ones only slightly longer than the nut and becoming reflexed. *H. gregaria* occurs often gregariously in primary forest on well-drained, hilly or steep places on stony or clayey soil at low altitudes. The density of the wood is 990–1110 kg/m^3 at 15% moisture content.

Selected sources 258, 461, 555, 744, 748.

Hopea helferi (Dyer) Brandis

Journ. Linn. Soc. Bot. 31: 62 (1895).

Synonyms *Hopea dealbata* Hance (1877).

Vernacular names Malaysia: giam lintah bukit (general), damar mata kucing, damar siput (Peninsular). Burma: thingan kyauk. Cambodia: kôki:(r) daèk, phdiek krâhâ:m. Thailand: krabok-krang (general), ngon-kaibok (peninsular), takhian-nuu (eastern). Vietnam: sao xanh.

Distribution Burma, Cambodia, Thailand, the Andaman Islands and Peninsular Malaysia.

Uses *H. helferi* is a valuable source of construction timber, especially for boat construction. The tree yields a resin which is used locally.

Observations A medium-sized or large tree of up to 50 m tall, bole often straight, branchless for 15–21 m and up to 165 cm in diameter, buttresses sometimes large and coarse, bark surface fibrous, dark brown; young parts densely buff puberulent, more or less caducous on twigs, leaf beneath and calyx; leaves oblong-lanceolate or occasionally oblanceolate, (5–)10–24 cm × (2–)4.5–8 cm, leathery, silvery lepidote beneath, base cuneate to occasionally cordate, subequal, apex shortly broadly acuminate or obtuse, venation scalariform, midrib shallowly channelled above, secondary veins (12–) 14–16 pairs, slender but prominent beneath, obscure above; stamens 15, ovary and stylopodium cylindrical, subtruncate, style shorter than ovary and stylopodium, columnar; 2 longer fruit calyx lobes up to 6.5 cm × 1.8 cm, spatulate, obtuse, 3 shorter ones up to 5 mm × 3 mm, ovate. *H. helferi* occurs on deep soils especially on sedimentary rocks on hill slopes and undulating land in semi-evergreen forest up to over 500 m altitude. The density of the wood is 895–1125 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 235, 253, 258, 297, 417, 514, 628, 677, 685, 748.

Hopea iriana v. Slooten

Reinwardtia 2: 28, f. 10 (1952).

Synonyms *Hopea nabirensis* v. Slooten (1952).

Vernacular names Indonesia: sian, saindorih (Japen), lilipga (Manikiong). Papua New Guinea: heavy hopea.

Distribution New Guinea, Japen Island and the Aru Islands.

Uses The wood is used as giam, mainly for wharf and bridge building, window framing, billiard-cue butts and external cladding.

Observations A large tree of up to 48 m tall, bole cylindrical, branchless for up to 30 m, with a diameter of up to 100 cm and flying buttresses, bark surface flaky, blackish, inner bark pale yellow or light brown, sapwood pale straw-coloured, heartwood dark brown; young parts buff puberulent; leaves lanceolate-falcate, 5–13 cm × 2–4.5 cm, leathery, dull greyish minutely stellate beneath, base unequal, cuneate, acumen slender, up to 1.5 cm long, margin frequently subrevolute, venation scalariform, secondary veins 7–11 pairs, slender but distinctly elevated beneath, slightly elevated above; stamens 15, in 3 subequal verticils, ovary and stylopodium conical-cylindric, sericeous, style short, columnar; all fruit calyx lobes saccate, 2 longer ones up to 7 cm × 1.8 cm, broadly spatulate, obtuse, 3 shorter ones up to 6 mm × 4 mm, ovate, acute. *H. iriana* is very variable showing regional variants. It occurs in evergreen forest on hills, especially on ridges at up to 600 m altitude. The density of the wood is about 1000 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 67, 87, 258, 259, 735, 744, 748.

Hopea malibato Foxw.

Elmer, Leafl. Philipp. Bot. 6: 1953 (1913).

Synonyms *Hopea woodiana* Gutierrez (1968), *Hopea dalingdingan* Gutierrez (1976).

Vernacular names Philippines: yakal kaliot (general), malibato (Manobo), dalingdingan tayakad (Tagalog).

Distribution The Philippines.

Uses The wood is used as giam for high-grade constructional works, bridges and wharves, ship building, piling and railway ties.

Observations A medium-sized to fairly large tree of up to 36 m tall, bole branchless for about 18 m and with a diameter of up to 80 cm, bark surface smooth, greyish to dark brown, sapwood reddish-brown, heartwood fawn-coloured, turning dark reddish-brown on exposure; leaves lanceolate-falcate, 5–9 cm × 1.5–4 cm, base cuneate, shortly decurrent, acumen very slender, up to 2 cm long, venation dryobalanoid, midrib distinctly raised above, secondary veins about 11 pairs, ascending, arched, with shorter veins in between, very slender but evident and elevated beneath; stamens 15, ovary ovoid, without stylopodium, style columnar, 1.5–2 times as long as the ovary; 2 longer fruit calyx lobes up to 3.5 × 0.9 cm, 3 shorter ones up to 4 mm × 4 mm, ovate, subacute, shorter than the apiculate nut. *H. malibato* is widespread and locally common in evergreen dipterocarp forest up to 600 m altitude. The density of the wood is about 1100 kg/m^3 at 15% moisture content.

Selected sources 175, 258, 579, 599, 748.

Hopea nutans Ridley

Fl. Mal. Pen. 1: 235 (1922).

Vernacular names Brunei: garang buaya daun kechil. Malaysia: giam, chengal batu (Peninsular), giam betul (Sabah, Sarawak).

Distribution Peninsular Malaysia and Borneo.

Uses The timber is used as high-grade giam, notably for keels and external planking for boats, long piles (sapwood treated), floors and heavy construction. An opaque, yellow resin can be tapped from the tree.

Observations A medium-sized tree of up to 30 m tall, bole often gnarled and comparatively short, with a diameter of up to 70 cm and short buttresses, bark surface shaggily scaly, dark brown, inner bark yellow, sapwood yellowish, heartwood yellow when fresh, deep tan or red-brown on exposure; young parts very shortly sparsely pale brown pubescent; leaves broadly ovate, 8–13 cm × 4.5–8.5 cm, leathery, greyish lepidote below in mature trees, base obtuse, acumen up to 1 cm long, margin frequently revolute, venation scalariform, midrib slightly raised above, secondary veins 7–10 pairs, curved at 50–60°, distinct; stamens 15, in 3 subequal whorls, ovary and stylopodium subcylindrical, glabrescent, style short; 2 longer fruit calyx lobes up to 8 cm × 1.5 cm, oblong, thinly leathery, obtuse, 3 shorter ones up to 10 mm long, acute. *H. nutans* occurs on sandy soils, often periodically inundated, near and on coastal hills. The density of the wood is 875–1205 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 258, 297, 359, 417, 476, 514, 677, 748.

Hopea pentanervia Sym. ex Wood

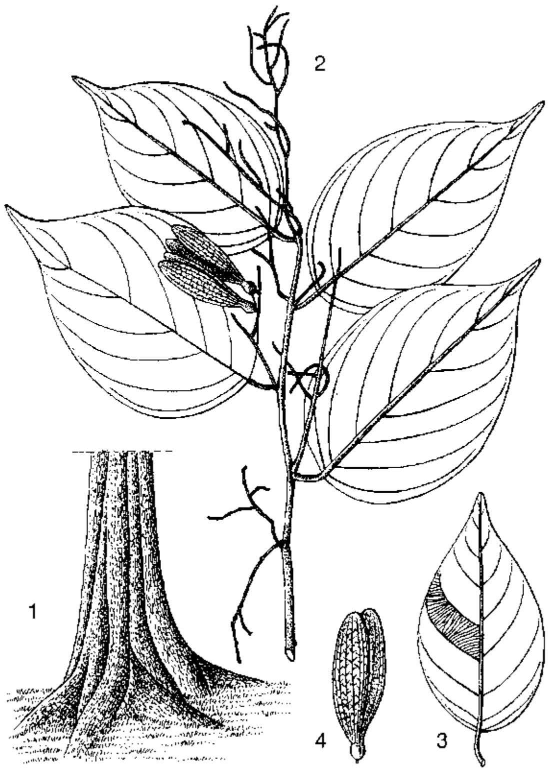
Gard. Bull. Sing. 17: 495 (1960).

Vernacular names Brunei: mang (Malay), chengal paya (Iban). Malaysia: selangan lima urat, selangan batu paya (Sabah), mang besi (Sarawak).

Distribution North-western Borneo.

Uses The wood is frequently used for hewn posts in heavy construction and is also popular for the keels of boats.

Observations A medium-sized to fairly large tree of up to 35 m tall, bole twisted, frequently crooked and ribbed, with a diameter of up to 125 cm and distinct buttresses, bark surface dark red-brown, inner bark pale brown, paler at the bright yellow cambium, sapwood pale straw-coloured, heartwood red-brown, honey-coloured when fresh; young parts puberulent, glabrescent; leaves ovate, 5–10 cm × 3.2–5 cm, leathery, base obtuse or broadly cuneate, acumen up to 1.5 cm long, margin slightly revolute, venation scalariform, midrib applanate above, secondary veins about 5 pairs, ascending at 45–55° but strongly curved; stamens



Hopea pentanervia Sym. ex Wood – 1, trunk base; 2, fruiting twig; 3, leaf showing tertiary venation; 4, fruit.

15, small, well spaced round the ovary, ovary and stylopodium cylindrical, truncate, glabrous, style short, slender; 2 longer fruit calyx lobes up to 5 cm × 1.2 cm, spatulate, chartaceous, obtuse, 3 shorter ones up to 4 mm × 3 mm, ovate, acute, saccate. *H. pentanervia* occurs in mixed peat-swamp forest over sand, on podzols on cuestas, plateaux and terraces, near present or Pleistocene coastlines; on ultrabasic rocks in eastern Sabah. The density of the wood is 1090–1215 kg/m³ at 15% moisture content.

Selected sources 30, 89, 100, 258, 476, 748.

Hopea plagata (Blanco) S. Vidal

Sinopsis: t. 15A (1883).

Synonyms *Dipterocarpus plagatus* Blanco (1845), *Hopea dasyrrachis* P. Ashton (1968) non v. Slooten.

Vernacular names Philippines: yakal saplungan (general), taggai (Iloko, Negrito), paina (Tagalog).

Distribution The Philippines and north-eastern Borneo.

Uses *H. plagata* is the most widespread heavy construction timber in the Philippines, used for general house construction (especially for posts), ship building, for bridges, wharves and railway ties.

Observations A large tree of up to 55 m tall, bole with a diameter of up to 180 cm, buttressed, bark surface flaky; all parts glabrous; leaves elliptical-lanceolate to ovate, 6–12 cm × 2.5–7 cm, more or less falcate, leathery, base cuneate to obtuse, more or less markedly unequal, acumen tapering, up to 1.5 cm long, venation scalariform, midrib raised above, secondary veins 8–11(–12) pairs, slender, elevated beneath, applanate above, ascending at 35–65°; stamens about 35, subequal, anthers elongate, ovary ovoid, with obscure stylopodium and short broad style; 2 longer fruit calyx lobes up to 4.5 cm × 2.0 cm, broadly oblong-spatulate, sometimes suborbicular, 3 shorter ones up to 7 mm × 4 mm, ovate. *H. plagata* is widespread and common in semi-evergreen seasonal forest or (less often) evergreen non-seasonal forest on limestone (Sarawak); often on coastal hills and ridges, at low and medium altitude. The density of the wood is about 1100 kg/m³ at 15% moisture content.

Selected sources 175, 258, 579, 599, 748, 815.

Hopea semicuneata Sym.

Gard. Bull. Str. Settl. 8: 24, pl. 6 (1934).

Synonyms *Hopea diversifolia* Miq. (1861), *Hopea multiflora* Foxw. (1932) non Brandis, *Hopea plagata* Sym. (1933) non (Blanco) S. Vidal.

Vernacular names Indonesia: jangkang putih, kerangan (Sumatra), bubuh (Bangka, Belitung). Malaysia: sama rupa chengal, chengal batu (Peninsular), giam kulit merah (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *H. semicuneata* is an important source of giam.

Observations A medium-sized to large tree of up to 45 m tall, bole frequently fluted or twisted but branchless for up to 27 m, buttresses small or stout and up to 6 m tall, bark surface dark brown, inner bark reddish-ochre or bright salmon pink, sapwood pale greyish-yellow, heartwood reddish-brown; young twigs and petioles fugacious puberulent, vegetative parts otherwise glabrous; leaves elliptical to ovate-lanceolate, 6.5–14 cm × 2–7 cm, papery, base narrowly to broadly cuneate, acumen slender, up to 2.5 cm long, frequently undulate, venation scalariform, midrib slightly depressed to slightly raised above, secondary veins 6–9 pairs, set obliquely at 45–65°, depressed above, slender but prominent beneath; stamens 15, in 3 unequal verticils, ovary and stylopodium cylindrical, truncate, sometimes constricted medially, style shortly columnar; 2 longer fruit calyx lobes up to 9.5 mm × 2 mm, broadly lorate, obtuse, 3 shorter ones up to 4 mm × 6 mm, broadly ovate, subacute, saccate. *H. semicuneata* occurs locally in dipterocarp forest on clay-rich alluvium, undulating land and hillsides below 500 m altitude. The density of the wood is 610–1215 kg/m³ at 15% moisture content.

Selected sources 100, 253, 258, 476, 557, 677, 748.

K.M. Kochummen (general part, selection of species),
W.C. Wong (properties),
S. Sudo (wood anatomy),
F.T. Frietema (selection of species)

Intsia Thouars

Gen. Nov. Madag.: 22 (1806).

LEGUMINOSAE

x = unknown; *I. bijuga*: $2n = 24$

Trade groups Merbau: heavy hardwood, e.g. *Intsia bijuga* (Colebr.) O. Kuntze, *I. palembanica* Miq.

Vernacular names Merbau: Malacca teak, mirabow, Moluccan ironwood (En). Indonesia: ipil (general), kayu besi (Moluccas, Irian Jaya).

Malaysia: merbau ipil (general). Papua New Guinea: kwila, bendora. Philippines: ipil, ipil laut, malaipil. Burma: tat-takun. Cambodia: krâkâs prêk. Thailand: lumpho (peninsular), lumphothale (Surat Thani). Vietnam: g[ox] n[uw][ows]c (general).

Origin and geographic distribution *Intsia* consists of about 8 species and occurs from East Africa and Madagascar towards Melanesia, Micronesia and northern Australia. Within Malesia 3 species are recorded. The most widespread species is *I. bijuga*.

Uses Merbau is a very good general-purpose timber. It is suitable for a wide range of purposes because of its favourable physical and mechanical properties, combined with a high natural durability and an attractive appearance. Merbau is used in construction work in house building, especially for high-class exterior joinery such as windows, solid panel doors, framing, and weatherboarding. It is also an excellent timber for high-grade flooring for both light and heavy pedestrian traffic. Other uses include furniture making, panelling, stairs, handrails, shopfittings, truck bodies, turnery, poles, fence posts, musical instruments and carving. Merbau is also particularly useful for waterwork construction such as bridges, wharves, sluices and sheet piles, and it is generally free of ship worm. The timber is suitable for making decorative veneer but is generally too hard for plywood manufacture.

The seeds of merbau are eaten locally after being soaked in salt water for 3–4 days and then boiled. A brown and yellow dye is obtained from an oily substance present in the wood and bark. Bark and leaves are used medicinally against rheumatism, dysentery, diarrhoea and urinary diseases.

Production and international trade The production and export of merbau is most important in Malaysia, particularly Peninsular Malaysia where log production fluctuated from 181 000 m^3 in 1982 to 246 000 m^3 in 1989 (maximum annual production) and 228 000 m^3 in 1990. The export of sawn merbau timber from Peninsular Malaysia was 73 000 m^3 (with a value of US$ 15.2 million) in 1981, reached a maximum of 92 000 m^3 (with a value of US$ 26 million) in 1988, and was 63 000 m^3 (with a value of US$ 23 million) in 1992. The average price of sawn merbau on the export market was 409 US$/$m^3$ in 1991. In 1987 the export of merbau logs from Sabah was 7200 m^3 (worth US$ 723 000), and in 1992 the export was 32 000 m^3 of logs and 3500 m^3 of sawn timber with a total value of US$ 7.2 million. Most of the Malaysian export of merbau is to the Netherlands, where the principal end uses are for windows (45%) and doors (35%), and to Germany where it is used, for instance, for parquet flooring.

Merbau was much less important in Indonesia until recently. In 1990 the export of sawn merbau timber was 1700 m^3 with a value of US$ 825 000. In 1991 the export was much larger, amounting to 17 000 m^3 with a value of US$ 7.8 million. The total production of merbau in 1992 in Indonesia was about 137 000 m^3. The main production areas are Aceh and the Moluccas (each about 8000 m^3/year), and particularly Irian Jaya (about 121 000 m^3/year).

In Papua New Guinea *Intsia* timber is grouped in MEP (Minimum Export Price) group 1, and fetched a minimum export price of US$ 130/m^3 for saw logs in 1992. Japan imports comparatively small amounts of merbau from Sabah, Sarawak and especially from Papua New Guinea.

Because of the demand for this timber, it is becoming increasingly difficult to obtain in many areas outside Peninsular Malaysia, and supplies will be limited from these areas until the next forest rotation.

Properties Merbau is heavy and hard without any characteristic figure. Heartwood light brown, orange-brown, to dark red-brown, darkening on exposure, sharply differentiated from the lighter sapwood, usually without lustre, but light-coloured wood sometimes slightly lustrous and with stripe figure on radial surface and zigzag design on tangential surface. The density is (500–)690–955(–1000) kg/m^3 at 12% moisture content. The grain is straight, interlocked or wavy, texture moderately coarse to coarse but even.

At 12% moisture content the modulus of rupture is 105–147 N/mm^2, modulus of elasticity 14 000–18 000 N/mm^2, compression parallel to grain 60–80 N/mm^2, compression perpendicular to grain 10–27 N/mm^2, shear 13–18 N/mm^2, cleavage 70–75 N/mm radial and c. 83 N/mm tangential, Janka side hardness 6700–8500 N and Janka end hardness 7750–8550 N.

The rates of shrinkage of merbau are very low, from green to 15% moisture content 0.6–0.9% radial and 0.7–1.6% tangential, from green to 12% moisture content 1.1–1.3% radial and 1.9–2.6% tangential. Generally merbau dries rather slowly by air seasoning and kiln drying. Test specimens of 30 cm × 20 cm × 2.5 cm took 53 days to air dry from 60% to 20% moisture content, and 20 days in the dehumidifying chamber. Extremely mild kiln schedules are required to obtain good results when drying thicker boards. When the timber is dried very slowly, degrade is almost negligible.

Working properties may vary considerably with the density and the direction of the grain of the wood, but generally merbau cuts cleanly in most operations. The surface of green timber may be marred by an oily exudate; during sawing the sawteeth may become covered with a gummy substance. Sawing of dried wood has a moderately blunting effect on cutting edges. A reduction of the cutting angle of 20° is advantageous in planing quarter-sawn material with interlocked grain and to prevent picking-up of grain. Turning and boring give no problems and generally a smooth finish. Pre-boring for nailing and screwing is advisable since the wood is liable to split. The wood stains and polishes satisfactorily, but requires considerable filling. Merbau is difficult to cut or slice into veneer, even after pre-steaming, mainly due to its high density. However, tests in Indonesia showed that 1.5 mm thick veneer can be made from logs of *I. palembanica* from the Moluccas at a peeling angle of 92° without pretreatment, while logs from South Kalimantan produced inferior veneer, even after boiling for 24 hours. When in contact with water, water-soluble extractives create blackish-lined dark-coloured spots on the surface which are very difficult to remove. Manufactured exterior joinery products have to be protected from water or rain on building sites until the finishing operation is completed. Merbau does not corrode iron, but it does stain black in the presence of iron and moisture. It glues satisfactorily with most modern types of glue.

The heartwood is durable. Stake tests show an average service life in contact with the ground of 6–11.5 years under tropical conditions and about 20 years under temperate conditions. Merbau is highly resistant to dry wood termites as well as subterranean termites; it is also resistant to decay caused by *Polystyctus versicolor*. When used for construction under cover (e.g. as roofing timber), it may be expected to last 30–40 years in the humid tropics. It is, however, reported to be susceptible to powder-post beetle attack. Merbau may have considerable resistance to marine borers, but no average lifetime can safely be predicted from the information available. The heartwood is very difficult to treat with preservatives.

Wood of *I. bijuga* contains 47% cellulose, 23% lignin, 17% pentosan, 0.9% ash and 0.2% silica. The solubility is 5.6% in alcohol-benzene and 8.2% in hot water.

Description Medium-sized or large, evergreen or deciduous trees up to 50 m tall; bole sometimes of poor shape, branchless for up to 20 m and with a diameter of up to 160(–250) cm; buttresses usually present; bark 0.5–1 cm thick, smooth to dimpled or scaly or rarely with boat-shaped fissures (like *Calophyllum*), grey to brown-red, flaking off in small pieces; inner bark very firm, fibrous, sometimes with an obscure granular layer at the surface, orange to pink outwards, pale red or pale fawn inwards; crown rather compact and dark-coloured. Leaves alternate, paripinnate with 2–4(–5) pairs of leaflets; stipules connate at base, forming a persistent scale; leaflets opposite or subopposite, often with a gland at the base on one or both sides, otherwise glabrous except for the midrib. Flowers arranged spirally in simple racemes or branched terminal or lateral panicles; bracts and bracteoles deciduous; sepals 4, with a distinct tube, imbricate, unequal, pulverulent; petals 1, large, clawed; stamens 3, very long, connate at base with the 4–7 filiform staminodes; ovary stipitate, connate to the dorsal side of the calyx tube, with many uniseriate ovules, style with a small dark stigma. Fruit a stipitate pod, compressed, dehiscent with more or less leathery valves, with several seeds. Seed large, hard, without an aril, dark brown at maturity. Seedling with epigeal germination.

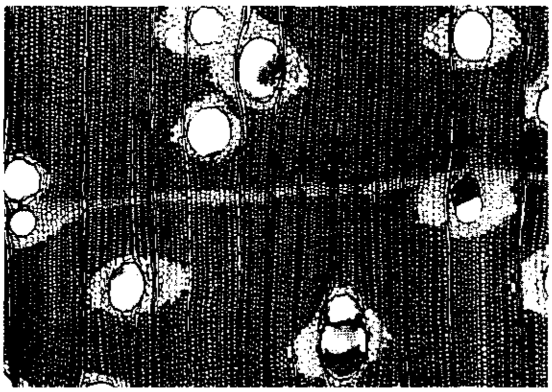
Wood anatomy

– Macroscopic characters:

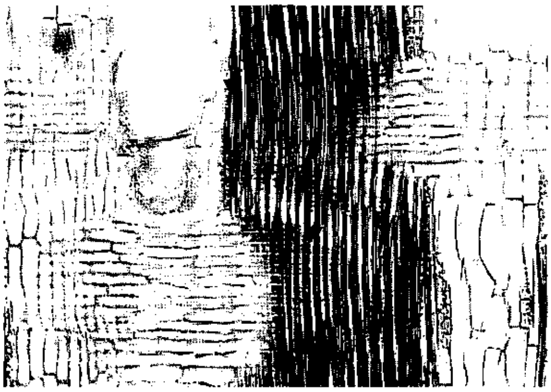
Heartwood light brown with some darker brown streaks, distinctly demarcated from the whitish to pale yellowish sapwood. Grain straight. Texture moderately coarse; wood more or less lustrous. Growth rings usually distinct, because generally vessels are less numerous in the outer part of a growth ring; vessels visible to the naked eye, in heartwood often filled with red-brown gum or yellow contents; aliform to confluent parenchyma distinct, rays only visible with a lens; ripple marks absent.

– Microscopic characters:

Growth ring boundaries marked by marginal parenchyma bands and/or differences in vessel frequency. Vessels diffuse, 2–3(–5)/mm^2, solitary and in radial multiples of 2–3(–5), usually completely surrounded by parenchyma, round to oval, mutually flattened in multiples, average tangential diameter 185–280 μm, of vessels in multiples 60–230 μm; perforations simple; intervessel pits alternate, distinctly vestured, usually polygonal, 6 μm, regularly with coalescent apertures; vessel-ray and vessel-parenchyma pits similar but less crowded and half-bordered. Fibres 560–790 μm



transverse section (×25)



radial section (×75)

tangential section (×75)

Intsia bijuga

long, non-septate, thick-walled, with simple pits confined to the radial walls. Axial parenchyma rather abundant, mainly paratracheal, but also marginal or seemingly marginal banded; paratracheal parenchyma lozenge- to winged-aliform, sometimes confluent surrounding 2–5 vessels, at the growth ring boundary lateral extensions forming long marginal bands 2–3 cells wide; parenchyma strands (2–)4-celled. Rays 5–8/mm, 1–3-seriate (often 2-seriate), up to 4–25 cells high, homocellular, entirely composed of procumbent cells, one row of marginal cells usually shorter in radial direction and higher longitudinally. Crystals prismatic, only in chambered axial parenchyma cells of both inner and outer sides of paratracheal and banded parenchyma. Deposits red-brown to sulphur-yellow, granular, often present in vessels; brown to yellow-brown contents often present in libriform fibres, axial and ray parenchyma cells. All elements non-storied.
Species studied: *I. bijuga*.

Growth and development Experiments showed that the cotyledons contribute to seedling development up to the stage of the first pair of leaves. Initial growth of the seedling is fast; seedlings reach an average height of 40–55 cm after 3 months. Then growth will slow down, and in the period from 3–10 months after germination it averages only 5–6 cm. Merbau seedlings need a high light intensity for optimal growth, and in the open growth is much faster than under closed canopy conditions. However, experiments in Indonesia showed that growth of seedlings under shelter or under shade trees was faster than in full sunlight. At Bogor, Indonesia, an 8-year-old stand of *I. bijuga* had an average height of 10.7 m and an average diameter of 15 cm. The maximum diameter which may be reached in 40 years is 43 cm for *I. palembanica*.

Other botanical information The genus *Intsia* is closely related to *Afzelia* (formerly called *Pahudia*). It is impossible to assign sterile material to either genus. *Intsia* differs from *Afzelia* by its three fertile stamens, its flat seeds lacking an aril, and its leathery pods. The differences between the South-East Asian species are small.

Ecology *I. bijuga* occurs most frequently in coastal areas, often in a zone behind the mangrove and is, therefore, often treated as a member of the Indo-Pacific strand flora. *I. palembanica* is found inland up to 1000 m altitude. Merbau prefers a rainfall of more than 2000 mm a year and grows in primary or old secondary forests on a wide variety of soils but usually not on peat. It is sometimes found growing gregariously, and occasionally dominantly. In New Guinea merbau is an especially common component of the lowland ridge flora in association with *Anisoptera* and *Hopea*.

Propagation and planting Merbau seeds are protected by a hard seed-coat which is impermeable to water. Mature seeds have a moisture content of less than 10% and hence can survive for more than 3 years without any specific treatment. Germination may take up to nearly 2 years. To promote rapid and simultaneous germination, scarification followed by soaking in water is necessary. The most effective scarification technique is to use a file to scrape off the small protrusion of the seed-coat (the strophiole) located at the opposite side of the hilum. Treatment with fungicides (e.g. benlate, daconil) may protect scarified seeds from damage by fungi. Immersion in concentrated sulphuric acid for one hour is also effective in rupturing the seed-coat. Seeds must be planted vertically with the hilum downward, so that the seed-coat is shed as the hypocotyl emerges from the soil. Seed may also be sown direct into the field. Almost 100% of scarified seeds of *I. palembanica* germinate after about 11 days, and the germination rate is the same in full sun and shade. Seeds of *I. bijuga* germinate better in full sun. Seedlings of *I. palembanica* grow best in soil mixed with 25% sand. Appropriate drainage and high air humidity are important. Seedlings can be transplanted into the field at about 3 months after sowing at a spacing of 3 m × 4 m or 5 m × 5 m.

Vegetative propagation of merbau by means of 60 cm long cuttings was tested in the Philippines. Six weeks after planting in a sandy clay-loam medium the mortality rate was 62%.

Silviculture and management Extensive stands of merbau occur in northern Papua New Guinea on sites destroyed by fire during natural droughts. The stands in the Gogol River valley were probably established after the 1918–1920 droughts. After logging, dormant seeds in the soil can germinate abundantly in gaps around the stumps. Merbau is apparently a successful secondary forest tree.

In Papua New Guinea a 50-year rotation for natural stands has been reported as suitable, but in Malaysia it has been estimated that a rotation of some 120 years would be required for merbau in plantations.

Diseases and pests The roots of seedlings of *I. bijuga* may be infected by nematodes; in the Philippines *Rotylenchulus* sp. and *Helicotylenchus* sp. have been found in nurseries. In Kalimantan young plantations suffered from grazing by deer and mouse deer, while rats are also considered a serious pest.

Harvesting Fresh logs sink in water and must be transported over land.

Yield Forest inventories in Peninsular Malaysia (1970–72 and 1981–82) showed that there is still sufficient merbau timber in the natural forests. Annual log production figures have been more or less stable from 1981–1991. The standing stock in Peninsular Malaysia is estimated at 2.8 trees/ha (gross volume 11.7 m^3/ha) over 15 cm diameter and 1.9 trees/ha (gross volume 10.8 m^3/ha) over 45 cm diameter. The yield is still good enough to make merbau one of the most important export timbers of Peninsular Malaysia.

Genetic resources Merbau was proposed for inclusion in Appendix II of CITES in 1992. It includes species which, although not necessarily threatened with extinction now, may become so unless trade in specimens of such species is strictly regulated in order to avoid over-utilization. Export of products from these species requires an export permit. Stands of merbau have been exploited for many years, because it is a popular hardwood for both domestic and international markets, and the *Intsia* species are considered to merit conservation. Malaysia successfully objected to the inclusion of merbau in CITES Appendix II based on the forest inventories and log production figures of Peninsular Malaysia, which apparently show no sign of stands being threatened. However, merbau seems to be seriously threatened with extinction in several areas outside Peninsular Malaysia, e.g. in parts of Borneo, the Philippines and Thailand.

Prospects The prospects for merbau seem to depend on whether the exploitation of the remaining stands is properly controlled. It is evident that cutting cycles should be long for these rather slow-growing trees; at least 60 years, though 80 years is probably more realistic. This means that a decrease in the amount of timber harvested is necessary in most areas. Nevertheless, supplies of merbau may be fair in the future, as merbau usually regenerates well in logged-over areas, and enrichment planting with nursery-raised seedlings seems promising. This very good and useful timber justifies more research and effort to ensure better and more sustainable management of natural stands.

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Selection of species

Intsia acuminata Merr.

Philipp. Govt. Lab. Bur. Bull. 17: 20 (1904).

Vernacular names The Philippines: malaipil (Pilipino).

Distribution The Philippines and possibly in Irian Jaya.

Uses The timber is used as merbau and is especially suitable for high-quality furniture.

Observations A small to medium-sized tree up to 25 m tall, bole up to 100 cm in diameter; leaves with 3–5 pairs of leaflets, leaflets leathery, usually less than 8 cm long and bluntly acuminate; flowers white or pink. *I. acuminata* occurs in forests near the seashore.

Selected sources 175, 750.

Intsia bijuga (Colebr.) O. Kuntze

Revis. gen. pl. 1: 192 (1891).

Synonyms *Intsia amboinensis* DC. (1826), *Afzelia bijuga* (Colebr.) A. Gray (1854), *Intsia retusa* (Kurz) O. Kuntze (1891).

Vernacular names Indonesia: merbau asam (Kalimantan), ipi (Lesser Sunda Islands). Malaysia: merbau ipil (Sarawak, Sabah), kayu besi (Peninsular). Papua New Guinea: kwila, pas. Philippines: ipil, ipil laut (Pilipino). Cambodia: krâkâs prêk. Thailand: lumpho-thale (Surat Thani), pradu-thale (central). Vietnam: g[ox] n[uw][ows]c (general), b[aaf]n [oo]i (southern).

Distribution From Tanzania and Madagascar through southern India and Burma, towards Malesia, northern Australia and Polynesia.

Uses *I. bijuga* is an important source of merbau timber. Bark and leaves are used medicinally and the seeds can be eaten after careful preparation.

Observations A medium-sized to large tree up to 50 m tall, bole branchless for up to 20 m and up to 160(–250) cm in diameter; leaves with 2(–3) pairs of leaflets, leaflets thinly leathery with an acute to cuneate base and an acute to emarginate apex, 3.5–11 cm × 1.5–8 cm; flowers white or pink. *I. bijuga* occurs most frequently in coastal forests and along tidal rivers but is also found inland up to 600 m altitude. The density of the wood is 630–1040 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 35, 67, 89, 97, 100, 102, 113, 151, 175, 184, 235, 316, 318, 362, 395, 408, 462, 477, 579, 626, 725, 750, 799.

Intsia palembanica Miq.

Fl. Ind. Bat., Suppl. 1 (Prodr. Fl. Sum.): 289 (1861).

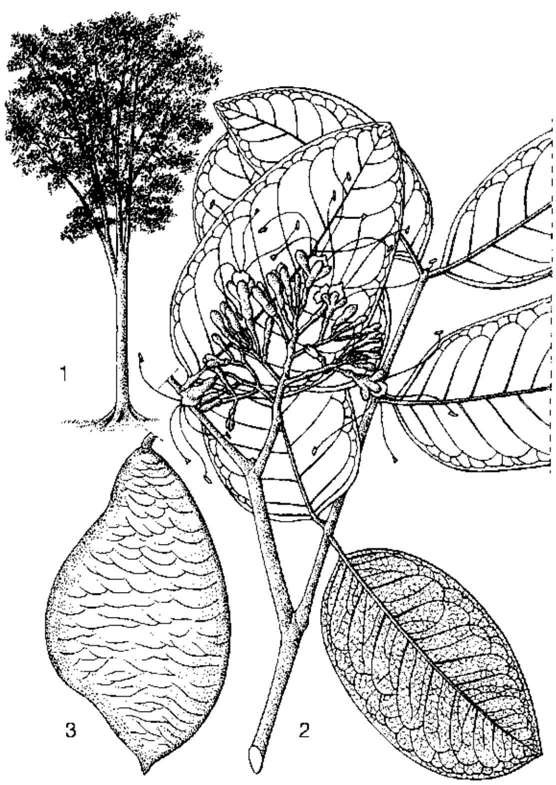
Synonyms *Afzelia palembanica* (Miq.) Baker (1879), *Intsia bakeri* (Prain) Prain (1901), *Intsia plurijuga* Harms (1917).

Vernacular names Indonesia: ipi, ipil (general), maharan (Kalimantan). Malaysia: anglai, alai (Peninsular). Papua New Guinea: kwila. Philippines: ipil (general). Thailand: lumpho, mue-ba (peninsular), salumpho (south-eastern).

Distribution Southern Burma, Thailand, Peninsular Malaysia, Sumatra, Borneo, Palawan, Sulawesi, the Moluccas and western New Guinea.

Uses *I. palembanica* is the main source of merbau timber. Young seeds are sometimes eaten. A dye is obtained from the bark and wood. Bark and leaves are used medicinally.

Observations A medium-sized or large tree up to 50 m tall, bole branchless for up to 22 m and up



Intsia palembanica Miq. – 1, tree habit; 2, flowering twig; 3, fruit.

to 150 cm in diameter; leaves with (3–)4(–7) pairs of leaflets, leaflets thickly leathery and glossy with a rounded or broadly cuneate base and a blunt to emarginate apex, 8–13.5 cm × 4–10.5 cm; flowers pale yellowish. *I. palembanica* often occurs near the coast but is found inland more frequently than *I. bijuga*, up to 1000 m altitude. The density of the wood is 500–1000 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 70, 71, 89, 100, 102, 153, 184, 318, 320, 395, 417, 448, 462, 477, 514, 601, 603, 626, 725, 750, 799.

R.J. Johns (general part),
P.B. Laming (properties),
R.W. den Outer (wood anatomy),
M.S.M. Sosef (selection of species)

Koompassia Maingay ex Benth.

Hooker's Icon. pl.: t. 1164 (1873).
LEGUMINOSAE
x = unknown

Trade groups
- Kempas: medium-heavy timber, *Koompassia malaccensis* Maingay ex Benth.
- Tualang: medium-heavy timber, *K. excelsa* (Becc.) Taubert.

Vernacular names
- Kempas. Brunei: impas. Indonesia: (m)engris (Aceh, Bangka, Belitung, Kalimantan), (h)ampas (Sumatra, Kalimantan), keranji (Sumatra). Malaysia: impas (Sabah, Sarawak), mengris (Peninsular, Sarawak), makupa (Peninsular). Thailand: thongbung (Phuket), makupa (Malay, Narathiwat), sifai (Patthalung).
- Tualang. Brunei: mangaris. Indonesia: mangaris (Kalimantan), sialang (Sumatra). Malaysia: sialang (Peninsular), kayu raja (Sabah, Sarawak, Peninsular), tapang, kussi (Sarawak), mengaris (Sabah). Philippines: manggis (Sulu, Tagbanua), ginoo (Palawan). Thailand: yuan, tolae (Yala, Pattani).

Origin and geographic distribution *Koompassia* consists of 3 species, 2 of which are distributed over southern Thailand, Peninsular Malaysia, Sumatra, Borneo and Palawan. The third (*K. grandiflora*) occurs in the western part of New Guinea (Irian Jaya).
Fossil wood resembling that of *K. malaccensis* has been described from the Tertiary of West Bengal, indicating a formerly more widespread or different distribution of the species or its ancestors.

Uses *Koompassia* timber is suitable for structural usage. For outdoor usage the timber should be treated with appropriate wood preservatives. Treated kempas is suitable for all heavy construction purposes such as railway sleepers, telegraph and transmission posts, beams, joists, rafters, piling, heavy duty columns, fender supports, pallets, door and window frames and sills, tool handles and marine constructions. When not treated it can be used for structural purposes under cover such as parquet and strip flooring (especially when resistance to acids and chemicals is needed), panelling, vehicle bodies and heavy duty furniture.
Tualang timber is used for the same purposes as kempas but it is less useful in severe conditions because it is moderately durable and it is difficult to apply preservatives.
Kempas wood produces charcoal of high quality.
Tualang is used for firewood, although the pres-

ence of tall buttresses in large trees (thus hindering felling) and its hardness make it unpopular. The bark of tualang is used traditionally among Malays to prepare a medicinal bath against fever. Large branches often bear masses of honeycombs containing honey produced by wild bees (*Apis cerana*). Villagers value tualang trees as sources of honey, which accounts for their objection to the felling of these trees.

Production and international trade Average annual log production of kempas and tualang for Peninsular Malaysia for the period 1982–1987 was 571 000 m^3 and 77 000 m^3, respectively. In that period the average price for logs was US\$ 68/m^3 for kempas and US\$ 45/m^3 for tualang. The average annual export of sawn timber in Peninsular Malaysia over the same period was 126 000 m^3 (average price US\$ 108/m^3) for kempas and 34 000 m^3 (average price US\$ 86/m^3) for tualang. The export of sawn timber of kempas from Peninsular Malaysia in 1990 was 114 000 m^3 (with a value of US\$ 14.6 million) and that of tualang 71 000 m^3 (with a value of US\$ 8 million), and in 1992 the export amounted to 49 000 m^3 (with a value of US\$ 9.2 million) for kempas and 71 000 m^3 (with a value of US\$ 9.5 million) for tualang. Major export destinations are eastern Asia, Europe, North America and western Asia.

Production and export figures from other regions are not available, except for Sabah: export of round logs of tualang in 1987 was 4000 m^3 with a value of US\$ 260 000; in 1992 the export of kempas was 29 000 m^3 of logs and 23 000 m^3 of sawn timber (with a total value of US\$ 6.3 million), and of tualang 70 000 m^3 of logs and 69 000 m^3 of sawn timber (with a total value of US\$ 16.9 million). Kempas and tualang probably are much less important for timber production elsewhere, as the trees are protected in several areas. At this moment there are no reports of the species being grown in plantations except for 9 ha of kempas and 1.6 ha of tualang at the Forest Research Institute Malaysia (FRIM).

Properties Kempas is a medium-weight hardwood. The heartwood is orange-red or red-brown, darkening on exposure, with numerous yellow-brown streaks, clearly defined from the very pale brown or pale yellowish sapwood. The density is (670–)770–1150(–1290) kg/m^3 (averaging 880 kg/m^3) at 15% moisture content. The grain is interlocked, sometimes wavy, texture coarse but even.

At 15% moisture content the modulus of rupture is 122–133 N/mm^2, modulus of elasticity 18 100–20 900 N/mm^2, compression parallel to grain 66–73 N/mm^2, compression perpendicular to grain 7.5 N/mm^2, shear 8–14 N/mm^2, cleavage 54–60 N/mm radial and 62–67 N/mm tangential, Janka side hardness 6000–7630 N and Janka end hardness 7700–8500 N.

Kempas timber needs 2–6 months to achieve air dry moisture content in Malaysia (18.1%) in air seasoning. Radial and tangential shrinkage from green to air dry averages 2.0% and 3.0%, respectively. It takes about 8 days to kiln dry 25 mm thick boards from about 50% to 10% moisture content. Kiln schedule E is used in Malaysia. Apart from springing and splitting of boards containing included phloem, the timber is free from defects in drying.

Kempas is somewhat difficult to machine and turn due to the interlocked grain and fibrous texture. The silica content is about 0.1%. Blunting of sawteeth is moderate to severe. When planing, the cutting angle should be reduced to 20° to avoid tearing. The wood can be satisfactorily stained and polished. Pre-boring is advisable before nailing. Good veneer of 1.5 mm thick can be made at a peeling angle of 92° without pretreatment. Wood without included phloem is suitable for plywood that meets the standards of Indonesia, Germany and Japan.

The heartwood of kempas is durable in temperate climates, but in tropical climates it is moderately durable. Graveyard tests in Indonesia showed an average service life in contact with the ground of 2 years. Treatment with preservatives is easy. Using the open tank method and an equal mixture of creosote and diesel, kempas can absorb 160 kg/m^3 on average. Using copper-chromium-arsenic preservatives, kempas can easily be treated to more than 16 kg/m^3 dry-salt retention. The sapwood is liable to attack by powder-post beetles and fungi. The heartwood is readily destroyed by termites. Kempas has shown a large and unexplained variability in natural resistance to marine borer attack.

Tualang is also a medium-weight hardwood. The heartwood is reddish-brown darkening to dark brown on exposure and distinctly demarcated from the greyish-white sapwood. The density is (570–)800–900(–1120) kg/m^3 at 15% moisture content. The grain is interlocked, texture moderately coarse to coarse and even.

At 15% moisture content the modulus of rupture is 121 N/mm^2, modulus of elasticity 17 800 N/mm^2, compression parallel to grain 62 N/mm^2, compression perpendicular to grain 8 N/mm^2, shear 16

N/mm^2, cleavage 57 N/mm radial and 59 N/mm tangential, Janka side hardness 7230 N and Janka end hardness 8900 N.

Usually tualang dries well, but the wood may split along included phloem. The shrinkage from green to air dry is 1.5% radial and 1.7% tangential. Tualang is easy to turn and plane to a moderately smooth finish. Nailing is easy but boring slightly difficult. The wood is seldom used for veneer and plywood.

The heartwood of tualang is moderately durable in contact with the ground, having an expected lifespan of 3–4 years under tropical conditions. Tualang is classified as moderately easy to treat with preservative. Using the open tank method, it absorbs about 130 kg/m^3 of an equal mixture of creosote and diesel. The frequent presence of included phloem is a major defect when large sizes of timber are required, as is often the case with tualang.

The chemical composition of kempas and tualang wood has been investigated in Malaysia. Kempas wood contains 76% holocellulose, 54% alphacellulose, 26% lignin, 4.2% alcohol-benzene solubles, 7.4% of 1% alkali solubles, 1.6% hot water solubles, 12% pentosans and 0.3% ash. Tests in Indonesia showed 47% cellulose, 29% lignin, 17% pentosan, 0.7% ash and 0.1% silica. The solubility is 3.1% in alcohol-benzene, 1.1% in cold water, 2.4% in hot water and 9.0% in a 1% NaOH solution. Tualang wood contains 66% holocellulose, 46% alphacellulose, 27% lignin, 2.0% alcohol-benzene solubles, 10.7% of 1% alkali solubles, 4.4% hot water solubles, 14% pentosans and 1.0% ash. The energy value of kempas wood is about 19 300 kJ/kg.

Description Very large deciduous trees, up to 85 m tall, bole columnar, unbranched for up to 30 m and up to 290 cm in diameter, with large, steep buttresses sometimes exceeding 4 m in height; outer bark thin, hard and brittle, inner bark normally less than 12.5 mm thick, hard, yellowish-brown or orange-fawn; crown made up of a few large branches. Leaves alternate, imparipinnate; leaflets 5–14(–17), more or less alternate, elliptical, more or less leathery, often with a blunt protruding apex, midrib sunken on the upper surface; stipules free, very small and early deciduous. Inflorescence an axillary or terminal panicle with many small flowers. Flowers bisexual, sessile or shortly pedicellate; calyx narrowly imbricate having 5 acute to acuminate and hairy sepals; petals 5, subequal, about as long as the sepals, glabrous, with an indistinct claw; stamens 5, alternating with the petals, anthers opening by 2 apical pores, usually followed by 2 basal pores; ovary sessile, with a single ovule, style and stigma very short and small. Fruit a flat, more or less elliptical pod, twisted 180° near the base, surrounded by a broad, veined and brittle wing, 1-seeded. Seed flat. Seedling with epigeal germination, phanerocotylar; first 2 leaves opposite, next leaves arranged spirally.

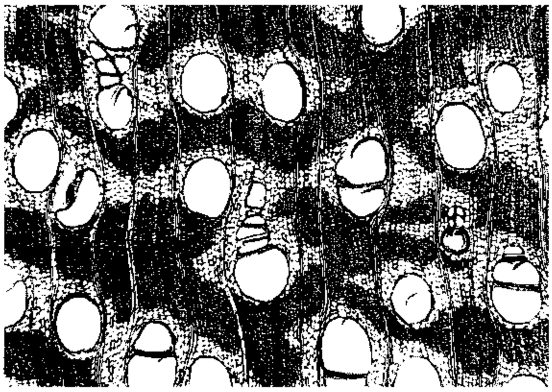
Wood anatomy

– Macroscopic characters:

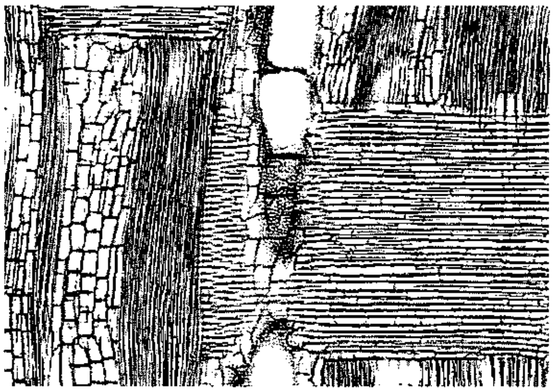
Heartwood reddish-brown, distinctly demarcated from the very light brown (almost whitish) to light yellowish-brown sapwood. Grain interlocked. Texture coarse to very coarse. The outer part of the mature stem with wide distinct concentric brown-coloured bands, if dried often with splits (not examined in *K. grandiflora*). Growth rings sometimes discernible; parenchyma bands visible to the naked eye.

– Microscopic characters:

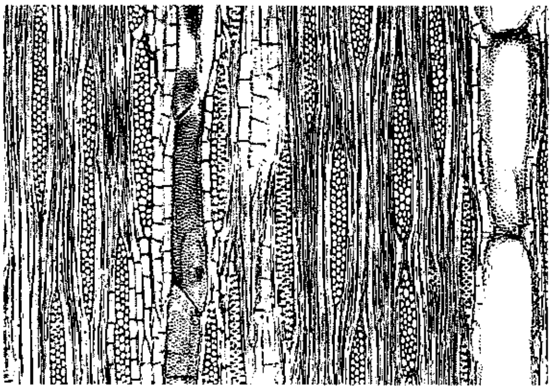
Growth rings, if present, marked by differences in wall thickness on either side of the ring boundary and/or by the periodic variation in the length of aliform and/or confluent parenchyma bands. Vessels diffuse, normally 1–6/mm^2, solitary and in radial multiples of 2–3 and rarely in clusters, usually 220–300(–360) μm in tangential diameter; perforations simple; intervessel pits alternate, non-vestured, 6–8 μm; vessel-ray and vessel-parenchyma pits almost similar to intervessel pits. Fibres 1.2–2.5 mm long, 3–4 μm wide, thick- to very thick-walled; pits small and minutely bordered, infrequent, confined to radial walls. Parenchyma vasicentric, winged-aliform, occasionally to short confluent (*K. malaccensis*) or confluent, more or less concentric and wavy, with periodical change in the band length (*K. excelsa, K. grandiflora*) and apotracheally diffuse-in-aggregates or in discontinuous lines, in 4–8-celled strands. Rays 7–11/mm, (1–)2–4(–5)-seriate, maximum height 600–800(–1100) μm, obscurely storied, homocellular and occasionally with one row of square marginal cells (Kribs type homogeneous to heterogeneous III). Included phloem in irregularly spaced concentric bands, usually present in the outer part of stem. Prismatic crystals numerous in axial parenchyma (more sporadic in *K. malaccensis*) and ray parenchyma cells (much more sporadic in *K. malaccensis*), in chambered cells, in long chains of up to 20 chambers; aliform and confluent parenchyma usually including the crystals in the cells of their outer layers. Druses rarely present in ray cells (*K. grandiflora*).



transverse section (×25)



radial section (×45)



tangential section (×45)

Koompassia malaccensis

Species studied: *K. excelsa, K. grandiflora, K. malaccensis.*

Growth and development Taproot and hypocotyl emerge laterally from the fruit. The germination period for kempas is 2–8 weeks, for tualang 1–3 weeks. A high percentage of germination has been observed. The growth of saplings of kempas is fairly rapid, 1.5 m in the first 2 years. Saplings of tualang grow well but not as quickly as those of kempas. Saplings are common on the floor of virgin forest but they may grow very slowly in the initial stages. Twenty 15-year-old saplings in a 17-year-old natural regrowth had reached an average height of only 1.85 m. The current annual diameter increment of kempas at the age of 17 years was recorded to be about 1.9 cm/year, but its growth decreased to about 0.9 cm/year from the age of 18–39 years. Kempas trees planted in Malaysia reached a maximum diameter of 64 cm at an age of 40 years, but tualang trees reached only 36 cm.
The lateral roots of kempas have been observed to run along rather than beneath the soil surface.
Koompassia trees shed all their leaves every year and remain leafless for a few days (kempas) or weeks (tualang). The flowers appear just after the new leaves, and the fruits ripen several months later. Kempas has been found flowering in Malaysia in the months May, July, August and September and bearing fruit throughout the year. Tualang flowers in May and June and fruits in August and September. Tualang has been observed to flower at irregular intervals of 5–6 years. Natural dispersal of the fruits of *Koompassia* species is by wind; the fruit has a papery wing and the seed is flattened.

Other botanical information *Koompassia* is a well defined genus of forest trees of exceptional beauty. It has affinities to *Cassia* and *Dialium*. Sometimes a fourth species called *K. borneensis* is recognized. This species, bearing the vernacular name 'impas', is said to be slightly different from kempas. This has, however, never been confirmed by botanists and, moreover, the Latin name has never been validly published.

Ecology *Koompassia* is a tree of primary tropical rain forest below 650 m altitude. It is widespread and sometimes abundant, and is occasionally the dominant upper-storey tree. *K. malaccensis* is found on both dry land as well as in peat-swamp and freshwater swamp forest.

Propagation and planting Freshly-collected fruits are used for propagation in Malaysia. No pretreatment is applied except for the removal of the wing. The average weight of a kempas seed is

1.2 g. Seeds can be sown on a seed-bed or directly in a polyethylene bag. A mixture of topsoil, sand and sawdust is generally used as a seed-bed medium.

The seeds of kempas have a moisture content of 15%. *Koompassia* seeds are not protected by a hard seed-coat. In order to ensure a high germination rate, the seed should not be stored for a long period. When stored, seeds are susceptible to fungus infection and should therefore be treated with a fungicide. Storage at low humidity is advised.

Silviculture and management No specific information is available. In Malaysia kempas is categorized as a preferred species for regeneration while tualang is an acceptable species. Kempas seedlings grow well in regeneration plots with increased light treatment.

Diseases and pests So far no serious diseases or pests have been reported.

Harvesting Kempas is harvested similar to other timber species. The logs of tualang, however, are known to be brittle and frequently shatter on falling. In sawn timber processing, debarking of *Koompassia* is unnecessary. However, logs can easily be debarked by using a hammer.

Yield Kempas is probably the third most abundant tree species in Peninsular Malaysia. A valuation survey has shown that it comprises up to 3.7% of the total number of trees and 6.1% of the wood volume in a generally rich forest. In Borneo it is usually a solitary tree with an average density of 1.1 trees per ha. In a superior hill forest of Peninsular Malaysia the stocking with a diameter of 15 cm and more ranges from 2.1 m^3/ha to 6.1 m^3/ha for kempas and from 3.1 m^3/ha to 6.3 m^3/ha for tualang.

Genetic resources No special in situ or ex situ conservation action has been taken in Peninsular Malaysia except the establishment of a few virgin jungle reserves and big tree plots. In Borneo *Koompassia* species are locally protected (e.g. in Sarawak and East Kalimantan).

Prospects *Koompassia* timber is currently gaining importance due to the shortage of heavy hardwood timbers. Kempas is becoming a valuable and highly valued species in the wood processing industry. The timber is much in demand for railway sleepers. Research priorities should be given to breeding, management and silvicultural and conservation aspects of the species.

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Selection of species

Koompassia excelsa (Becc.) Taubert

Engl. & Prantl, Nat. Pflanzenfam. 3, 3: 156 (1892).

Synonyms *Koompassia parvifolia* Prain ex King (1897).

Distribution Southern Thailand, Peninsular Malaysia, north-eastern Sumatra, Borneo and Palawan.

Uses The timber is used as tualang. The wood is sometimes used as firewood. The bark is used medicinally.

Observations A very large tree up to 85 m tall with a buttressed columnar bole up to 25 m long and 100 cm in diameter but sometimes reaching 290 cm, bark quite smooth, hooped, shiny, purplish-grey, commonly tinged delicate fluorescent green, especially upwards, crown made up of many smaller sub-crowns; leaves with 7–12(–17) leaflets of 3–4.2 cm × 1–1.7 cm; flowers small, sepals and petals up to 3 mm long, ovary oblong, glabrous; pod 7.5–12.5 cm long. *K. excelsa* is a common but usually not very abundant species which in Peninsular Malaysia is strangely absent south of the line connecting Kuala Lumpur and Kuantan. It holds the record for the tallest recorded broadleaf rain forest tree and is the sixth tallest of all trees. Solitary trees standing alone in the open are encountered comparatively often because they are difficult to cut and because local people harvest honey from the many bee nests usually present in the crown. See also the table on wood properties.

Selected sources 42, 45, 46, 73, 89, 100, 102, 146, 159, 183, 185, 190, 200, 237, 239, 252, 297, 298, 359, 426, 428, 448, 506, 559, 578, 581, 601, 609, 614, 626, 779, 784, 806.

Koompassia grandiflora Kosterm.

Bull. Bot. Gard. Buitenzorg, ser. 3, 18: 443 (1950).

Distribution Irian Jaya.

Uses The timber may be used as kempas or tualang.

Observations A fairly large tree up to 37 m tall with large, tall buttresses and a bole up to 25 m long and up to 100 cm in diameter, bark rather smooth, grey-brown; leaves with 8–11 ovate-lanceolate leaflets of 3.5–10 cm × 1.5–3.5 cm; flowers comparatively large, sepals and petals c. 10 mm long, ovary ellipsoid, hairy at base; pod narrowly obovate, 9–12 cm long. *K. grandiflora* is fairly common in the lowland near Manokwari.

Selected sources 375.

Koompassia malaccensis Maingay ex Benth.

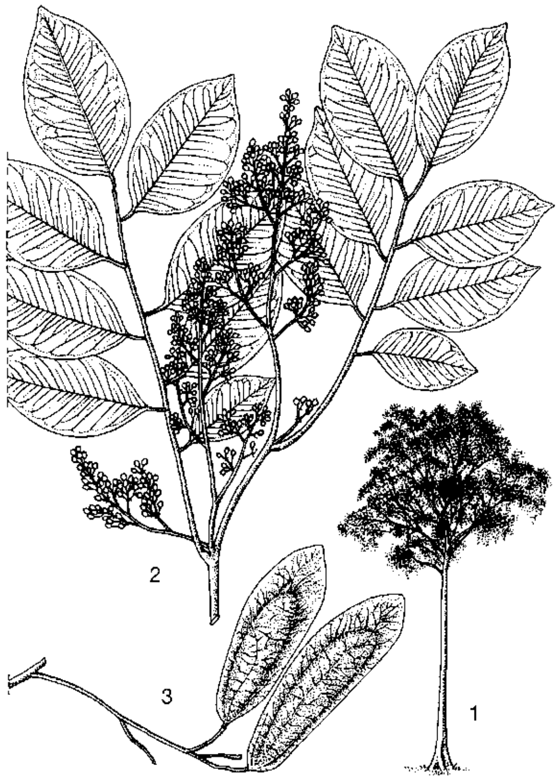
Hooker's Icon. pl.: t. 1164 (1873).

Synonyms *Koompassia beccariana* Taubert (1892).

Distribution Southern Thailand, Peninsular Malaysia, Sumatra, the Riau Archipelago, Bangka, Belitung and Borneo.

Uses The timber is used as kempas. The wood is sometimes used as firewood.

Observations A very large tree up to 60 m tall with columnar bole on average 60 cm in diameter but sometimes up to 210 cm, and large buttresses, bark very finely, irregularly, closely fissured, dark grey or blackish to reddish-brown, crown made up of large sub-crowns; leaves with 5–9(–14) leaflets of 5.5–12.5 cm × 2–4 cm; flowers small, sepals and petals up to 3 mm long, ovary compressed globular, hairy; pod 9.5–13 cm long. *K. malaccensis* is considered to be the third commonest big forest tree in Peninsular Malaysia and occurs from sea-level up to 600 m altitude. It is a frequently encountered tree in peat-swamp forests. See also the table on wood properties.



Koompassia malaccensis Maingay ex Benth. – 1, tree habit; 2, flowering twig; 3, fruits.

Selected sources 39, 42, 45, 46, 73, 74, 89, 100, 102, 135, 144, 146, 159, 183, 185, 190, 237, 239, 252, 297, 298, 359, 417, 426, 428, 448, 462, 506, 507, 518, 538, 562, 564, 578, 581, 601, 609, 611, 626, 779, 784, 806.

Wan Razali Wan Mohd. (general part, properties, selection of species),
S. Sudo (wood anatomy)

Lophopetalum Wight ex Arn.

Ann. Nat. Hist. 3: 150 (1839).

CELASTRACEAE

x = unknown; *L. wightianum*: $n = 20$

Trade groups Perupok: lightweight hardwood, e.g. *Lophopetalum javanicum* (Zoll.) Turcz., *L.*

multinervium Ridley, *L. subobovatum* King, *L. wightianum* Arn.

Vernacular names Perupok. Brunei: adau, dual. Indonesia: perupuk (general), medang kerupuk (Sumatra), pasana (Kalimantan). Malaysia: dual (Sabah). Philippines: abuab (Pilipino). Burma: taung-yemaré. Thailand: phuamphrao (Trang), dimi (Kanchanaburi), samet-thung (Nakhon Ratchasima). Vietnam: ba kh[is]a.

Origin and geographic distribution *Lophopetalum* at present comprises about 18 species and occurs in eastern Pakistan, western India, Indo-China, Thailand and throughout the Malesian area except for eastern Java and the Lesser Sunda Islands. The main centres of endemism of this genus are in Borneo and New Guinea, each with 3 endemic species. *L. javanicum* is the most widespread species; it occurs from Thailand towards New Guinea.

Uses The wood of perupok is often attractively figured. This, in combination with its very easy working qualities, makes perupok especially suitable for joinery and cabinet work as well as for decorative veneer. Furthermore the timber is suitable for light general construction, interior finishing, panelling and furniture manufacture as well as for bobbins, matchboxes and pencils. The odourless and tasteless wood is used for food containers and tea chests. The untreated timber is non-durable and should be applied under cover and not in contact with the ground. The timber is suitable for veneer and plywood production. A special application of perupok is for the manufacture of quality wooden mathematical instruments.

The bark of most species yields a strong poison, which is used locally as dart poison. The bark is also inflammable due to the presence of oil in a thin outer layer and is used as tinder.

Production and international trade Perupok has been generally used on a local scale and used not to be a very important export timber. It has gained importance, however, from the end of the 1980s, e.g. in Kalimantan.

Export figures from Peninsular Malaysia indicate that in 1983 3200 m^3 of sawlogs with a value of US$ 125 000 was exported to Singapore, and in 1984 2500 m^3 with a value of US$ 100 000. In 1987 logs with a volume of 13 500 m^3 and a value of US$ 940 000 (US$ 70/m^3) were exported from Sabah and in 1992 23 000 m^3 of logs and 27 000 m^3 of sawn timber with a total value of US$ 13 million. Sarawak exports a considerable amount of perupok. Perupok is very popular in Japan, and fetches very high prices. Indonesia exports perupok sawn timber to Japan but no export figures are available. In 1991 the price for sawn timber from Kalimantan was about US$ 1000/m^3 and US$ 1400/m^3 for mouldings.

Properties Perupok is a lightweight, soft to moderately hard wood. The heartwood is light yellow or light yellow-brown with a pinkish tinge when fresh. The sapwood is not clearly demarcated from the heartwood, but generally somewhat paler. The density is (300–)480–640(–690) kg/m^3 at 15% moisture content. The grain is fairly straight to interlocked, texture moderately fine and even. Planed surfaces are moderately lustrous, and the tangential surface shows a feathery pattern.

At 15% moisture content the modulus of rupture is 59–79 N/mm^2, modulus of elasticity (8000–) 8600–12 600 N/mm^2, compression parallel to grain 30–43 N/mm^2, compression perpendicular to grain 5–6 N/mm^2, shear 7–9 N/mm^2, cleavage c. 34 N/mm radial and 42 N/mm tangential, Janka side hardness c. 2930 N and Janka end hardness c. 4470 N.

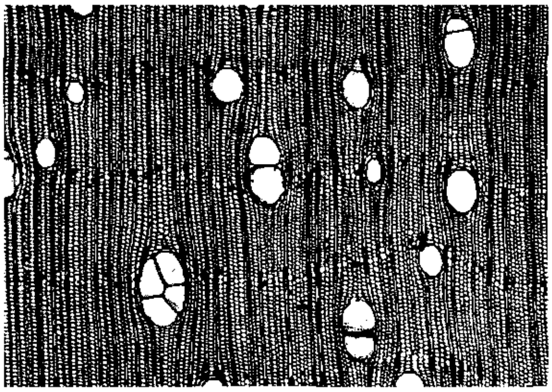
The rates of shrinkage are fairly low to moderate, from green to 15% moisture content 1.3–2.4% radial and 2.7–3.0% tangential, from green to oven dry up to 3.5% radial and 5.9% tangential. The timber air dries rapidly without serious degrade, except for slight cupping, surface and end checking and splitting. The wood is moderately liable to insect attack and blue stain during drying. Boards of 15 mm thick can be air dried in about 1 month, boards of 40 mm thick in 1.5 months. Kiln drying is satisfactory.

The wood is easy to saw, plain, bore and turn and gives a smooth finish, both in green and dry condition. The resistance to splitting when nailed is poor. The wood is easy to rotary peel into veneers of 1.5 mm thickness at a peeling angle of 91°. The veneer can be glued with urea-formaldehyde to produce good plywood. Perupok is not used for the manufacture of fibreboard or hardboard.

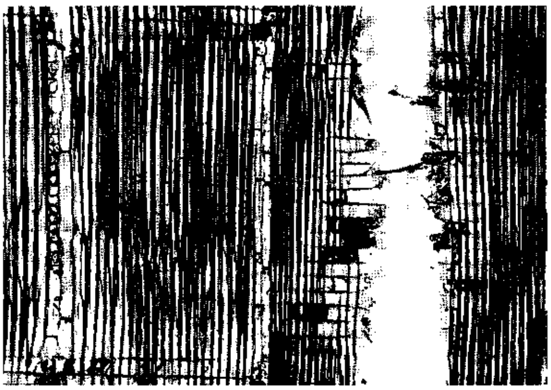
Perupok is rated as non-durable. Graveyard tests in Malaysia showed an average life of stakes in contact with the ground of 1–2 years. The heartwood is rather difficult to treat with preservatives. Using the open tank method and an equal mixture of creosote and diesel fuel, an average absorption of 61 kg/m^3 has been achieved in Malaysia. The sapwood is more amenable to preservative treatment. Treated perupok wood can be very durable.

Wood of *L. javanicum* contains 47% cellulose, 26% lignin, 19% pentosan, 1.4% ash and 0.1% silica. The solubility is 2.4% in alcohol-benzene, 1.7% in cold water, 3.4% in hot water and 16.5% in a 1% NaOH solution. The energy value is 19 240 kJ/kg. The bark of *L. javanicum* contains cardenolides (cardiac glycosides). At least 15 glycosides have been demonstrated to be present, e.g. several glycosides of strophanthidin and antiarigenin.

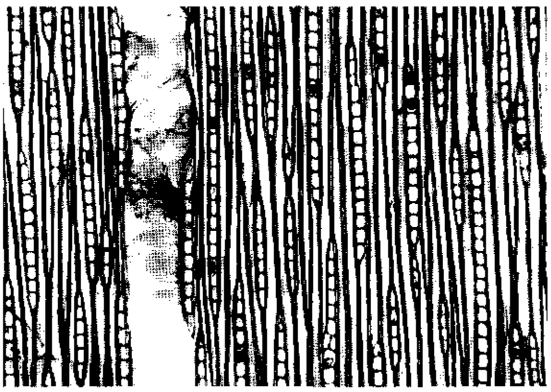
Description Small to fairly large (rarely very large), evergreen trees, up to 40(–62) m tall; bole usually straight, branchless for up to 30 m, and up to 70(–195) cm in diameter, fluted or with prominent buttresses up to 8 m high; outer bark surface usually smooth, hoop-marked to scaly and with large lenticels, pale grey-brown or chocolate brown and grey mottled, c. 10 mm thick, inner bark c. 6 mm thick, orange and yellow mottled to pink, sapwood white or sometimes yellow-brown; branchlets mostly dark, usually terete but flattened at the nodes. Leaves simple and entire, decussate or opposite, sometimes subopposite (occasionally a few leaves arranged spirally on the upper part of a branchlet), ovate to elliptical-oblong or lanceolate, rarely subpeltate; petiole distinct, sometimes very short; stipules consisting of a tuft of hair-like appendages, caducous. Inflorescence consisting of 1(–3) axillary, distinctly pedicellate to almost sessile thyrses; bracts deltoid or lanceolate, usually short-ciliate or fimbriate. Flowers bisexual, actinomorphic, 5-merous (except for the ovary), small and greenish; pedicel distinct, usually articulated at base; calyx saucer-shaped, lobes rounded or triangular, usually spreading, sometimes inflexed or reflexed; corolla with free and imbricate petals, inner surface usually partly covered with cristate, lamellate, or fimbriate appendages, rarely bearing a tuft of fleshy papillae at the central part (*L. beccarianum*), sometimes naked; disk usually fleshy and more or less flat, in bud usually slightly concave, sometimes thin and saucer-shaped, upper surface smooth or denticulate, rounded or distinctly 5-lobed or 5-angled; stamens inserted on the disk, usually between pistil and margin, sometimes quite near the margin, alternating with the petals, rarely each of them in a small pit (*L. pallidum*), filaments filiform, anthers dorso-centrally fixed, usually broadly ovoid or broadly ellipsoid, versatile; ovary superior but usually partly immersed in the disk, 3-celled, with 4–18 ovules in two rows in each cell on axile placentas, trigonal or pyramidal, gradually narrowed into a cylindrical, short style, with an obscure stigma. Fruit an oblong or slightly spindle-shaped, 3-lobed, 3-winged or 3-angular, dehiscing capsule. Seed oblong, flat, attached in the middle, winged all round, with little or no endosperm.



transverse section (×25)



radial section (×75)



tangential section (×75)

Lophopetalum javanicum

Seedling with epigeal germination; cotyledons sessile, flat but succulent; first two leaves opposite, next leaves subopposite or arranged spirally.

Wood anatomy

- Macroscopic characters:

Heartwood pale yellow or pale yellow-brown with a pinkish tinge when fresh, not distinctly demarcated from the generally somewhat paler sapwood. Grain fairly straight to interlocked. Texture fine to moderately fine and even; wood with a medium lustre and an attractive feathery figure on the tangential surface. Parenchyma distinct to the naked eye, in wide darker concentric bands, regularly spaced, forming a growth ring-like pattern with lighter fibre layers; vessels sometimes with white deposits.

- Microscopic characters:

Vessels diffuse, usually 5–12/mm^2, infrequently solitary, usually in radial multiples of 2–3, rarely in small clusters, 80–160 μm in tangential diameter; perforations simple; intervessel pits alternate, round, 2–3 μm; vessel-ray and vessel-parenchyma pits similar to intervessel pits but half-bordered; tyloses absent. Fibres in a more or less distinct radial alignment, 800–1200 μm long, very thin-walled (wall 1.5–2 μm thick), with small, more or less distinctly bordered pits confined to the radial walls. Parenchyma abundant, apotracheal, in regularly spaced concentric bands, (2–)4–5 cells wide. Rays 12–17/mm, homocellular (Kribs type homogeneous), uniseriate, rarely with biseriate portions. Crystals prismatic, generally in chambered axial parenchyma cells, often in chains of up to 25 chambers.

Species studied: *L. beccarianum, L. javanicum, L. torricellense* Loes.

Growth and development During germination, the hypocotyl and taproot emerge from the margin at the side of the seed. The hypocotyl elongates up to 2 cm, carrying the enclosed, sessile cotyledons above the soil level. The leaves of the leader shoot of saplings are generally alternate, whereas those of the branches are opposite. Branching is diffuse.

Generally, perupok flowers and fruits annually or even 2–3 times per year. The flowers, having a nectariferous disk, are insect-pollinated. The winged seeds are probably dispersed by wind.

Other botanical information The genus *Kokoona* is nowadays usually treated as different from *Lophopetalum*, although it is closely related. It differs in both floral and seed characteristics. *Lophopetalum* has imbricate petals, generally with appendages, and seeds with a wing all around, whereas *Kokoona* is characterized by contorted petals without appendages and seeds with a unilateral wing. The distinction is supported by characteristics of the wood anatomy. The wood of *Kokoona* was formerly traded together with *Lophopetalum* as perupok but is now traded separately as 'mata ulat'. It is generally heavier than perupok (density usually over 800 kg/m^3 at 15% moisture content). The genus *Lophopetalum* has been merged with *Solenospermum*. The latter has also been treated as a distinct subgenus within *Lophopetalum*.

Ecology Perupok occurs in a wide variety of primary lowland forest types. It grows on flat or undulating land, ridge tops, hillsides, near streams and in peat or freshwater swamps on both clay and sandy soils. It generally avoids areas with good drainage and is neither tolerant to sediment brought in by floods nor to salt water. Perupok is found from sea-level up to 1500(–2500) m altitude. In some swamp areas in eastern Kalimantan *L. multinervium* is dominant and occurs in association with *Cephalomappa* spp., *Eugenia* spp., *Litsea* spp., *Myristica* spp. and *Shorea* spp.

Propagation and planting Germination of perupok seeds has been reported to be fair and more or less simultaneous. Germination usually starts within 15 days after sowing, but may sometimes take more than a month.

Perupok can also be propagated by cuttings and wildlings. Growing wildlings in a nursery bed gave good results and properly treated cuttings showed a survival rate of 90%.

Silviculture and management Not much is known about appropriate management of natural perupok stands. From logged-over forest in East Kalimantan it is reported that 2 years after logging natural regeneration is abundant, in particular on rather open places. This may indicate that selective logging can be successfully practised. A diameter limit of 40 cm has been recommended in Indonesia.

Diseases and pests Perupok seedlings are often attacked by swamp crabs. Enrichment planting using seedlings 40 cm tall has been recommended to counterbalance possible attack.

Harvesting Logging of perupok trees is often not easy, because they usually grow in swampy areas. The problems encountered in harvesting are comparable to cutting ramin (*Gonystylus bancanus* (Miq.) Kurz). Woodslide tracks are often made to reach the trees to be felled, and logs must be hauled on wood sleds by manpower. Freshly unbarked perupok logs are very vulnerable to blue stain and should be quickly removed from the forest.

Yield In East Kalimantan a survey was made of primary and logged-over perupok forest. Of the about 400 trees of more than 10 cm diameter present in one ha of primary swamp forest along the Betayau river, 43% (with a volume of 141 m^3/ha) were identified as perupok. Perupok constituted 12.5% (with a volume of 22 m^3/ha) of the trees over 10 cm diameter in the same forest type but logged over 2 years before. However, in swamp forest along the Pimping river logged more than 2 years ago, 84% of the trees (with a volume of 340 m^3/ha) proved to be perupok. The yield can thus be very high locally.

Genetic resources and breeding Perupok timber is currently in great demand because it is considered as very decorative. The increasing efforts to meet the demand might easily result in genetic erosion, particularly of the species which are narrow endemics.
Selection of superior mother trees of *L. floribundum*, *L. javanicum* and *L. multinervium* has been carried out in East Kalimantan.

Prospects Being of increasing economic interest, perupok has good prospects but the exploitation of stands of perupok as practised now is seldom based on sustainable management. Much more research effort is needed, especially on growth, planting and yield on a sustainable basis, to ensure the availability of this timber in the future.

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Selection of species

Lophopetalum beccarianum Pierre

Fl. forest. Cochinch. 4: t. 307 (1894).

Synonyms *Lophopetalum scortechinii* King (1896), *Lophopetalum havilandii* Ridley (1931).

Vernacular names Brunei: kekan bukit. Indonesia: aras (Dusun, Kalimantan), bulalangabuk (Kujau, Kalimantan), dual bukit (Kedayan, Kalimantan). Malaysia: perupok (general), kapas, sisilao (Sarawak).

Distribution Peninsular Malaysia and Borneo (Sarawak, Sabah, Brunei and eastern Kalimantan).

Uses The timber is used as perupok.

Observations A small to fairly large tree up to 35 m tall, bole straight or sinuous, up to 55 cm in diameter, without buttresses, bark surface grey-brown, often hooped, smooth to slightly fissured, inner bark pale brown; leaves (7–)11–16(–30) cm long, with an obtuse or sometimes acute or acuminate apex, olivaceous above when dry; inflorescence up to 18 cm long; petals 1.2–2.5 mm long, naked or with hair-like appendages inside, disk saucer-shaped, 2–3 mm across, distinctly 5-lobed. *L. beccarianum* occurs in primary forest, often on crests of hills, on sandstone, sand, tuff or sometimes on clay, from the lowland up to 1800 m altitude.

Selected sources 33, 146, 183, 748, 779, 794.

Lophopetalum floribundum Wight

Ill. Ind. bot. 1: 178 (1840).

Vernacular names Malaysia: perupok, kongkor (Peninsular).

Distribution Burma and Peninsular Malaysia.

Uses The timber is used as perupok.

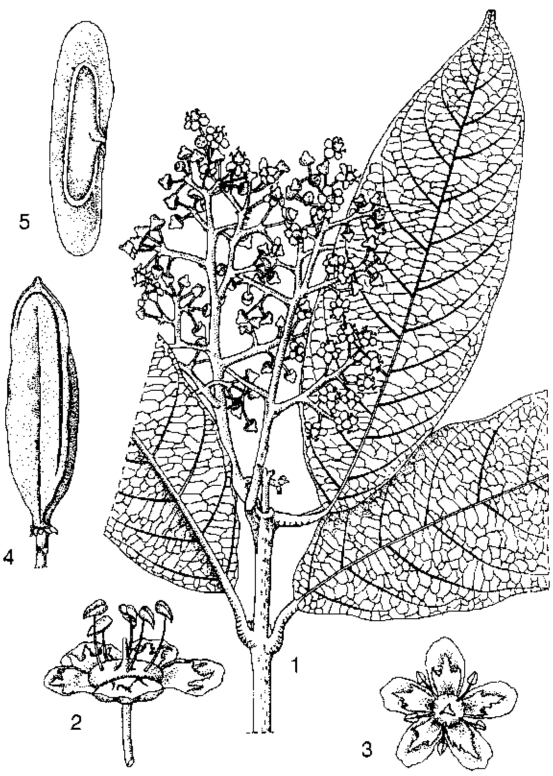
Observations A small to fairly large tree up to 36 m tall, bole up to 80 cm in diameter, not buttressed, bark surface smooth to cracking or dimpled, greenish-yellow, middle bark turmeric yellow, inner bark pink, sapwood white; leaves 7–10 cm long, acuminate, reddish-brown when dry; inflorescence up to 8 cm long; petals c. 3 mm long, naked, disk saucer-shaped, c. 2.5 mm across, 5-lobed. *L. floribundum* is widely distributed and locally common in lowland rain forest, up to 350 m altitude. See also the table on wood properties.

Selected sources 625, 748, 779, 794.

Lophopetalum javanicum (Zoll.) Turcz.

Bull. Soc. Nat. Hist. Mosc. 36: 598 (1863).

Synonyms *Lophopetalum fuscescens* Kurz (1875), *Lophopetalum oblongifolium* King (1896), *Lophopetalum toxicum* Loher (1897).



Lophopetalum javanicum (Zoll.) Turcz. – 1, flowering twig; 2, flower, side view; 3, flower, top view; 4, fruit; 5, seed.

Vernacular names Indonesia: madang-gambici (Batak, Sumatra), mandalaksa (Javanese, Java), tatokwa (Irian Jaya). Malaysia: perupok, kachang rimba (Peninsular), perupok dual (Sabah). Philippines: abuab (general), sampol (Bisaya), buyun (Sulu). Thailand: phuamphrao (Trang).

Distribution Thailand, Peninsular Malaysia, Sumatra, Java, Borneo, the Philippines, Sulawesi, the Moluccas and New Guinea. Probably most common on Borneo.

Uses The timber is used as perupok. The bark is a constituent of dart poison and is also used as tinder.

Observations A medium-sized to large tree up to 45 m tall, bole up to 100 cm in diameter, buttresses absent or small, bark surface smooth or rugose with surface cracks, grey or greenish, middle bark bright yellow, inner bark pink to red-brown, sapwood pale yellow; leaves 5.5–18 cm long, usually acute to short-acuminate at apex, usually with 5–8 pairs of secondary veins, brown to reddish when dry; inflorescence up to 19 cm long; petals 2–3 mm long, with a large, 3-lobed or dentate appendage, disk fleshy and thick, 2.5–3(–4) mm across, obscurely 5-angular or more or less rounded. *L. javanicum* is a fairly common species of lowland rain forest, and often grows in periodically inundated areas or peat swamps and on river banks; it is sometimes found at higher altitudes up to 1400 m. The density of the wood is 300–560 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 33, 35, 83, 100, 146, 175, 183, 372, 437, 462, 625, 721, 748, 759, 779, 794, 807.

Lophopetalum ledermannii (Loes.) Ding Hou

Fl. Malesiana, Ser. I, 6: 271 (1962).

Synonyms *Solenospermum ledermannii* Loes. (1936).

Vernacular names Indonesia: sidomoku (Moluccas), tengarenop, wajarora (Irian Jaya).

Distribution The Moluccas and New Guinea.

Uses The timber can be used as perupok.

Observations A small to medium-sized tree up to 26 m tall, bole up to 56 cm in diameter; leaves 5–10 cm long, with an acute or acuminate apex, opaque; inflorescence up to 9 cm long; petals 2–3 mm long, with small simple appendages, disk fleshy and papillose, rounded, c. 2 mm across. *L. ledermannii* grows in primary or rarely secondary forest up to 850 m altitude.

Selected sources 748.

Lophopetalum multinervium Ridley

Kew Bull.: 39 (1931).

Synonyms *Solenospermum aquatile* Ridley (1938).

Vernacular names Indonesia: perupuk talang (Palembang), pupu (Bengkalis), bako (Dayak, Kalimantan). Malaysia: tinjau tasek (general), perupok (Sabah).

Distribution Peninsular Malaysia, Sumatra, Bangka and Borneo; probably most common on Borneo.

Uses The timber is used as perupok.

Observations A medium-sized to large tree up to 45 m tall, bole straight, cylindrical, up to 90 cm in diameter, with buttresses up to 2 m high, often spreading out to 8 m from the base, typically with short columnar pneumatophores, bark surface smooth, becoming shallowly cracked and thinly flaky, lenticellate, pale grey-brown, inner bark pink-brown mottled, sapwood pale yellow; leaves 10–18(–23) cm long, acuminate, with 10–15 pairs of secondary veins, brown to reddish when dry; inflorescence up to 12 cm long; petals 2.5–3 mm long, with a conspicuous, lobed and broad-based appendage at the inner surface, disk fleshy and flat, c. 3 mm in diameter, obscurely 5-angular. *L. multinervium* is common and locally frequent in lowland peat-swamp and inundated forest, generally at low altitudes but sometimes up to 1500 m.

Selected sources 33, 100, 146, 748, 779, 794, 807.

Lophopetalum pachyphyllum King

Journ. As. Soc. Beng. 65(2): 348 (1896).

Vernacular names Malaysia: terupuk, perupok (Peninsular).

Distribution Peninsular Malaysia and Sumatra.

Uses The timber is used as perupok.

Observations A small to fairly large tree up to 36 m tall, bole up to 40 cm in diameter, bark surface smooth and becoming shallowly cracked, pale grey, middle bark white; leaves 11–20 cm long, with an acute to short acuminate apex, densely covered with papillae beneath; inflorescence up to 21 cm long; petals c. 6 mm long, with a small appendage at the base inside, disk orbicular, 7–9.5 mm across, obscurely 5-lobed. *L. pachyphyllum* grows in dryland forest, on slopes, ridges and limestone cliffs, up to 450 m altitude.

Selected sources 513, 748, 779, 794, 807.

Lophopetalum pallidum M. Lawson

Hook.f., Fl. Brit. India 1: 615 (1875).

Synonyms *Lophopetalum curtisii* King (1896), *Solenospermum pallidum* (M. Lawson) Loes. (1936).

Vernacular names Indonesia: dorojolang (Kalimantan). Malaysia: kerueh (general), kelempait (Peninsular), keroi (Sarawak).

Distribution Peninsular Malaysia, southern Sumatra and Borneo.

Uses The timber is used as perupok. The bark is a source of dart poison.

Observations A medium-sized to large tree up to 53 m tall, bole up to 90 cm in diameter, sometimes with tall and steep buttresses, bark surface grey or grey-brown, distantly shallowly fissured, middle bark pale, inner bark orange-brown; leaves 7–12 cm long, acute to short-acuminate at apex, ash-grey or blue-grey when dry; inflorescence 3–7 cm long; petals 2.5–3 mm long, with fleshy, lobed appendages in the centre inside, disk saucer-shaped, 3–4 mm across, 5-angular, with fleshy subulate appendages around the base of the filaments. *L. pallidum* occurs in dryland primary rain forest, often on hillsides or ridge tops or in sandy country, up to 300 m altitude.

Selected sources 33, 748, 779, 794, 807.

Lophopetalum rigidum Ridley

Kew Bull.: 38 (1931).

Synonyms *Lophopetalum subsessile* Ridley (1931).

Vernacular names Indonesia: galagah, parupuk, kerupok (Kalimantan).

Distribution Northern half of Borneo.

Uses The timber is used as perupok.

Observations A small to medium-sized tree up to 30 m tall, bole up to 40 cm in diameter, not buttressed, bark surface smooth, with vertical lines of small lenticels, grey-brown, inner bark pale purplish-brown, sapwood yellow-brown; leaves 4.5–12.5 cm long, with an acuminate apex; inflorescence up to 10 cm long; petals 1–2.5 mm long, naked inside but with a few papilla-like appendages outside, disk flat, 1.5–3.5 mm across, suborbicular or obscurely 5-angular. *L. rigidum* is locally frequent in heath forest and freshwater swamp forest, but it also occurs frequently in pole forest on ridges up to 2400 m altitude.

Selected sources 33, 100, 748.

Lophopetalum subobovatum King

Journ. As. Soc. Beng. 65(2): 349 (1896).

Synonyms *Solenospermum apiculatum* Ridley (1938).

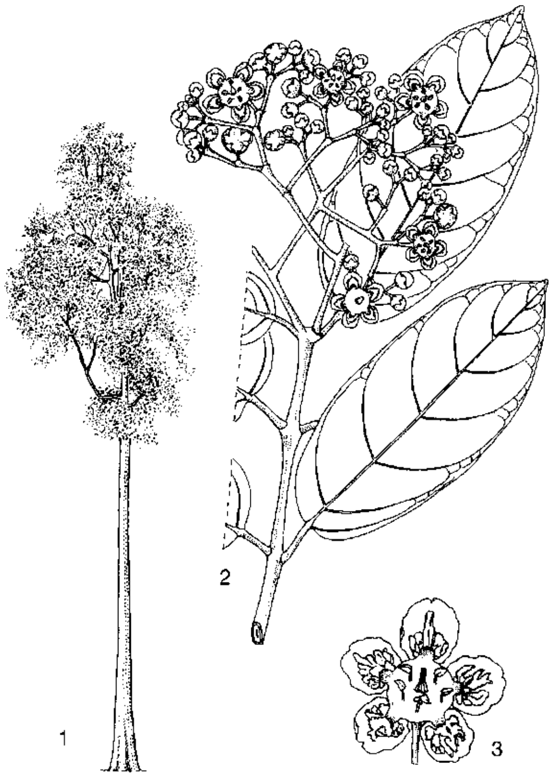
Vernacular names Brunei: duol, dual. Indonesia: kadjo (Dayak, Kalimantan). Malaysia: perupok (general), kungkur, paropo (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as perupok.

Observations A medium-sized to fairly large tree up to 40 m tall, bole up to 80 cm in diameter, with low and thick buttresses, bark surface at first smooth, becoming irregularly shallowly shortly cracked and coming away as crumbly scales, greyish to pale brown or ochreous, sometimes dark brown, middle bark deep orange-yellow, inner bark pink-brown; leaves 4.5–13 cm long, subobovate, apex obtuse and apiculate, above dark grey to black and below chocolate brown when dry; inflorescence up to 10 cm long; petals 3–3.5 mm long, with small simple appendages in the upper half, disk fleshy, c. 3 mm across, slightly angular. *L. subobovatum* occurs in lowland rain forest, on leached clay-rich soils on periodically flooded alluvium, undulating land or ridges up to 400(–700) m altitude. See also the table on wood properties.

Selected sources 33, 100, 146, 748, 779, 794, 807.



Lophopetalum wightianum Arn. – 1, tree habit; 2, flowering twig; 3, flower.

Lophopetalum wightianum Arn.

Ann. Nat. Hist. 3: 151 (1839).

Synonyms *Lophopetalum fimbriatum* Wight (1840), *Lophopetalum winkleri* Loes. (1936).

Vernacular names Brunei: nasi-nasi. Indonesia: bau langit (eastern Sumatra), terupuk talang (Malay, Sumatra), perupuk unung (Malay, Kalimantan). Malaysia: keruie (Lakai, Peninsular), medang assam (Peninsular). Thailand: deemee (Kanchanaburi), samet-thung (Nakhon Ratchasima). Vietnam: ba kh[is]a.

Distribution Eastern Pakistan, western India, Burma, Indo-China, Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as perupok.

Observations A medium-sized or large tree up to 50(–62) m tall, bole straight, up to 65(–195) cm in diameter, sometimes with large and thick buttresses, bark surface coarsely fissured, brown or dark grey, middle bark white, inner bark often dull purplish-brown; leaves 8–25 cm long, usually subpeltate, acute or acuminate at apex, drying grey above; inflorescence up to 12 cm long; petals 3–4 mm long, with distinctly cristate, lamellate or rarely fimbriate appendages, disk flat or saucer-shaped, c. 5 mm across, distinctly 5-lobed to almost orbicular. *L. wightianum* grows in everwet lowland forest, riverine forest, temporarily inundated forest or sometimes near the shore just above the high-water mark, but also on sandy dryland and coral limestone; in India ascending to 900 m altitude.

Selected sources 100, 146, 625, 748, 779, 794, 807.

J. Kartasubrata (general part),
R.H.M.J. Lemmens (properties),
S. Sudo (wood anatomy),
M.H.A. Hoffman (selection of species)

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

Syst. nat. 2: 773, 799 (1791).
SAPOTACEAE
x = unknown
Trade groups
- Nyatoh: lightweight to medium-heavy hardwood, e.g. *Madhuca burckiana* (Koord.) H.J. Lam, *M. malaccensis* (C.B. Clarke) H.J. Lam, *M. motleyana* (de Vriese) J.F. Macbr., *M. sericea* (Miq.) H.J. Lam.
- Bitis: heavy hardwood, e.g. *M. betis* (Blanco) J.F. Macbr., *M. utilis* (Ridley) H.J. Lam ex K. Heyne.

Vernacular names
- Nyatoh: padang (En). Indonesia: nyatuh. Philippines: nato.
- Bitis. Malaysia: nyatoh batu (Sabah, Sarawak). Philippines: betis. Burma: meze kamzaw. Thailand: masang.

Origin and geographic distribution *Madhuca* (including *Ganua*), comprising about 100 species, has a western Malesian centre of diversity. Borneo and Peninsular Malaysia are particularly rich in species, about 40 and 30 respectively. The genus is distributed from India, Sri Lanka and south-eastern China to New Guinea, and has about 5 species in eastern Indonesia and Papua New Guinea and about 10 in the Philippines. Widely distributed species include *M. burckiana* (the Philippines to New Guinea), *M. malaccensis* (Thailand to Borneo) and *M. utilis* (Peninsular Malaysia, Sumatra and Borneo).

Uses Nyatoh is used for house building, but it rots rather quickly in contact with the ground. It is in demand for the manufacture of fine-grained furniture, decorative doors, veneers, and for panelling and partitioning. Other uses include strip and parquet flooring, ceilings, boat decking, rotary and sliced veneers used for plywood, and pallets.

Bitis may be used for heavy construction work, e.g. for wharf, bridge and ship building, and for posts, foundation sills, sleepers, paving blocks and tool handles. In the Philippines it is considered an excellent wood for purposes requiring great strength and durability. Bitis is not suited for furniture, interior finishing and veneer, as it is difficult to work, often displaying considerable shrinkage and lack of figure.

The latex from several species gives a gutta-percha of inferior quality, which is sometimes used as an adulterant for the good-quality gutta-percha from *Palaquium gutta* (Hook.f.) Baillon and *Payena leerii* (Teijsm. & Binnend.) Kurz.

The seeds of *M. betis* yield an oil which is used for illuminating, but which is not used as extensively as the oil from the Indian *M. longifolia* (J. Koenig) J.F. Macbr. The oil from the latter species is also used in food, and for making soap and candles. Oil from the seeds of *M. motleyana* may also be used for cooking, e.g. in Malaysia.

The fruits of *M. obovatifolia* are edible. Bark, leaves and latex of *M. betis* are said to be used medicinally in the Philippines.

Production and international trade The lighter types of timber from *Madhuca* species are not traded separately. They are generally obtainable in very limited quantities and mixed with the timber from other *Sapotaceae* genera such as *Palaquium, Payena* and *Pouteria,* and sold collectively as nyatoh or mixed light hardwood.

Exports of nyatoh sawn timber from Peninsular Malaysia decreased from 16 500 m^3 (with a value of US$ 2.1 million) in 1981 to 9500 m^3 (with a value of US$ 1.3 million) in 1986. From 1986 onward the export increased to 32 500 m^3 with a value of US$ 6.1 million in 1990, but in 1992 it amounted only 8000 m^3 with a value of US$ 2.8 million. Large amounts of nyatoh are also exported from Sarawak and Sabah; the export of round logs from Sabah was 65 000 m^3 (worth US$ 6.3 million) in 1987, and in 1992 the export of logs was 14 000 m^3 and of sawn timber 8500 m^3 with a total value of US$ 4.4 million. In Papua New Guinea nyatoh is ranked in MEP (Minimum Export Price) group 1, and fetched a minimum export price of US$ 100/m^3 for saw logs in 1992.

Together with *Palaquium ridleyi* King & Gamble and *P. stellatum* King & Gamble, *Madhuca utilis* and *M. betis* are the main bitis-producing species. However, this timber is only obtainable in small quantities and is used domestically.

Properties *Madhuca* timber, with its density diverging from 420–1150 kg/m^3 at 15% moisture content, is classified amongst the lightest to heaviest nyatoh timbers or as bitis timber. The limit between nyatoh and bitis is often considered to be 850 kg/m^3, but in some regions (e.g. East Malaysia) bitis is not accepted as a separate group of timber.

A general description of nyatoh and bitis is given here.

Nyatoh is a light to medium-weight, moderately hard to hard, red meranti-like wood. The heartwood is pinkish-brown to reddish-brown and only moderately distinct from the lighter sapwood. The density is (420–)550–800(–850) kg/m^3 at 15% moisture content; the majority of the commercial supply being 600–700 kg/m^3. The grain is shallowly interlocked, texture moderately fine and even.

At 15% moisture content the modulus of rupture is 70–130 N/mm^2, modulus of elasticity 10 000–18 000 N/mm^2, compression parallel to grain 28–54 N/mm^2, compression perpendicular to grain 2.5–7 N/mm^2, shear 8.5–11(–17) N/mm^2, cleavage 39–77 N/mm radial and 49–87 N/mm tangential, Janka side hardness 3700–7000 N and Janka end hardness 3900–7600 N.

The recorded rates of shrinkage of nyatoh are moderate, from green to 15% moisture content 1.3–3% radial and 2.3–4% tangential, from green to oven dry about 4.1% radial and 7.6% tangential. The timber usually air dries easily without much degradation if properly stacked. Air drying of boards of 25 mm thick takes about 2 months, of 50 mm thick boards about 5 months. The timber can be satisfactorily dried by using kiln schedule E (Malaysia). Form stability is medium to good when dry.

The sawing properties are variable, probably depending on the species, but variation may also be large within a species. Some nyatoh-producing species contain silica, which makes the timber difficult to work (e.g. *M. malaccensis, M. motleyana* and *M. sericea*). Nyatoh is easy to polish. The wood is easy to turn. Pre-boring for nails and screws is advised because of easy splitting. Gluing gives no problems. The fine grain and colour make it suitable for veneer; sometimes the wood is figured and then the veneer can be very attractive, especially when radially sliced. Peeling is reported as easy to fairly difficult, and a good plywood can be made from the timber. The logs are reasonably free from defects.

Nyatoh is rated as only moderately durable. It is prone to termite attack and susceptible to fungal attack, but not to powder-post beetles. Treated nyatoh timber can be very durable. However, it is very resistant to preservative treatment. Using the open tank method and an equal mixture of creosote and diesel, the heartwood absorbs an average of only 11 kg/m^3. Bitis comprises heavier timber, with density of 850–1150 kg/m^3 at 15% moisture content. The heartwood is reddish-brown to dark brown, and clearly differentiated from the lighter sapwood. The grain is fairly straight, texture moderately fine and even. Bitis is very hard and strong, and much more durable than nyatoh.

At 15% moisture content the modulus of rupture is 105–170 N/mm^2, modulus of elasticity 10 000–23 800 N/mm^2, compression parallel to grain 65–90 N/mm^2, compression perpendicular to grain 9–12.5 N/mm^2, shear 10–17 N/mm^2, cleavage c. 86 N/mm radial and 67 N/mm tangential, and Janka side hardness 14 400–14 900 N.

Bitis is difficult to dry; shrinkage rates are rather high (from green to 15% moisture content 3.0% radial and 4.0% tangential) and there is a tendency to surface checking. Boards of 40 mm thick take about 6 months to air dry. A mild kiln schedule (B in Malaysia) should be used.

Bitis is difficult to work, rapidly blunting saws and cutters due to the presence of silica, but it produces a smooth surface in planing and takes stain and polish satisfactorily. The timber tends to split in boring and mortising. It is not suitable for veneer and plywood because it is difficult to peel.

Bitis is durable (test stakes of *M. utilis* showed an average service life in contact with the ground of 5.5 years), but it is very difficult to impregnate. Substances poisonous to termites are present in wood of *M. betis*. Timber of *M. utilis* is not very resistant to marine borers.

Freshly felled wood often has a sour smell and a bitter taste. It lathers freely when rubbed with water.

The seeds often contain saponins. De-fatted seed kernels of *M. longifolia* contain 26–50% saponin. Seeds of *M. motleyana* contain cyanides. The oil from the seed kernels principally consists of palmitic and stearic acids.

Description Small to large trees, with latex, sometimes up to 50 m tall, usually with columnar bole up to 100 cm in diameter, buttressed or not, often branchless for a considerable length; outer bark smooth, cracked or fissured, usually brownish, inner bark soft and fibrous, 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, simple and entire, usually obovate or elliptical, often glabrous when mature but sometimes velvety (e.g. *M. sericea*) 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; petiole generally of even thickness throughout its length; stipules usually small and caducous, more rarely large and fairly persistent. 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.

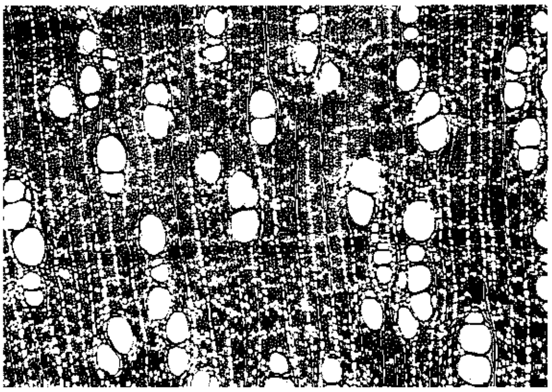
Wood anatomy

– Macroscopic characters:

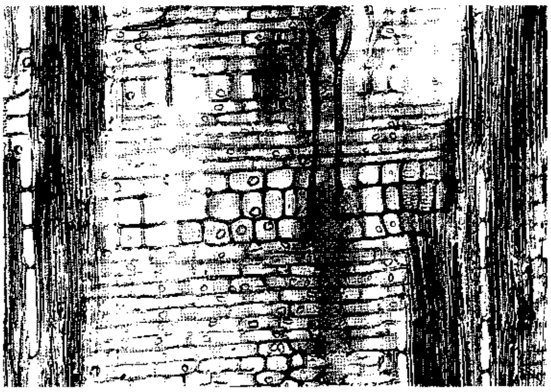
Heartwood light brown, red brown to purple or chocolate red-brown, with lighter streaks, distinctly demarcated from the yellow-brown to purple- grey-brown sapwood. Grain straight or shallowly interlocked. Texture moderately fine to fine. Growth rings indistinct to distinct, delimited by a narrow, often darker band of fibrous tissue at the beginning of the ring, and indicated by a zone with few or no vessels and without parenchyma; vessels barely visible to the naked eye; parenchyma and rays usually only visible with a lens.

– Microscopic characters:

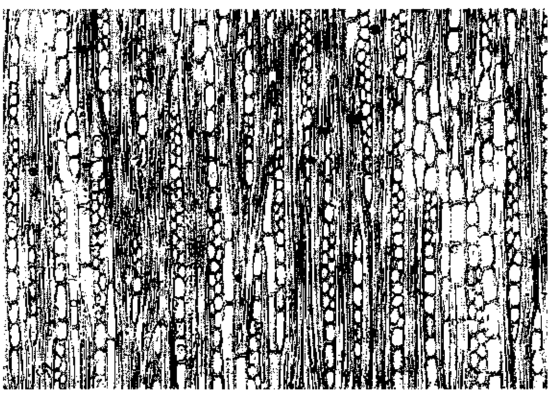
Growth rings, if present, indicated by a zone with few or no vessels and/or without parenchyma. Vessels diffuse, occasionally in a weakly pronounced oblique pattern, 5–11(–20)/mm², mainly in radial multiples of 2–4(–6), round to oval, average tangential diameter 120–180 μm; perforations simple; intervessel pits alternate, round, (5–)7–8(–10) μm; vessel-ray pits mainly confined to the upright and square cells, mainly large and simple, horizontally to vertically elongated or round, partly half-bordered, scarce in procumbent cells; helical thickenings absent; normal or sclerotic tyloses present in heartwood. Fibres c. 1000–1900 μm long, non-septate, typically very thick-walled, occasionally medium thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, diffuse, diffuse-in-aggregates or in fine continuous to discontinuous 1–2(–3)-seriate wavy bands sometimes forming a reticulate pattern, (5–)7–14 bands per radial mm, in strands of 5–8(–10) cells. Rays 8–13(–15)/mm, 1–2(–3)-seriate, in some species mainly uniseriate in others mainly 2(–3)-seriate but then with uniseriate tails, up to 1200 μm high, typically



transverse section (×25)



radial section (×75)



tangential section (×75)

Madhuca utilis

heterocellular with 2–4(–6) marginal rows of upright or square cells and procumbent body cells. Crystals absent. Silica bodies sometimes present in ray cells, occasionally in parenchyma or fibres.
Species studied: *M. betis, M. longifolia, M. sericea, M. utilis.*

Growth and development Large seedlings and saplings may have leaves that are larger, narrower, and more pointed than those of mature trees.
M. longifolia and perhaps also other species are believed to be pollinated by bats which are attracted by and eat the very sweet corollas. Monkeys have been observed to eat the seeds of *M. utilis*. Many seeds are destroyed in this way, but the ones dropped accidentally are dispersed over some distance.

Other botanical information 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. Some trees such as meranti (*Shorea* spp.), terentang (*Campnosperma* spp.) and mengkulang (*Heritiera* spp.) may look rather like nyatoh or bitis. The presence of latex in nyatoh and bitis is, however, a sufficient distinguishing characteristic. Several species dealt with here under *Madhuca* (e.g. *M. motleyana*) have often been considered to belong to the separate genus *Ganua*, which was said 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*.
In India the timber from *M. longifolia* is used for furniture, boats and carts.

Ecology Like other nyatoh or bitis-producing trees, *Madhuca* is found in primary forest. Several species occur in permanent or seasonal freshwater forest or peat-swamp forest (e.g. *M. motleyana*). Usually *Madhuca* species are restricted to lowland rain forest and occur up to 1000 m altitude. The montane species *M. endertii* forms an exception. Some species are common locally, e.g. *M. motleyana* and *M. utilis* in Peninsular Malaysia.

Propagation and planting Seeds of *M. utilis* take 3–16 weeks to germinate.

Silviculture and management Very little or no special attention is given to nyatoh or bitis in silvicultural practices. Regeneration in logged-over forest is usually plentiful, similar to that in other *Sapotaceae* genera. In the forest the trees are managed and harvested in the same way as meranti, as they often grow together with *Shorea* trees and the timber is similar. Planting is not practised.

Genetic resources Not much is known about eventual depletion of the stands of species, but as the trees are sometimes harvested as meranti and not subject to enrichment planting, it might be expected that several species are liable to genetic erosion or even extinction.

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Selection of species

Madhuca beccarii (Engl.) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 177 (1925).

Vernacular names Malaysia: nyatoh padi, nyatoh putih (Sarawak).

Distribution Malaysia (Sarawak).

Uses The timber is probably used as nyatoh.

Observations A medium-sized to fairly large tree up to 35 m tall; leaves evenly distributed, elliptical to obovate, 11–16 cm × 3.5–6 cm, with secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 3 mm long, caducous; flowers with sepals puberulous outside, glabrous inside, 7–8-lobed corolla sericeous outside, 13–16 stamens and glabrous pistil; fruit ellipsoid to obovoid, 2–2.5 cm × 0.8–1.5 cm with thin pericarp; seed incompletely known. *M. beccarii* is not very common and is rather unknown.

Selected sources 733, 781.

Madhuca betis (Blanco) J.F. Macbr.

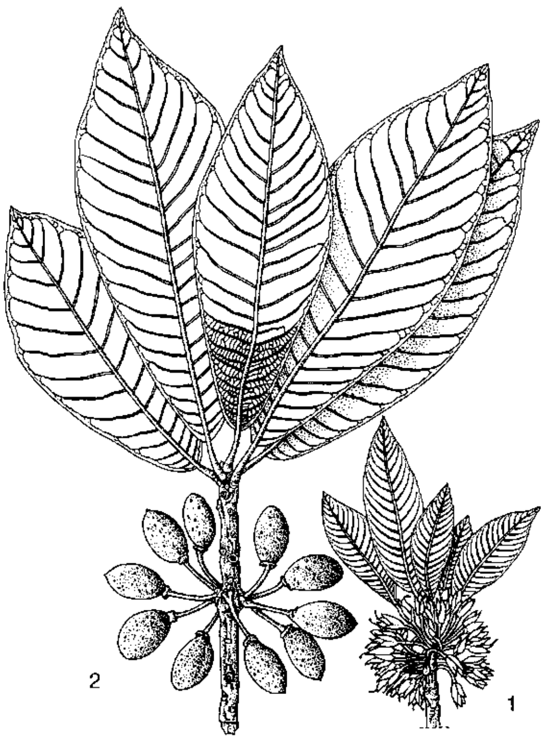
Contr. Gray Herb. Harvard Univ., New Ser. 53: 18 (1918).

Synonyms *Madhuca philippinensis* Merr. (1922).

Vernacular names Indonesia: puntik (Kalimantan), lotoo tulu, sulewe (Sulawesi). Philippines: betis (general), manilig (Magindanao), banitis (Bikol).

Distribution The Philippines (Luzon, Mindoro, Mindanao), Borneo and Sulawesi.

Uses The timber is used as bitis in the Philippines, for wharf, bridge, house and ship building. The oil from the seeds may be used for illumination, and the bark and leaves are used in traditional medicine.



Madhuca betis (Blanco) J.F. Macbr. – 1, flowering twig; 2, fruiting twig.

Observations A fairly large tree up to 35(–45) m tall with bole up to 80(–100) cm in diameter; leaves clustered at tips of twigs, narrowly obovate to obovate, 15–50 cm × 7–15 cm, secondary veins diminishing until inconspicuous near margin, yellowish-brown pubescent beneath, stipules up to 12 mm long, caducous; flowers with sepals yellowish pubescent on both sides, 8–11-lobed glabrous corolla, 16–20 stamens and glabrous pistil; fruit ellipsoid to oblong, 2–4 cm × 1.5–2 cm, 1-seeded; seed with thin shining testa, membranous albumen and thick cotyledons. *M. betis* occurs in primary lowland forest, in Sulawesi up to 300 m altitude. The timber is heavy, about 1000 kg/m^3 at 15% moisture content. It is known as a strong and durable wood. In the Philippines the stands of *M. betis* are depleted due to logging and shifting cultivation. See also the table on wood properties.

Selected sources 102, 175, 484, 486, 578, 579, 733, 781.

Madhuca boerlageana (Burck) Baehni

Boissiera 11: 37 (1965).

Synonyms *Ganua boerlageana* (Burck) Pierre ex Dubard (1908).

Vernacular names Indonesia: arupa merah, arupa putih (Ambon), raka (Morotai).

Distribution The Moluccas and Irian Jaya.

Uses The timber is used in house building and for ship masts.

Observations A medium-sized tree with straight bole; leaves evenly distributed, narrowly obovate to obovate or elliptical, 14–24 cm × 4–7 cm, secondary veins joined near margin, glabrous, stipules very small or lacking; flowers with fringed sepals glabrous inside, 7–8-lobed corolla pubescent on both sides near apex of lobes, 16–20 stamens and glabrous pistil; fruit ovoid, c. 3.5 cm × 1.5 cm, with thin pericarp, usually 2-seeded; seed with thin testa, thin or lacking albumen and thick cotyledons. Plants from Irian Jaya have been distinguished as var. *latifolia* v.d. Assem, differing slightly in leaf characteristics. *G. boerlageana* is found in lowland forest, in Irian Jaya up to 800 m altitude. The density of timber from Irian Jaya is 620–850 kg/m^3 at 15% moisture content.

Selected sources 36, 318, 728.

Madhuca burckiana (Koord.) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 172 (1925).

Synonyms *Madhuca fusicarpa* (Elmer) Merr. (1923), *Isonandra burckiana* (Koord.) Baehni (1965).

Vernacular names Indonesia: kume motutu (Sulawesi), arupa putih (Ambon). Philippines: malobon, silanangsang (Manobo).

Distribution The Philippines (Luzon, Dinagat, Mindanao, Surigao), Borneo (Sarawak), Sulawesi, the Moluccas and Irian Jaya.

Uses The timber is used as nyatoh.

Observations A fairly large tree up to 35 m tall with bole up to 40 cm in diameter; leaves evenly distributed, elliptical to obovate, 9–29 cm × 3.5–9 cm, secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 3 mm long, caducous; flowers with sepals yellowish pubescent except at lower part inside, 8-lobed corolla glabrous except between stamens, 16–22 stamens and hairy ovary; fruit ovoid-fusiform, 2–2.5 cm × 1 cm, 1-seeded; seed brownish. *M. burckiana* occurs in primary rain forest up to 1000 m altitude.

Selected sources 36, 100, 486, 733, 781.

Madhuca coriacea (Merr.) Merr.

Enum. Philipp. fl. pl. 3: 276 (1923).

Vernacular names Philippines: lisong, lisong-insik (Tagalog).

Distribution The Philippines (Luzon, Samar, Leyte).

Uses The timber is probably used as nyatoh or bitis.

Observations A medium-sized tree; leaves evenly distributed, oblanceolate, 8–15 cm × 2.5–4 cm, secondary veins irregularly joined near margin, glabrous, stipules c. 2.5 mm long, caducous; flowers incompletely known; fruit obovoid, 2–4 cm × 1–1.5 cm, 1-seeded; seed with thin endosperm and thick cotyledons. *M. coriacea* occurs in primary forests at low altitudes. Nomenclatorial confusion with *Ganua coriacea* Pierre ex Dubard, a medium-sized tree (up to 30 m) from Sumatra, Riau and northern Borneo, might occur because a combination in *Madhuca* has not yet been made for this species.

Selected sources 486, 733.

Madhuca crassipes (Pierre ex Becc.) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 180 (1925).

Synonyms *Croixia crassipes* (Pierre ex Becc.) Baehni (1965).

Vernacular names Indonesia: jematuk, papungu putih (Kalimantan).

Distribution Sumatra and Borneo (Sarawak, Kalimantan).

Uses The timber is possibly used as nyatoh or bitis.

Observations Probably a medium-sized tree; leaves clustered at tips of twigs, obovate to spatulate, 5–10 cm × 2.5–4 cm, secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 4 mm long, caducous; flowers with sepals hairy outside and glabrous inside, 8–9-lobed corolla sericeous outside and woolly inside between the stamens, 17–19 stamens and glabrous pistil; fruit ellipsoid to obovoid, 4–5.5 cm × 2–3.5 cm, with fleshy pericarp, 1-seeded; seed with thin reddish-brown testa, thin albumen and thick cotyledons. *M. crassipes* grows in lowland forest.

Selected sources 36, 733, 781.

Madhuca cuneata (Blume) J.F. Macbr.

Contr. Gray Herb. Harvard Univ., New Ser. 53: 18 (1918).

Synonyms *Bassia cuneata* Blume (1825), *Isonandra cuneata* (Blume) Baehni (1965).

Vernacular names Indonesia: mayang batu, nyatuh sudu-sudu (Sumatra), merading (Kalimantan).

Distribution Sumatra, Java and Borneo (Kalimantan). Erroneously recorded from Peninsular Malaysia.

Uses The timber is locally used for posts and planks in house building.

Observations A medium-sized tree up to 30 m tall with bole up to 50 cm in diameter; leaves more or less clustered at tips of twigs, obovate or elliptical, 7–12 cm × 2–5 cm, secondary veins joined or diminishing until inconspicuous near margin, glabrous, stipules up to 2 mm long, caducous; flowers with sepals sericeous outside and glabrous inside, 8-lobed corolla pubescent on both sides, c. 16 stamens and ovary hairy at base; fruit ovoid to ellipsoid, 2.5–4 cm × 1.5–2 cm, with thin pericarp, 1-seeded; seed brown, with thin albumen and thick cotyledons. This species occurs in coastal and mountainous regions, in primary forest; in Java up to 1200 m altitude. The timber is reportedly not very durable.

Selected sources 35, 36, 102, 318, 733, 779, 781.

Madhuca curtisii (King & Gamble) Ridley

Fl. Mal. Pen. 5 (Suppl.): 319 (1925).

Synonyms *Ganua curtisii* (King & Gamble) H.J. Lam (1925), *Madhuca chrysocarpa* (Pierre ex Dubard) Ridley (1925), *Madhuca perakensis* (King & Gamble) Ridley (1925).

Vernacular names Malaysia: mentua taban (Peninsular).

Distribution Peninsular Malaysia and Borneo.
Uses The timber is probably used as nyatoh.
Observations A medium-sized tree up to 30 m tall with columnar bole up to 60 cm in diameter, buttresses absent or small; leaves evenly distributed to loosely clustered, narrowly obovate to obovate or elliptical, 7.5–15.5 cm × 3.5–7 cm, secondary veins joined near margin, glabrous, stipules up to 5 mm long, caducous; flowers with sepals tufted with some hairs at apex, 8–10-lobed corolla, glabrous except for apex of lobes, 16–22 stamens and a hairy ovary; fruit ovoid to ellipsoid, c. 2 cm × 1.3 cm, reddish-brown and minutely hairy, 1–2-seeded; seed with very thin endosperm or lacking endosperm, and thick cotyledons. *M. curtisii* grows on low hills up to 700 m altitude and is locally common (Penang, Perak). The density of the wood is 670–700 kg/m^3 at 15% moisture content.
Selected sources 36, 100, 581, 728, 733, 779, 781.

Madhuca endertii H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 458 (1927).
Distribution Borneo (Sabah, East Kalimantan).
Uses The timber is possibly used as nyatoh or bitis.
Observations A medium-sized tree up to 30 m tall; leaves evenly distributed, ovate, obovate to elliptical, 5–13(–18) cm × 2–6 cm, secondary veins joined near margin, glabrous, stipules c. 2 mm long, caducous; flowers with sepals greyish pubescent outside and glabrous inside, 6–8-lobed corolla pubescent outside and glabrous inside except between the stamens, 12–16 stamens and glabrous pistil; fruit ellipsoid, 2–4.5 cm × 1 cm, dark purple when ripe, 1-seeded. *M. endertii* occurs at 1500–3700 m altitude.
Selected sources 733, 781.

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

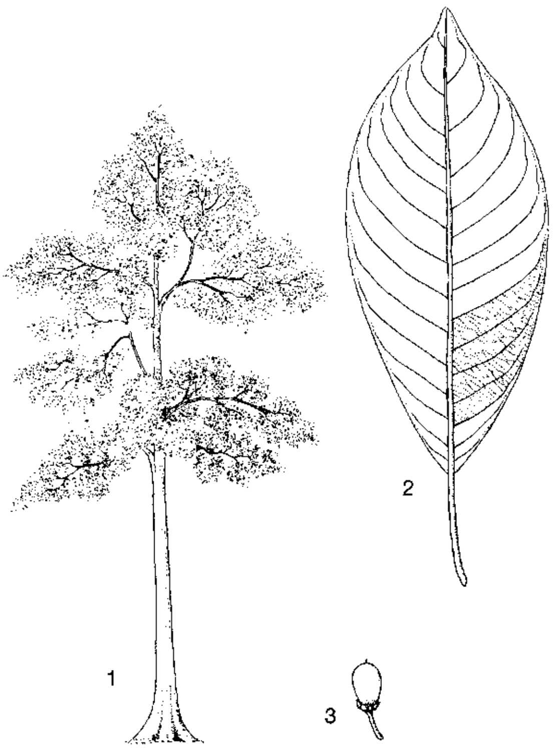
Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 170 (1925).
Synonyms *Bassia erythrophylla* King & Gamble (1905).
Distribution Peninsular Malaysia, Lingga, Sumatra and Borneo.
Uses The timber is possibly used as nyatoh or bitis.
Observations A medium-sized to fairly large tree up to 35 m tall with bole up to 100 cm in diameter; leaves loosely clustered at tips of twigs, obovate to elliptical, 7.5–26 cm × 3.5–7.5 cm, secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 10 mm long, caducous; flowers incompletely known, sepals finely woolly outside and glabrous inside; fruit globose, 1–2 cm in diameter, finely woolly, 1-seeded. *M. erythrophylla* is reported to be locally common in Peninsular Malaysia on low hillsides and ridges below 300 m altitude.
Selected sources 581, 733, 779, 781.

Madhuca kingiana (Brace ex King & Gamble) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 159 (1925).
Synonyms *Bassia kingiana* Brace ex King & Gamble (1905), *Ganua kingiana* (Brace ex King & Gamble) v.d. Assem (1953).
Vernacular names Indonesia: putatat putatat (Sumatra).
Distribution Peninsular Malaysia, Singapore, Sumatra and northern Borneo (Sabah, East Kalimantan).
Uses The timber is locally used as nyatoh.
Observations A medium-sized tree up to 30 m tall with columnar bole up to 60 cm in diameter, buttresses small or absent; leaves densely clustered at tips of twigs, narrowly elliptical to elliptical or obovate, 17.5–32.5 cm × 5–10 cm, secondary veins joined in arches near margin, glabrous, stipules up to 18 mm long, fairly persistent; flowers with sepals finely woolly outside, 12–16-lobed whitish corolla, 24–36 stamens and hairy ovary; fruit ovoid to globose, c. 1.5 cm in diameter, with rather thin pericarp. *M. kingiana* occurs in lowland rain forest, on hills and ridges, up to 400 m altitude. It is locally common in Peninsular Malaysia and Sabah. The density of the wood is about 750 kg/m^3 at 15% moisture content.
Selected sources 36, 100, 581, 728, 779, 781, 792.

Madhuca korthalsii (Pierre ex Burck) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 168 (1925).
Synonyms *Bassia braceana* King & Gamble (1905).
Vernacular names Indonesia: kosal (Sumatra), katiau senaman, katiau tanduk (Kalimantan).
Distribution Peninsular Malaysia, Sumatra and Borneo.
Uses The timber is possibly used as nyatoh or bitis.
Observations A small to medium-sized tree up to 25(–35) m tall with bole up to 35 cm in diame-



Madhuca korthalsii (Pierre ex Burck) H.J. Lam – 1, tree habit; 2, leaf; 3, fruit.

ter; leaves evenly distributed, narrowly obovate to obovate or elliptical to lanceolate, 9–32 cm × 3–12.5 cm, secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 2.5 mm long, caducous; flowers with sepals finely hairy on both sides, 8-lobed corolla glabrous except between the stamens, 16–18 stamens and usually glabrous ovary; fruit ellipsoid or ovoid, 2–2.5 cm × 1–1.5 cm, 1-seeded; seed with thin endosperm and thick cotyledons. *M. korthalsii* grows in lowland rain forest up to 300 m altitude and usually occurs scattered.

Selected sources 100, 102, 581, 733, 779, 781.

Madhuca kunstleri (Brace ex King & Gamble) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 158 (1925).

Synonyms *Bassia kunstleri* Brace ex King & Gamble (1905).

Distribution Peninsular Malaysia and Borneo (Sarawak).

Uses The timber is possibly used as nyatoh or bitis.

Observations A small to medium-sized tree up to 20 m tall with columnar bole up to 20 cm in diameter; leaves evenly distributed, narrowly obovate or elliptical or lanceolate, 9–23 cm × 2–7.5 cm, secondary veins joined in arches near margin and forming an intramarginal vein, glabrous, stipules up to 2 mm long, caducous; flowers with sepals brownish pubescent outside and glabrous inside, 10–16-lobed corolla finely hairy outside, 25–32 stamens and a hairy ovary; fruit ovoid, 2–2.5 cm × 1–1.5 cm, hairy, 1–2-seeded; seed with endosperm lacking or very thin, and thick cotyledons. *M. kunstleri* occurs in lowland rain forest up to 800 m altitude and is locally common in Peninsular Malaysia.

Selected sources 581, 733, 779, 781.

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

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 176 (1925).

Synonyms *Bassia laurifolia* King & Gamble (1905), *Madhuca rupicola* (King & Gamble) H.J. Lam (1925).

Vernacular names Thailand: paduwa, puduwa (Malay, Songkhla).

Distribution Southern Thailand, Peninsular Malaysia and Sumatra.

Uses The timber is possibly used as nyatoh or bitis.

Observations A medium-sized to fairly large tree up to 35 m tall with columnar bole up to 50 cm in diameter, buttresses absent or small; leaves evenly distributed or loosely clustered at tips of twigs, narrowly elliptical or obovate to lanceolate, 8.5–25 cm × 2.5–9 cm, secondary veins diminishing until inconspicuous near margin, glabrous, stipules up to 7 mm long, caducous; flowers with sepals woolly outside and glabrous inside, 6–10-lobed corolla pubescent on middle line and at tips of the lobes outside and woolly between the stamens inside, (10–)13–16 stamens and a glabrous pistil; fruit ellipsoid, 1.5–2 cm × 1 cm, with thin fleshy pericarp, 1-seeded; seed with thin, dark brown testa, endosperm absent or thin, cotyledons thick. *M. laurifolia* is closely related to *M. penangiana* and occurs scattered in lowland rain forest, up to 700 m altitude. The density of the dark red-brown wood is about 950 kg/m^3 at 15% moisture content.

Selected sources 102, 190, 581, 733, 779, 781.

Madhuca leucodermis (K. Krause) H.J. Lam

Nova Guinea 14(4): 556 (1932).

Synonyms *Illipe leucodermis* K. Krause (1923).

Distribution New Guinea.

Uses The timber is probably used as nyatoh or bitis.

Observations A fairly large tree up to 30 m tall; leaves evenly distributed or loosely clustered at tips of twigs, narrowly ovate to elliptical, 15–35 cm × 5.5–11 cm, secondary veins joined in arches or diminishing until inconspicuous near margin, scattered beneath with minute hairs, stipules up to 5 mm long, caducous; flowers with sepals hairy outside and glabrous inside, 8-lobed corolla entirely glabrous, 16 stamens and hairy ovary; fruit ellipsoid, c. 2.5 cm × 1.5 cm, with fleshy pericarp, 1-seeded; seed lacking albumen, with thick cotyledons. *M. leucodermis* occurs in forest up to 900 m altitude. The density of the wood is 750–870 kg/m^3 at 15% moisture content.

Selected sources 733.

Madhuca macrophylla (Hassk.) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 162 (1925).

Synonyms *Payena macrophylla* (Hassk.) Burck (1886).

Vernacular names Indonesia: pasra, karet munding (Sundanese, Java).

Distribution Western Java.

Uses The timber may be used in house building.

Observations A medium-sized tree up to 25(–35) m tall; leaves clustered at tips of twigs, broadly spatulate to spatulate or obovate, 15–55 cm × 6–22 cm, secondary veins diminishing until inconspicuous near margin, glabrous or sparsely hairy beneath, stipules up to 3.5 mm long, caducous; flowers with sepals pubescent outside and along margins and at tip inside, 8–13-lobed corolla woolly on both sides, 22–28 stamens and hairy ovary; fruits often two together, pendulous, ellipsoid, 2.5–4 cm × 1.5–3 cm, 1–2-seeded; seed with thin, shining brown testa, albumen absent and cotyledons thick. *M. macrophylla* grows in mixed forest below 600 m; it is an uncommon species. The timber is reported to be fairly durable.

Selected sources 35, 36, 318, 733.

Madhuca malaccensis (C.B. Clarke) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 167 (1925).

Synonyms *Bassia malaccensis* (C.B. Clarke) King & Gamble (1905).

Vernacular names Malaysia: basong, kamayan (Sabah). Singapore: sundek.

Distribution Southern Thailand, Peninsular Malaysia, Singapore and Borneo (Sabah); probably also Sumatra and Bangka.

Uses The timber is probably used as nyatoh.

Observations A medium-sized tree up to 25 m tall, with bole up to 30 cm in diameter; leaves evenly distributed or loosely clustered at tips of twigs, narrowly obovate to obovate or elliptical, 10–54 cm × 5–20 cm, secondary veins diminishing until inconspicuous near margin, glabrous when mature, stipules up to 5 mm long, caducous; flowers with sepals finely hairy outside and glabrous inside, 10–12-lobed corolla sparsely hairy outside and inside but woolly between the stamens, 19–25 stamens and glabrous or hairy pistil; fruit ellipsoid or obovoid, 2–3 cm × 1–2 cm, 1–2-seeded; seed with thin or without endosperm and thick cotyledons. *M. malaccensis* is a variable species, often confused with other species (*M. korthalsii*, *M. laurifolia*, *M. penangiana*). It occurs scattered in lowland rain forest, rarely up to 800 m altitude. The density of the wood is about 760 kg/m^3 at 15% moisture content.

Selected sources 100, 102, 190, 581, 733, 779, 781.

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), *Ganua scortechinii* (King & Gamble) H.J. Lam (1925).

Vernacular names Indonesia: ketiau, bengku (Sumatra), nyatu bekas (Kalimantan). Malaysia: nyatoh ketiau (Peninsular), ketiau (Sarawak, Sabah). Thailand: sateeyo (Narathiwat).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra, the Riau Archipelago, Belitung and Borneo.

Uses The timber is used as nyatoh. The latex is sold as an inferior quality of gutta-percha. The fat from the seeds is used in foods.

Observations 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; leaves evenly distributed or loosely clustered at tips of twigs, ovate, obovate or elliptical, 5–20 cm × 2.5–8.5 cm, secondary veins joined in arches near margin, glabrous, stipules very small, caducous; flowers with sepals pubescent outside and tufted with some dark hairs at apex, 8–10-lobed corolla glabrous except for throat, 16–22 stamens and glabrous or hairy ovary; fruit ellipsoid, 1.5–3 cm ×

1–2 cm, green, yellowish to reddish, 1–2-seeded; seed with thin or without endosperm and thick cotyledons. *M. motleyana* is common in freshwater and peat-swamp forests, generally near sea-level. The wood is yellowish-brown and has a density of 405–690 kg/m^3 at 15% moisture content. It is easy to saw, plane and bore. The seeds contain about 50% oil and no or little cyanide. See also the table on wood properties.

Selected sources 36, 89, 100, 102, 190, 315, 318, 581, 699, 728, 779, 781, 792.

Madhuca oblongifolia (Merr.) Merr.

Enum. Philipp. fl. pl. 3: 277 (1923).

Vernacular names Philippines: malabetis (general), kalakalachuche (Tagalog).

Distribution The Philippines (Luzon).

Uses The timber is used as bitis, similar to *M. betis*.

Observations A medium-sized tree up to 20 m tall; leaves loosely clustered at tips of twigs, narrowly elliptical or oblong, 15–21 cm × 4–7 cm, secondary veins joined in irregular arches, hairy beneath, stipules up to 6.5 mm long, fairly persistent but ultimately caducous; flowers incompletely known, with sepals densely hairy outside and glabrous inside, and glabrous pistil; fruit and seed incompletely known. *M. oblongifolia* occurs in primary forest at low altitudes. The timber is obtainable in very limited quantities and is pinkish-brown to reddish-brown.

Selected sources 484, 486, 733.

Madhuca obovatifolia (Merr.) Merr.

Enum. Philipp. fl. pl. 3: 277 (1923).

Synonyms *Ganua obovatifolia* (Merr.) v.d. Assem (1953).

Vernacular names Philippines: pianga (Ibanag, Iloko).

Distribution The Philippines (Luzon).

Uses The timber is used as bitis, similar to *M. betis*. The fruit is edible.

Observations Probably a medium-sized tree; leaves loosely clustered at tips of twigs, obovate to elliptical, 6–13 cm × 3–7 cm, secondary veins joined in arches near margin, glabrous, stipules very small or absent; flowers with sepals (almost) glabrous and often tufted with some dark hairs at apex, 8-lobed corolla pubescent near apex of lobes on both sides, 15–16 stamens and glabrous pistil except for a few hairs at base of ovary; fruit c. 2 cm long, with thin pericarp; seed with thin testa, albumen thin, cotyledons thick. *M. obovatifolia* is found in primary forest at low altitudes. The reddish-brown timber is obtainable in very limited quantities.

Selected sources 484, 486, 728, 752.

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

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 168 (1925).

Synonyms *Bassia penangiana* King & Gamble (1905).

Distribution Peninsular Malaysia (Kedah, Penang, Perak).

Uses The timber is used as nyatoh.

Observations A medium-sized tree up to 25(–30) m tall with bole up to 60 cm in diameter; leaves evenly distributed or loosely clustered at tips of twigs, lanceolate or narrowly elliptical, 8–27 cm × 2–8 cm, secondary veins diminishing until inconspicuous at margin, glabrous, stipules up to 3 mm long, caducous; flowers with sepals finely hairy outside and glabrous inside, 8-lobed corolla hairy outside and woolly between the stamens inside, 13–18 stamens and glabrous pistil; fruit ellipsoid, 1.5–2 cm × 1 cm, 1-seeded; seed lacking endosperm and with thick cotyledons. *M. penangiana* occurs on hills and mountains at 150–1200 m altitude, is locally common, and is closely related to *M. laurifolia*. The wood has a density of about 730 kg/m^3 at 15% moisture content.

Selected sources 102, 581, 733, 779, 792.

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

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 166 (1925).

Synonyms *Bassia penicillata* King & Gamble (1905).

Distribution Peninsular Malaysia.

Uses The timber is used as nyatoh.

Observations A medium-sized to fairly large tree up to 35 m tall with columnar bole up to 60 cm in diameter and small buttresses; leaves evenly distributed or more or less clustered at tips of twigs, elliptical or narrowly elliptical to obovate or narrowly obovate, 7.5–30 cm × 4–9.5 cm, secondary veins diminishing until inconspicuous near margin, finely yellowish-brown hairy beneath, stipules up to 2 mm long, caducous; flowers with sepals puberulous outside and glabrous inside and tufted with some dark hairs at apex, 8–13-lobed corolla glabrous but woolly between the stamens, 20–25 stamens and hairy ovary; fruit globose to ovoid, c. 2.5 cm × 2 cm, finely hairy, 1-seeded; seed with thin endosperm and thick cotyledons. *M. penicillata* has often been confused with *M. sericea,* from which it differs in larger flowers and more reticulate tertiary venation. It grows scattered in lowlands and on hills up to 350 m. The density of the wood is about 760 kg/m^3 at 15% moisture content.

Selected sources 102, 581, 733, 779, 792.

Madhuca ridleyi H.J. Lam

Gard. Bull. Str. Settl. 9: 105 (1935).

Distribution Peninsular Malaysia.

Uses The timber is possibly used as nyatoh or bitis.

Observations A fairly small tree up to 17 m tall with bole up to 50 cm in diameter; leaves very densely clustered at tips of twigs, obovate to spatulate, 11–26 cm × 4–11 cm, secondary veins diminishing until inconspicuous near margin, initially finely hairy below but glabrescent, stipules up to 11 mm long, caducous; flowers with sepals pubescent on both sides, 16–17-lobed glabrous corolla, 33–37 stamens and glabrous pistil; fruit globose, 2.5–3 cm in diameter, with thick fleshy pericarp, 2–4-seeded; seed with fleshy endosperm and thin cotyledons. *M. ridleyi* occurs scattered, usually on limestone hills at 150–450 m altitude. More rarely it is found in seasonally swampy regions.

Selected sources 733, 779.

Madhuca sericea (Miq.) H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 163 (1925).

Synonyms *Bassia argentea* C.B. Clarke (1882).

Vernacular names Indonesia: melikuran, kemodan, ketiau (Sumatra). Malaysia: sundik (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra, Lingga, Bangka and Borneo (Sabah, East Kalimantan).

Uses The timber is used as nyatoh, particularly for construction purposes such as house and bridge building.

Observations A fairly large tree up to 35 m tall with columnar, straight bole up to 50 cm in diameter, sometimes with small buttresses; leaves scattered or loosely clustered at tips of twigs, narrowly elliptical to elliptical or obovate, 6.5–25 cm × 3–10 cm, secondary veins diminishing until inconspicuous near margin, yellowish-brown or silvery-grey velvety beneath, stipules up to 2 mm long, fairly persistent but ultimately caducous; flowers with sepals hairy at both sides but inner sepals glabrous inside, 8–11-lobed corolla glabrous except between stamens, 18–24 stamens and hairy ovary; fruit ellipsoid or ovoid, 2–3.5 cm × 1–1.5 cm, with woody pericarp initially hairy, 1–2-seeded; seed with very thin albumen and fleshy cotyledons. Var. *ridleyi* (Gand.) Ng from Peninsular Malaysia and Singapore differs in the longer petiole which has a closed groove above. *M. sericea* has been confused with *M. penicillata* and occurs scattered in primary lowland forest up to 700 m altitude. The timber is purplish-brown to greyish-brown and has a density of 670–920 kg/m^3 at 15% moisture content, which makes it a heavy nyatoh or even bitis.

Selected sources 100, 102, 190, 318, 581, 733, 779, 781, 792.

Madhuca spectabilis P. v. Royen

Blumea 10: 24 (1960).

Vernacular names Indonesia: natu bulang, kijan (Kalimantan).

Distribution Borneo (Sabah, East Kalimantan).

Uses The timber is possibly used as nyatoh or bitis.

Observations A medium-sized tree up to 26 m tall with stout twigs; leaves evenly distributed, narrowly obovate, very large, 25–48 cm × 8–14 cm, secondary veins joined in arches near margin, glabrous, stipules up to 20 mm long, fairly persistent but ultimately caducous; flowers comparatively large with sepals hairy outside and glabrous inside, 8–9-lobed corolla glabrous except for longitudinal streaks of hairs on the tube outside and between the stamens inside, 18–21 stamens and hairy ovary; fruit and seed unknown. *M. spectabilis* grows in lowland forest.

Selected sources 100, 733, 781.

Madhuca utilis (Ridley) H.J. Lam ex K. Heyne

Nutt. pl. Ned. Ind., ed. 2: 1231 (1927).

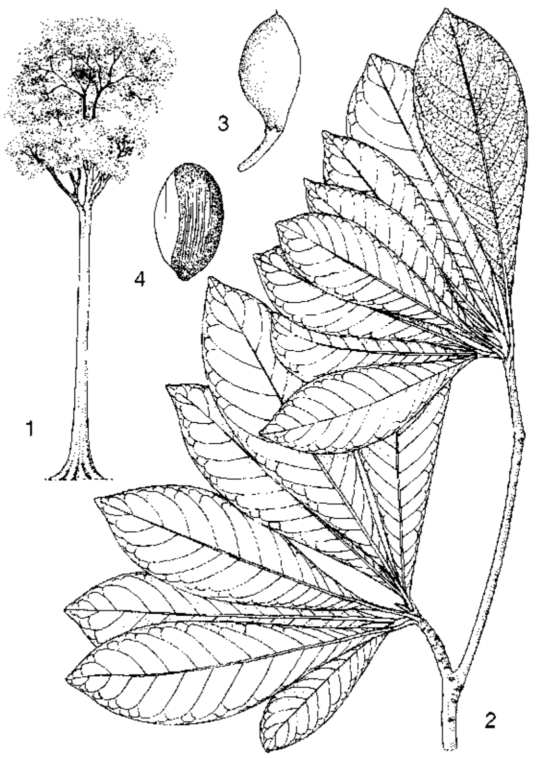
Synonyms *Payena utilis* Ridley (1918), *Madhuca stenophylla* H.J. Lam (1925), *Isonandra utilis* (Ridley) Baehni (1965).

Vernacular names Malaysia: bitis, seminai, belian (Peninsular).

Distribution Peninsular Malaysia, Sumatra and northern Borneo.

Uses The timber is used as bitis, for heavy constructional work, paving blocks, agricultural implements and turnery. The oil from the seeds is used locally in Sumatra for cooking.

Observations A large tree up to 50 m tall with bole up to 1 m in diameter and buttresses up to 2 m high; leaves closely clustered at tips of twigs, obovate to spatulate, 4–12.5(–18) cm × 1.5–6 cm, secondary veins joined in irregular arches near



Madhuca utilis (Ridley) H.J. Lam ex K. Heyne – 1, tree habit; 2, sterile twig; 3, fruit; 4, seed.

margin, glabrous and glaucous beneath, stipules up to 3 mm long, caducous; flowers with sepals yellowish-brown woolly outside and glabrous inside except near tips, 8–9-lobed corolla sparsely woolly outside and glabrous inside except between stamens, 10–16 stamens and glabrous ovary; fruit ellipsoid to fusiform, 3.5–5.5 cm × 1.5–3 cm, with woody or fleshy pericarp, 1-seeded; seed 3–4 cm long, with thin, brown testa and very large greyish scar, endosperm very thin or absent, cotyledons thick. *M. utilis* is locally common, particularly in Peninsular Malaysia, in lowland primary forest; also found in swampy forest. The wood is dark red-brown, often with a purplish tinge. The density is 920–1200 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 36, 100, 102, 190, 318, 359, 432, 578, 581, 699, 733, 779, 781, 792.

J. Kartasubrata (general part),
N. Tonanon (properties),
R.H.M.J. Lemmens (properties, selection of species),
R. Klaassen (wood anatomy)

Manilkara Adans.

Fam. pl. 2: 166 (1763).
SAPOTACEAE
x = unknown

Trade groups Manilkara: heavy hardwood, e.g. *Manilkara fasciculata* (Warb.) H.J. Lam & Maas Geest., *M. kanosiensis* H.J. Lam & B.J.D. Meeuse, *M. kauki* (L.) Dubard.

Vernacular names Manilkara. Indonesia: sawo. Malaysia: sawah. Philippines: duyok-duyok. Papua New Guinea: sner. Burma: khayay-rgn. Thailand: lamut-thai, lamut-sida, ket (central). Vietnam: g[aw]ng n[es]o, vi[ees]t.

Origin and geographic distribution The genus *Manilkara* consists of about 65 species, of which about 30 occur in tropical America, about 20 in tropical Africa and about 15 in tropical Asia, Australia and the Pacific. In Malesia 4 species occur naturally, and one other species is found in India, Sri Lanka, Burma, Thailand and Indo-China. *M. kauki* has the largest distribution area in South-East Asia. *M. zapota* (L.) P. v. Royen (sapodilla or ciku) from South America has been introduced and is commonly planted as a fruit tree in South-East Asia.

Uses *Manilkara* timber is used for heavy construction, also in contact with the ground or exposed to the weather: for house and bridge building, railway sleepers and telephone poles. It is also used for flooring and furniture. The wood of *M. kauki* has a good reputation in Indonesia for use in furniture and fine carving (particularly in Bali). The timber is also suitable for turnery, and has been used particularly for mills. The wood shows excellent properties for the production of charcoal. The fruits of *M. kauki* are edible but without much flavour. Fruits of *M. duplicata* Dubard and *M. hexandra* are edible as well. *M. kauki* is also used successfully as rootstock for sapodilla fruit trees, and flowers and seeds of this species are applied in local medicine.
Trees of *M. kauki* have been planted near palaces and temples, often during ceremonial events.

Production and international trade *Manilkara* timber has no economic importance for export, although small amounts of timber from *M. kanosiensis* are exported from Papua New Guinea to Japan. Carvings made from *M. kauki* wood are highly prized, and sold on a fairly small scale in shops and markets in Indonesia.

Properties *Manilkara* timber is heavy and hard. The heartwood is brown, dark brown or reddish-brown, sometimes with reddish streaks, and more or less lustrous. The sapwood is lighter brown, and distinctly demarcated from the heartwood, especially in freshly cut trees. The density is 900–1150 kg/m^3 at 12% moisture content. The grain is straight to interlocked, texture fine to very fine.

At 12% moisture content the modulus of rupture (of *M. kanosiensis* timber) is 164 N/mm^2, modulus of elasticity 21 200 N/mm^2, compression parallel to grain 83 N/mm^2, shear 19 N/mm^2, cleavage 109 N/mm tangential, and Janka side hardness 12 640 N.

The rates of shrinkage are high. Timber of *M. fasciculata* from Irian Jaya showed a shrinkage from green to 15% moisture content of 2.5% radial and 8.7% tangential, and from green to oven dry of 4.8% radial and 12.2% tangential. The timber air dries slowly, and end checking during drying is common. Drying should therefore be done very slowly and carefully. Rapid drying of boards at 100°C shows much checking and deformation, but may be done in about 5 days. Using a reasonable drying schedule, it takes more than 3 weeks to dry from green to air dry. A 30% solution of polyethylene glycol can minimize shrinkage.

Although *Manilkara* timber is very hard, working properties when using modern equipment are usually good. It contains little or no silica. It gives a very fine and smooth polish due to its fine texture, and this, in combination with the unusual colour, makes the wood an attractive medium for fine carvings. The wood should be pre-bored for nailing and screwing, as it is hard and splits easily.

The timber is rated as durable in contact with the ground or weather; it is resistant to fungal and insect attack. However, it is not resistant to teredos, and should only be used in water free of teredos. For most applications, preservative treatment is not needed.

The fine dust of air-dried wood may cause irritation to nose, throat and eyes.

The seeds contain saponins (seed kernels of *M. hexandra* contain more than 10%).

Description Usually medium-sized, but sometimes fairly large trees up to 40 m tall, with straight cylindrical or twisted bole, sometimes free of branches for over 30 m and up to over 100 cm in diameter, but often less, buttresses to 1.5 m high or lacking; outer bark cracked to deeply fissured, greyish-brown to dark brown, inner bark soft and fibrous, pinkish or reddish, exuding latex; crown often rounded and dense. Leaves arranged spirally, simple and entire, leathery, usually obovate with rounded tip, with parallel secondary and tertiary veins; petioles often slender; stipules small and caducous or absent. Inflorescences in axils of leaves or leaf scars, 1–many-flowered. Flowers bisexual or rarely unisexual, pedicellate; calyx consisting of 2 whorls of (2–)3(–4) free or shortly united sepals; corolla 6(–9)-lobed, each lobe usually divided to the base into 3 segments with median segment clasping a stamen, glabrous; stamens 6(–12), epipetalous and inserted at the top of the corolla tube, alternating with (0–)6(–12) staminodes; pistil 1, with 6–14-locular, hairy or glabrous ovary and exserted style. Fruit a fleshy berry, 1–6-seeded. Seed ellipsoid or obovoid, usually strongly laterally compressed, with a hard and shining testa and narrowly elongate scar, basi-ventral or extending along most of the adaxial surface; cotyledons foliaceous, endosperm copious. Seedling (of *M. kauki*) with epigeal germination; hypocotyl erect and straight; cotyledons shortly petiolate; leaves arranged spirally; latex present.

Wood anatomy

– Macroscopic characters:

Heartwood brown, dark brown to reddish-brown, sometimes with red-brown streaks, distinctly demarcated from the light brown sapwood, especially in freshly cut trees. Grain straight to interlocked. Texture fine to very fine; wood more or less lustrous. Growth rings indistinct to vague; radial vessel files sometimes visible as white lines to the naked eye, solitary vessels only in the sapwood just visible to the naked eye; parenchyma and rays not distinct without a hand lens.

– Microscopic characters:

Growth rings indistinct, sometimes vaguely present by differences in spacing of tangential parenchyma lines. Vessels diffuse, 10–20(–24)/mm^2, in radial multiples of 2–4(–16), round to oval, average tangential diameter 60–150 μm; perforations simple; intervessel pits alternate, round, 3–7 μm; vessel-ray pits mainly confined to the upright and square cells, mostly large and simple, horizontally to vertically elongated or round, partly half-bordered, scarce in procumbent cells; helical thickenings absent; red gum-like deposits and thin-walled, rarely sclerotic tyloses present in heartwood. Fibres c. 1200–1900 μm long, non-septate, very thick-walled with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, diffuse, diffuse-in-aggregates or in fine discontinuous 1(–2)-seriate very wavy to straight bands sometimes forming a reticulate pattern, 4–8 bands per radial mm, in

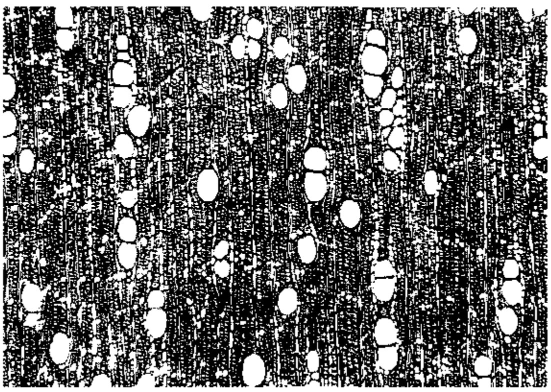
strands of 5–8(–12) cells. Rays 8–14/mm, (1–)2(–4)-seriate with uniseriate tails, up to 1 mm high, heterocellular with 2–4(–5) rows of upright to square marginal cells and procumbent body cells. Prismatic crystals present in chambered axial parenchyma cells, in chains of 4–6(–10) chambers, rare in ray cells. Silica bodies recorded in ray cells and parenchyma.
Species studied: *M. fasciculata, M. hexandra, M. kauki, M. littoralis* (Kurz) Dubard, *M. zapota*.

Growth and development Flowering and fruiting of *M. kauki* is reported to occur throughout the year in Indonesia, differing per region. In Bali, ripe fruits are found from April to July. The trees are considered slow growers. Trees of *M. kauki* reach a trunk diameter of 2–6 cm after 8 years. The architecture of the tree is according to Aubréville's model.

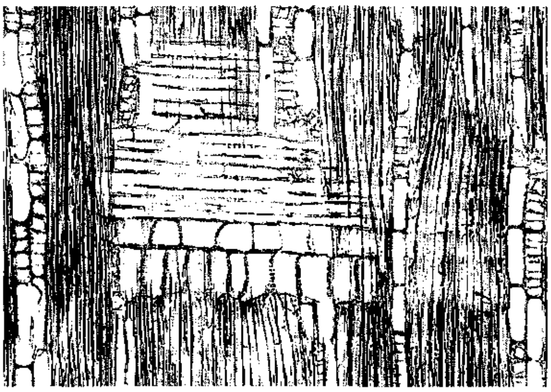
Other botanical information The timber of *M. bidentata* (A.DC.) A. Chev. (synonym: *M. balata* (Pierre) Dubard) is traded from South and Central America as bullet-wood. *Manilkara* shows much variation in the division of the corolla lobes and number of staminodes, but is otherwise a remarkably consistent genus.

Ecology *Manilkara* trees occur in lowlands, sometimes in hills up to 500 m altitude. They are often more or less confined to coastal areas, and are particularly found in the drier regions of South-East Asia. *M. kauki* grows especially on regosols; it prefers sandy loam soils, often at banks of small seasonal streams and on coral beaches, and is commonly associated with *Drypetes* spp., *Eugenia* spp., *Schoutenia ovata* Korth., *Pterospermum diversifolium* Blume, *Pongamia pinnata* (L.) Pierre and *Diospyros maritima* Blume.

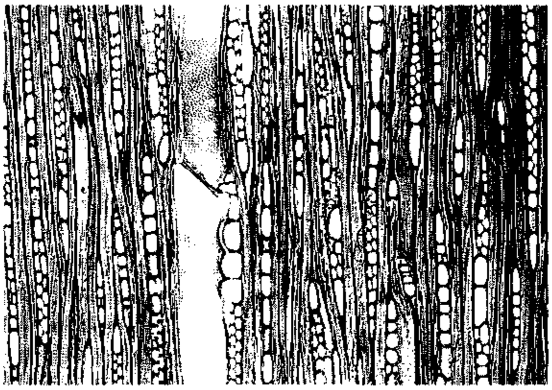
Propagation and planting Seeds should be sown in the shade. Germination starts 2.5–5 weeks after sowing. Experiments with *M. kauki* showed that the position of the seed in the soil is important for successful germination. Germination occurs most rapidly when the longitudinal axis of the seed is in a horizontal position. A germination percentage of 80% may be reached, although germination of *M. hexandra* seeds in nurseries in India is reported to be much lower. When seeds are soaked in an ethephon or chlormequat chloride solution for 24 hours, 55–66% of the seeds germinate. Seedlings of *M. kauki* are transplanted into the field when they are about 45 cm tall. Experiments with *M. kauki* seedlings showed that growth is promoted by applying 50 mg per kg potting medium of NPK fertilizer.



transverse section (×25)



radial section (×75)



tangential section (×75)

Manilkara fasciculata

Silviculture and management Seedlings of *M. kauki* are planted into the field at spacings of 2 m × 1 m. Plantations tend to become very dense after about 8 years, and thinning is then necessary.

Harvesting Logs of *M. kauki* to be used for carving are usually not debarked directly, and are not treated with preservatives. The logs can be stacked for a long time without any risk of serious damage. Resin lacquer (shellac) can be used as a cheap material for stabilizing craft products made of *M. kauki* wood for the tourist industry.

Genetic resources *M. kauki* has become rare, particularly in areas where the wood is much used for carving, e.g. in Java and Bali. In situ conservation is done through the establishment of nature reserves, ex situ conservation is practised by encouraging establishment of plantations, especially in Bali.
M. fasciculata and *M. kanosiensis* are locally common, particularly in New Guinea. Large-scale exploitation of forest may, however, seriously threaten the stands of these species, as the trees are slow growers and not planted.

Prospects The establishment of plantations of *M. kauki* might be profitable economically. Carvings made of the wood of this species are in great demand and fetch high prices.

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Selection of species

Manilkara celebica H.J. Lam

Blumea 4: 331 (1941).

Vernacular names Indonesia: timbuwolo, amibolo, komea (Sulawesi).

Distribution Eastern Sulawesi.

Uses The timber is possibly used for construction.

Observations A medium-sized tree, up to 27 m tall, with bole up to 75 cm in diameter; leaves clustered at apex of twigs, sparsely and appressed hairy beneath but glabrescent; flower buds club-shaped, pedicels gradually incrassate, calyx up to 10 mm long, ovary without a disk; fruit pyriform to globose, up to 2.5 cm long. *M. celebica* is closely related to *M. kauki*. It is locally common, and occurs in dry forest up to 300 m altitude.

Selected sources 731.

Manilkara fasciculata (Warb.) H.J. Lam & Maas Geest.

Blumea 4: 335 (1941).

Synonyms *Northia fasciculata* (Warb.) H.J. Lam (1925), *Manilkara merrilliana* H.J. Lam (1941), *Abebaia fasciculata* (Warb.) Baehni (1964).

Vernacular names Philippines: duyok-duyok.

Distribution The southern Philippines (southern Luzon, Samar, Mindanao), Sulawesi, the northern Moluccas and Irian Jaya.

Uses The timber is used for heavy construction, furniture and implements.

Observations A medium-sized to fairly large tree, up to 40 m tall, with straight and cylindrical bole, free of branches up to 30 m, having a diameter of up to 100(–180) cm; leaves more or less clustered at apex of twigs, entirely glabrous; flower buds ovoid, pedicels gradually incrassate or slender and not incrassate, calyx up to 5 mm long, ovary without a disk; fruit globose to obovoid, up to 3.5 cm long. *M. fasciculata* is locally common (e.g. in Irian Jaya), in primary forest, on clayey soil and limestone, up to 500 m altitude. The density of the wood is 1000–1200 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 263, 484, 731, 814.

Manilkara hexandra (Roxb.) Dubard

Ann. Inst. Bot.-Géol. Colon. Marseille, sér. 3, 3: 9 (1915).

Synonyms *Manilkara emarginata* H.J. Lam (1925).

Vernacular names Cambodia: kes. Thailand: ket. Vietnam: g[aw]ng n[es]o.

Distribution Eastern India, Sri Lanka, Thailand, Cambodia, Vietnam and Hainan.

Uses The timber is used for construction and turnery. The fruits are edible.

Observations A medium-sized tree, up to 20 m tall, but sometimes much larger, with bole up to 50 cm in diameter; leaves more or less clustered at apex of twigs, glabrous; flower buds ovoid, pedicels not incrassate, calyx up to 4.5 mm long, ovary with a shallow, glabrous disk; fruit ovoid to subglobose, up to 1.5 cm long. *M. hexandra* occurs in dry, deciduous forest. See also the table on wood properties.

Selected sources 102, 641, 731.

Manilkara kanosiensis H.J. Lam & B.J.D. Meeuse

Blumea 4: 337 (1941).

Vernacular names Papua New Guinea: manilkara.

Distribution The Moluccas (Tanimbar Islands) and Papua New Guinea.

Uses The timber is used for construction.

Observations A medium-sized tree; leaves evenly distributed, glabrous; flower buds ovoid, pedicels not incrassate and slender, calyx up to 11 mm long, ovary with glabrous disk; fruit unknown. Although the timber of *M. kanosiensis* is reported to be exported from Papua New Guinea to Japan, not much is known about this species. The timber is heavy, with a density of about 1030 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 10, 67, 731.

Manilkara kauki (L.) Dubard

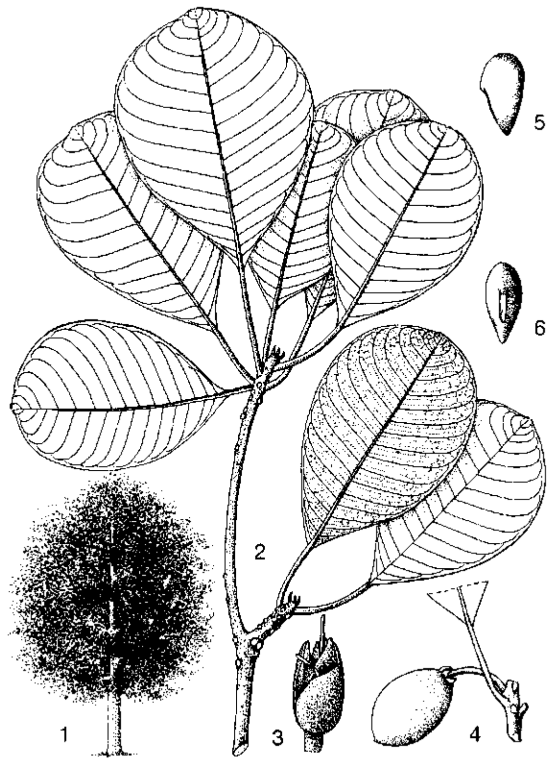
Ann. Inst. Bot.-Géol. Colon. Marseille, sér. 3, 3: 9 (1915).

Synonyms *Mimusops kauki* L. (1753).

Vernacular names Indonesia: sawo kecik (Java, Bali), kayu sawo (Java), sabo (Bali). Malaysia: sawah, sawai, sawau (Peninsular). Papua New Guinea: sner. Thailand: lamut-thai, lamut-sida (central). Vietnam: vi[ees]t.

Distribution Burma, Indo-China, Thailand, Peninsular Malaysia, throughout Indonesia (except Kalimantan), Papua New Guinea and north-eastern Australia.

Uses The timber is used for construction and particularly for furniture and carving; it is also used for turnery and mills. The fruits are edible. This species is used as rootstock for sapodilla



Manilkara kauki (L.) Dubard – 1, habit of young tree ; 2, sterile twig; 3, flower; 4, twig with fruit; 5, seed in side view; 6, seed in front view.

(*Manilkara zapota*). Flowers and seeds are used medicinally. The trees are planted as fruit trees and ornamentals, often near palaces and temples.

Observations A medium-sized tree, up to 25 m tall, often with gnarled and low-branched bole, sometimes columnar, up to 100 cm in diameter; leaves clustered at apex of twigs, silky white velvety beneath; flower buds ovoid, pedicels not incrassate, curved and long, calyx up to 7 mm long, ovary with distinct glabrous disk; fruit ovoid or obovoid, up to 3.7 cm long. *M. kauki* usually grows in coastal regions with a comparatively dry climate, generally below 500 m altitude.

Selected sources 102, 165, 166, 167, 201, 304, 318, 346, 356, 618, 640, 673, 682, 686, 731, 760, 779, 783.

I.G.M. Tantra (general part),
N. Tonanon (properties),
R.H.M.J. Lemmens (properties, selection of species),
R. Klaassen (wood anatomy)

Neobalanocarpus P. Ashton

Fl. Malesiana, ser. I, 9: 388 (1982).
DIPTEROCARPACEAE
$x = 7$; $2n = 14$

Trade groups Chengal: heavy hardwood, a single species, *Neobalanocarpus heimii* (King) P. Ashton, Fl. Malesiana, ser. I, 9: 388 (1982), synonym: *Balanocarpus heimii* King (1893).

Vernacular names Chengal. Malaysia: chengai, penak. Thailand: takhian-chan, takhian-chantamaeo (peninsular), chi-ngamat (Narathiwat).

Origin and geographic distribution Chengal occurs throughout Peninsular Malaysia and in the southernmost part of peninsular Thailand, where it may be extinct.

Uses Chengal is a very durable and heavy timber and is therefore suitable for many heavy-duty purposes. It was the standard timber for durable heavy construction in Peninsular Malaysia and can be applied both indoors and outdoors. It is suitable for railway sleepers, piles, bridges, telegraph and power-line poles, vats, casks, tanks and frameworks, especially for wooden houses but even for e.g. lorries and buses. Indoors it is used for flooring (medium and heavy duty) and joinery. Chengal has been used in constructing wharves, ships and boats both in fresh and salt water conditions, with good results. Despite its hardness it is used for carving; carving is comparatively easy, especially when the wood is fresh.

Good-quality resin, known in Peninsular Malaysia as 'damar penak', can be obtained by wounding the tree. It has been used only on a limited scale in the manufacture of certain classes of varnish.

Production and international trade Chengal is a popular and well-known timber of Peninsular Malaysia. For the period 1986–1990 the average domestic log and sawn timber prices in December were US$ 123/m^3 and US$ 242/m^3 respectively. In this period Peninsular Malaysia exported an average of 28 500 m^3 of sawn timber annually, while 69 000 m^3 or 71% was consumed domestically. In 1992 the export of sawn chengal timber was 8000 m^3 with a value of US$ 2.1 million. Malaysia is the only exporter of chengal sawn timber; Thailand is the main importer. Because collecting the dammar is fairly labour-intensive, an attempt to create a firm trade has failed.

Properties Chengal is a heavy hardwood. The sapwood is pale yellow with fine yellow ripple marks visible to the naked eye, distinctly demarcated from the heartwood. The colour of the heartwood is yellow-green when freshly cut, weathering to dark tan-brown. The density is 915–980 kg/m^3 at 15% moisture content. The grain is interlocked, texture moderately fine and even.

At 15% moisture content the modulus of rupture is 149 N/mm^2, modulus of elasticity 19 600 N/mm^2, compression parallel to grain 75 N/mm^2, compression perpendicular to grain 12 N/mm^2, shear 14 N/mm^2, cleavage 55 N/mm radial and 49 N/mm tangential and Janka side hardness 9480 N. See also the table on wood properties.

Shrinkage is fairly low to moderate, averaging 1.1% radial and 2.6% tangential from green to 15% moisture content. The timber dries rather slowly. Air seasoning does not develop serious defects except for end and surface checks. Boards of 40 mm thick take about 6 months to air dry. The timber is subject to fungal infestation if stacked in badly ventilated locations. Chengal also kiln dries slowly and is extremely prone to surface checking. Radial boards tend to dry much slower than tangential boards. It takes 30 days for 25 mm thick boards to kiln dry from green to 10% moisture content. It is recommended that kiln-drying schedule B (Malaysia) is used and the timber should be air dried to below 30% moisture content before kilning.

Air-dried chengal is slightly difficult in rip-sawing but moderately easy in cross cutting especially in relation to other timbers of the same class. This ease may be partly attributed to the low content of silica and partly to the comparatively slight interlocking of the grain. Planing, boring and turning are rated as easy, giving a smooth finish. The resistance to splitting when nailed is rated as very poor.

Chengal is classified as naturally durable and is normally very resistant to termite attack and fungal infestation. Under graveyard test conditions, untreated stakes of 50 mm × 50 mm × 600 mm lasted 9 years. Treated stakes of the same size and under the same test conditions lasted about 19 years. Untreated railway sleepers (238 mm × 125 mm × 1950 mm) laid under severe environmental conditions had an average life of 19 years. Chengal is rated as moderately difficult to treat with preservatives. Using test sticks of 900 mm × 65 mm × 65 mm, and applying the standard open tank treatment using a mixture of equal parts of creosote and diesel fuel, an average absorption of 68 kg/m^3 was obtained.

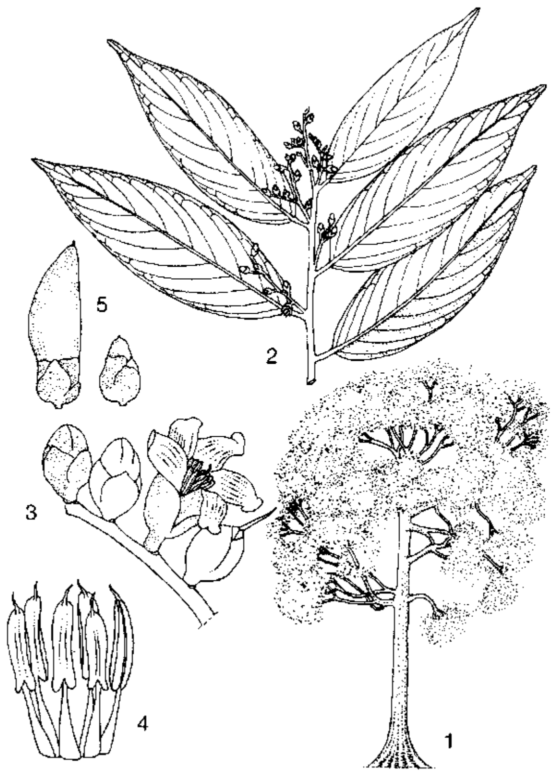
After 6 hours extraction, chengal flour was found to have 23% hot water extractives and 32.6% methanol extractives. Impregnation of these extractives into rubberwood conferred a certain degree of resistance to the fungus *Coriolus versicolor*, while chengal wood blocks extracted with water or methanol retained their resistance to the same fungus.

When dry-wood termites (*Cryptotermes cynocephalus*) are exposed to wood blocks and wood extractives of *N. heimii* and the light red meranti *Shorea ovalis* (Korth.) Blume, the termites' survival and wood consumption is significantly higher in the meranti than in chengal. The bioassays with sawdust, extracted sawdust and treated filter paper further indicated that the dry-wood termites survived significantly better on *S. ovalis* than on *N. heimii* test material.

Early reports of a comparatively poor resistance of chengal to salt water have been contradicted by more recent results.

The best grades of the dammar are pale and transparent but it darkens when stored. It is a usable material for making spirit-varnish, normally with turpentine or naphtha as a solvent. The usual melting point of 90–100°C and its hardness make it superior to other dammars of the same type. The defect of cloudiness in no way detracts from the utility of the varnish, which is to produce a lustrous coating.

Description A large tree, sometimes over 60 m tall; bole straight and cylindrical, unbranched for 30 m or more (but sometimes irregular and low-



Neobalanocarpus heimii (King) P. Ashton – 1, tree habit; 2, flowering twig; 3, inflorescence; 4, stamens; 5, young and mature fruit.

branched), with an average diameter of 90 cm, prominently buttressed; outer bark hard, shallowly irregularly longitudinally fissured, becoming shaggy in old specimens, falling in long scales, dark-coloured; inner bark 1.5 cm thick, fibrous, yellow, exuding a clear, colourless or golden dammar; twigs slender, ribbed, glabrescent. Leaves alternate and simple, leathery, elliptical-lanceolate, 7–17 cm × 2.3–5 cm, acuminate, at base rounded to cuneate, unequal, pinnately veined with 9–12 pairs of ascending and arched veins, slightly sunken on the upper surface, but prominent and glabrous or only sparsely pubescent on the lower, tertiary venation reticulate-scalariform; petiole 5–10 mm long; stipules narrowly oblong, to 12 mm long, spreading, early caducous. Inflorescence paniculate, terminal or axillary, up to 9 cm long, singly branched, puberulent. Flowers bisexual, actinomorphic, ovoid in bud, up to 4 mm × 3 mm; sepals 5, subequal, imbricate at base, broadly ovate, acute, outside caducous puberulent; petals 5, elliptical, cream-white or greenish-yellow, outside densely buff pubescent; stamens 15, glabrous, filaments slender and tapering, anthers linear-oblong, yellow, with small, straight appendages; ovary single, ovoid, glabrous, surmounted by a filiform style with a minute stigma. Fruit an oblanceolate, cylindrical nut on a short, stout stalk, up to 5.5 mm × 2.5 mm, shortly apiculate, shining, embraced at the base by a cup formed by the enlarged, woody, saccate sepals, the outer 2 of which are slightly smaller and thicker than the inner 3. Seedling with epigeal germination; cotyledons very unequal, only the dorsal one reaching the apex of the nut; first 4–5 leaves in a whorl, subsequent ones arranged spirally.

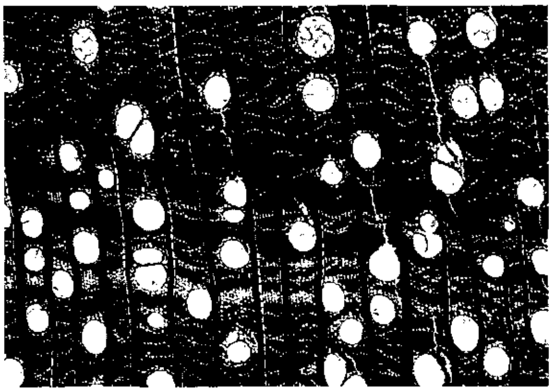
Wood anatomy

– Macroscopic characters:

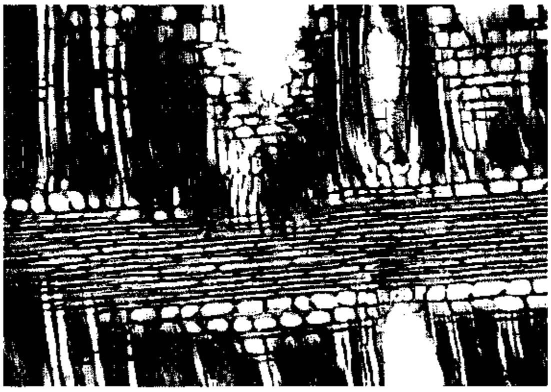
Heartwood dark brown, light yellow-brown when fresh; sapwood pale yellow and distinct from the heartwood. Grain generally shallowly to deeply interlocked, rarely straight. Texture fine; planed surface lustrous, often with vague stripe figure. Growth rings indistinct or absent; vessels not visible to the naked eye, tyloses visible with hand lens; parenchyma barely visible with a lens, generally in very fine, short tangential lines, marginal parenchyma rarely present; rays visible with a lens, rather narrow and short; ripple marks distinct and visible to the naked eye. Intercellular canals visible with a lens in long tangential rows appearing as white lines, sometimes infrequent.

– Microscopic characters:

Growth rings indistinct or absent. Vessels diffuse, (7–)11–14(–18)/mm^2, often solitary, but occasionally in short radial multiples, 120–220 μm in diameter, 400–700 μm in vessel element length; perforation plates simple; intervessel pits alternate, vestured, circular to oval, 6–8 μm; vessel-ray pits with much reduced borders to apparently simple, rounded or angular (occasionally horizontal to vertical and of two distinct sizes, sometimes difficult to find); tyloses common. Vasicentric tracheids present. Fibres 1.2–2.0 mm long, non-septate, thin- to very thick-walled, with simple to minutely bordered pits. Axial parenchyma predominantly diffuse to diffuse-in-aggregates, occasionally scanty paratracheal to vasicentric, with 4–8 cells per parenchyma strand. Rays 6–8/mm, 330–380 μm in height, mostly heterocellular with 1(–3) rows of upright and/or square marginal cells, often procumbent, square and upright cells mixed throughout the ray, mostly 3–5 cells wide; sheath cells often present; all rays storied, 3 tiers/mm. Prismatic crystals generally in ray cells (up-



transverse section (×25)



radial section (×75)

tangential section (×75)

Neobalanocarpus heimii

right/square cells and procumbent cells), often not common. Silica bodies absent. Intercellular canals in long tangential lines, infrequent to occasional, often occluded with white deposits.

Growth and development As in most *Dipterocarpaceae*, germination of chengal seeds is rapid, almost without any dormancy. Germination is similar to that in *Hopea*. The radicle extrudes from the apex of the nut, splitting it into 3 equal valves. Seedling leaves have very long drip-tips and are purple-bronze or bluish when young. Saplings are frequently sympodial in growth which is the result of their intermittent growth. Shoot elongation takes place in flushes during which several nodes and leaves are produced in rapid sequence. These periods alternate with dormancy, during which the apical bud is aborted. The branchlets are drooping.

Growth is comparatively slow. It is estimated that chengal will attain a diameter of 64 cm in 75 years under optimal conditions. A tree planted in Kepong (Peninsular Malaysia) had a diameter of 48 cm after 40 years.

Chengal populations flower sporadically. Usually years with heavy flowering and fruiting occur at intervals of several years. Flowering appears to take place over about 3 weeks at some time between November and May, and fruiting in January–June. As in most *Dipterocarpaceae* the flowers are fragrant. Pollination is by insects, most particularly honey bees. The only method of dispersal of the heavy, wingless seeds of chengal might be by rolling down hill slopes or by means of animals.

Other botanical information The chief diagnostic features of chengal are the dark coloured, scaly bole, the exudation of transparent, almost colourless dammar, the yellow inner bark, the hard, pale yellow sapwood with fine ripple marks, the 15 stamens with slender filaments and short terminal appendages and the acorn-like, large, wingless fruits.

The taxonomic position of *Neobalanocarpus* is dubious but it is believed to be closely related to *Hopea* section and subsection *Hopea*. The highly irregular pattern of meiosis might be a reflection of hybridity which may account for the doubt about its taxonomic position.

The generic name *Neobalanocarpus* was invalidly published by Ashton in 1978 (a Latin description is lacking); the new combination of *N. heimii* was therefore also invalid. Later, in 1982, the generic and specific names were validated.

Ecology Chengal is widespread in mixed dipterocarp forest below 1000 m, especially on well-drained friable soils on undulating land. In peninsular Thailand it occurs frequently in hill dipterocarp forest along slopes and in valleys, and is often found together with *Shorea curtisii* Dyer ex King.

Propagation and planting Natural regeneration beneath parent trees is rarely abundant in virgin rain forest except on ridges in hill forest. The few seedlings usually encountered beneath a parent tree are capable of surviving for very long periods under dense shade, but light is required for further development. Well-established young trees are found in felling gaps, although they respond slowly to an opening in the canopy and readily become smothered. When very young, chengal seedlings are sensitive to drought and overexposure. Planting has been attempted in Peninsular Malaysia with indifferent results. Insects attacked the seedlings badly. Planting in open, unshaded conditions, in association with rubber, has failed. Planting in secondary forest was carried out successfully. The seedlings need shaded conditions.

The fruits are best stored at about 14°C. After storing the fruits at this temperature for 50 days with a loss of 18.7% of the original moisture content and application of a fungicide, they showed no damage. Further reducing of the moisture content to just over half of that of fresh fruits did not kill them either.

Diseases and pests Chengal fruits are often attacked by a seed beetle, *Coccotrypes graniceps*, and its larvae. A *Laspeyresia* species (*Lepidoptera-Tortricidae*) is a shoot-borer often causing severe damage to saplings 1–3 m high. It shows a marked preference for strong, sappy shoots. A pinhole borer attacks the living tree; it has not yet been collected but it is presumed to be a species of *Diapus* (*Coleoptera-Platypodidae*).

Genetic resources Chengal is much rarer nowadays than it was early in the 20th Century. Because of its limited distribution in combination with its great commercial value, chengal might become endangered in the near future. In 1987 the Forestry Department of Peninsular Malaysia took steps to ensure some protection of chengal by increasing the cutting limit to 60 cm diameter at breast height.

Prospects Chengal is a highly valued timber. Demand will always remain high but availability is expected to decrease due to exploitation, and efforts should therefore be made to replenish the species.

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Other selected sources 6, 32, 96, 144, 159, 190, 297, 359, 417, 473, 511, 809.

W.C. Wong (general part, properties),
R.B. Miller (wood anatomy),
G. dos Santos (wood anatomy)

Palaquium Blanco

Fl. Filip.: 403 (1837).
SAPOTACEAE
x = unknown; *P. gutta*: $2n = 24$

Trade groups

- Nyatoh: lightweight to medium-heavy hardwood, e.g. *Palaquium amboinense* Burck, *P. burckii* H.J. Lam, *P. hexandrum* (Griffith) Baillon, *P. luzoniense* (Fernandez-Villar) S. Vidal, *P. maingayi* (C.B. Clarke) King & Gamble, *P. microphyllum* King & Gamble, *P. obovatum* (Griffith) Engl., *P. obtusifolium* Burck, *P. rostratum* (Miq.) Burck, *P. xanthochymum* (de Vriese) Pierre ex Burck.
- Bitis: heavy hardwood, e.g. *P. ridleyi* King & Gamble, *P. stellatum* King & Gamble.

Vernacular names

- Nyatoh: padang (En). Indonesia: nyatuh. Malaysia: jangkar (Sarawak). Papua New Guinea: pencil cedar. Philippines: red nato. Thailand: chik-khao (Chumphon, Surat Thani). Vietnam: ch[aa]y.
- Bitis. Malaysia: nyatoh batu (Sabah, Sarawak). Thailand: chik-nom (Ranong, Satun), khanunnok (Chanthaburi).

Origin and geographic distribution The genus *Palaquium* consists of about 110 species and is distributed from western India and Sri Lanka to southern China and east to Polynesia (Samoa). The centre of diversity is western Malesia; most species are found in the Philippines (about 30) and Borneo (about 35), many of them endemic. Peninsular Malaysia and Sumatra are somewhat less rich in species (about 20). New Guinea is considered an important secondary centre of diversity with about 13 species. The most widely distributed species are *P. amboinense* and *P. obtusifolium* (western Indonesia to New Guinea), *P. obovatum* (India to the Philippines and the Moluccas) and *P. ridleyi* (Indo-China to New Guinea).

Uses Nyatoh wood is in general suitable for house construction, but not when in contact with the ground. Some *Palaquium* species may even be used for columns, beams and rafters. Sometimes the trees are used for making canoes. The most important uses of nyatoh are for the manufacture of fine furniture, decorative doors and veneers, and panelling. The wood is also suitable for flooring boards, partitions, household appliances and sometimes for musical instruments, whereas the buttress wood is commonly used for making oars, cartwheels, and handles of hoes and axes.

Bitis, being generally more heavy and more durable than nyatoh, is generally used for heavy construction, heavy-duty flooring, posts, door and window frames, and paving blocks.

Gutta-percha, i.e. latex from *Palaquium* trees, especially *P. gutta*, has been praised for its insulating property and imperviousness to water. As such, it has been in demand for the insulation of subterranean and submarine electrical cables. It has also been used in the manufacture of golf balls, certain types of surgical appliances, transmission bells, and acid-resistant receptacles. Other uses have included splints for fractures, supports, pipes, speaking tubes, in telephone receivers, as adhesives and an ingredient of chewing gum. 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.

The fruits of several species (e.g. *P. burckii, P. eriocalyx* H.J. Lam, *P. hexandrum, P. lanceolatum, P. macrocarpum, P. philippense, P. rostratum, P. stellatum* and *P. walsurifolium*) are edible. The seeds often contain a fat which is used for cooking or as an illuminant, and is sometimes used for the manufacture of soap and vegetable butter.

Production and international trade Timber from *Palaquium* species is usually traded as nyatoh together with the timber of other *Sapotaceae* genera, particularly *Payena, Pouteria* and *Madhuca*. However, in many places *Palaquium* species supply the bulk of the timber sold as nyatoh. The export of nyatoh sawn timber from Peninsular Malaysia decreased from 16 500 m^3 (with a value of US$ 2.1 million) in 1981 to 9500 m^3 (with a value of US$ 1.3 million) in 1986. From 1986 onward the export increased to 32 500 m^3 with a value of US$ 6.1 million in 1990, but in 1992 it was only 8000 m^3 with a value of US$ 2.8 million. Large amounts of nyatoh are also exported from Sarawak and Sabah; the export of round logs from Sabah was 65 000 m^3 (worth US$ 6.3 million) in 1987, and in 1992 the export was 14 000 m^3 of logs and 8500 m^3 of sawn timber with a total value of US$ 4.4 million. In Papua New Guinea nyatoh is ranked in MEP (Minimum Export Price) group 1, and fetched a minimum export price of US$ 100/m^3 for saw logs in 1992.

Timbers of the bitis class are usually converted to scantling sizes, and sold unclassified. The bulk of the 'seriah' sold in Singapore consists of logs of *Palaquium* and *Payena*, and probably other Sapotaceous trees imported from Indonesia.

Some *Palaquium* species have latex in sufficient amounts to make them commercially important in gutta-percha trade. The best grade of gutta-percha is produced by *P. gutta*. International trading in gutta-percha, in particular to Europe, started in the second half of the 19th Century with Singapore as the centre. After the trees around Singapore were 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 ultimately to the Philippines. Export of Indonesian gutta-percha is mainly to Singapore (93%) and to a much lesser extent to the United States, Germany, Britain and Hong Kong. The total gutta-percha potential of Indonesia is estimated at 10 000 t/year, most of it present in Kalimantan (38%), South Sumatra (23%) and South Sulawesi (23%). However, trade in gutta-percha has decreased drastically due to the replacement by synthetic plastics.

Properties A general description of nyatoh and bitis is given here. *Palaquium* timber with its density of (400–)450–1120 kg/m^3 at 15% moisture content is classified in both groups, depending on the weight of the timber; the arbitrary limit between the groups lies at 850 kg/m^3.

Nyatoh is a light to medium-weight, moderately hard to hard red meranti-like wood. The heartwood is pinkish-brown to reddish-brown and only moderately distinct from the lighter sapwood. The density is (420–)550–800(–850) kg/m^3 at 15% moisture content; that of the majority of the commercial supply is 600–700 kg/m^3. The grain is shallowly interlocked, texture moderately fine and even.

At 15% moisture content the modulus of rupture is 70–130 N/mm^2, modulus of elasticity 10 000–18 000 N/mm^2, compression parallel to grain 28–54 N/mm^2, compression perpendicular to grain 2.5–7 N/mm^2, shear 8.5–11(–17) N/mm^2, cleavage 39–77 N/mm radial and 49–87 N/mm tangential, Janka side hardness 3700–7000 N and Janka end hardness 3900–7600 N.

The recorded rates of shrinkage of nyatoh are moderate, from green to 15% moisture content 1.3–3% radial and 2.3–4% tangential, from green to oven dry about 4.1% radial and 7.6% tangential. Air drying of 40 mm thick boards takes approximately 4 months, 25 mm thick boards about 2 months. The timber can be satisfactorily dried by using kiln schedule E (Malaysia). Form stability is medium to good when dry.

The sawing properties are variable, probably depending on the species; but variation may be large within species too. Some nyatoh-producing species contain silica, which makes the timber difficult to work (e.g. *P. gutta* and *P. walsurifolium*). Gum may clog cutters. Nyatoh is easy to polish when the grain is properly filled. The wood is easy to turn. Pre-boring for nails and screws is advised because of easy splitting. Gluing is trouble-free. The fine grain and colour make it suitable for veneer; it can be peeled at a 91° peeling angle without pretreatment. Sometimes the wood is figured and then the veneer can be very attractive, especially when radially sliced. Peeling is reported as

easy to fairly difficult, and a good plywood can be made from the timber. The logs are reasonably free from defects.
Nyatoh is rated as only moderately durable. It is prone to termite attack and susceptible to fungal attack, but not to powder-post beetles. Treated nyatoh timber can be very durable. However, it is very resistant to preservative treatment. Using the open tank method and an equal mixture of creosote and diesel, the heartwood absorbs on average only about 11 kg/m^3. Bitis comprises heavier timber, with density of 850–1150 kg/m^3 at 15% moisture content. The heartwood is reddish-brown to dark brown, and clearly differentiated from the lighter sapwood. The grain is fairly straight, texture moderately fine and even. Bitis is very hard and strong, and much more durable than nyatoh.
At 15% moisture content the modulus of rupture is 105–170 N/mm^2, modulus of elasticity 10 000–23 800 N/mm^2, compression parallel to grain 65–90 N/mm^2, compression perpendicular to grain 9–12.5 N/mm^2, shear 10–17 N/mm^2, cleavage c. 86 N/mm radial and 67 N/mm tangential, and Janka side hardness 14 400–14 900 N.
Bitis is difficult to dry; shrinkage rates are rather high (from green to 15% moisture content 3.0% radial and 4.0% tangential), and there is a tendency to surface checking. A mild kiln schedule (B in Malaysia) should be used.
Bitis is difficult to work, rapidly blunting saws and cutters due to the presence of silica, but it produces a smooth surface in planing and takes stain and polish satisfactorily. The timber tends to split in boring and mortising. Bitis is not suitable for veneer and plywood because it is difficult to peel.
Bitis timber is rated as durable and is resistant to termite attack, but it is very difficult to impregnate.
Freshly felled wood often has a sour smell and a bitter taste. It lathers freely when rubbed with water. Dust from sawn nyatoh and bitis timber may cause irritation to skin and mucous membranes.
Wood of *P. microphyllum* contains 52% cellulose, 22% lignin, 17% pentosan, 1.0% ash and 0.05% silica. The solubility is 3.2% in alcohol-benzene, 1.4% in cold water, 5.4% in hot water and 14.8% in a 1% NaOH solution. The energy value of the wood is 20 430 kJ/kg.
Gutta-percha is a non-elastic rubber derived from the latex. The fresh greyish-white latex turns reddish-brown when exposed to the air. It is then a marble-like solid mass. In contrast, pure gutta-percha is colourless and translucent when sliced thinly. At 25°C it becomes pliable and it gradually softens upon heating. At 60°C, it is so plastic that it can be drawn into threads of any form. The hardest gutta-percha will soften at 65°C. Insoluble in cold water, gutta-percha dissolves easily in benzene, carbon disulphide, chloroform and all solvents of rubber. Concentrated alkalies, dilute acids and even hydrofluoric acid do not affect the composition of gutta-percha. *P. gutta* gives the best quality of gutta-percha, containing up to 80% poly-isoprene and then only 20% resin. Many other *Sapotaceae* trees may also provide gutta-percha, but the proportion of poly-isoprene and resin is usually much less favourable.

Description Small to very large trees, with latex, 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 (but massive in *P. clarkeanum*), 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, 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; petiole usually of even thickness throughout its length; stipules small to large, usually early caducous, rarely absent. 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, rarely hilum narrow (e.g. *P. ridleyi*, *P. stellatum*); endosperm usually absent and cotyledons thick and fleshy, but rarely endosperm abundant and cotyledons thin (e.g. *P. ridleyi*). Seedling usually with epigeal germination (sometimes hypogeal, e.g. *P. gutta* and *P. obovatum*), with strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves arranged spirally and soon similar to leaves of adult trees.

Wood anatomy

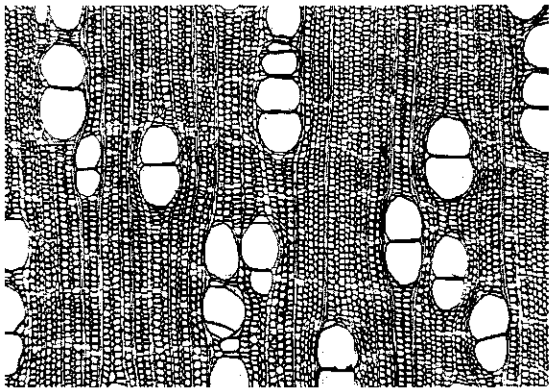
- Macroscopic characters:

Heartwood deep pink, red, red-brown or purple-brown, sometimes with dark streaks, distinctly to indistinctly demarcated from the pale red sapwood, sometimes with a sour smell when freshly sawn. Grain shallowly to moderately interlocked, sometimes wavy. Texture moderately fine to coarse; wood dull, sometimes glossy. Growth rings indistinct to vaguely visible; vessels and parenchyma indistinct to barely visible to the naked eye; rays and parenchyma not distinct without a lens.

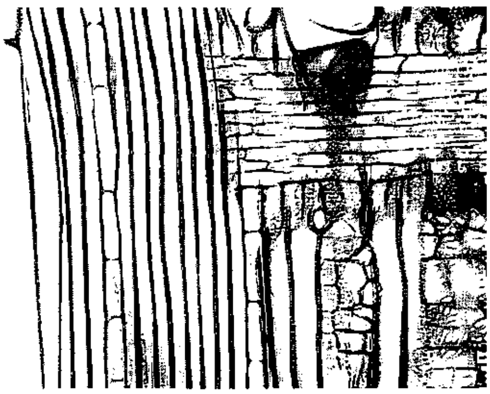
- Microscopic characters:

Growth rings indistinct, if present marked by differences in spacing of tangential parenchyma bands, and/or in fibre wall thickness on either side of the ring boundary. Vessels diffuse, 6–14/mm^2, mainly in radial multiples of 2–5(–8), sometimes in a radial or radial to oblique pattern, round to oval, average tangential diameter 100–220 µm; perforations simple; intervessel pits alternate, round, (4–)6–8 µm; vessel-ray pits mainly confined to the upright and square cells, mostly large and simple, horizontally to vertically elongated or round, partly half-bordered, scarce in procumbent cells; helical thickenings absent; gum-like deposits and thin-walled tyloses sometimes present. Fibres generally 1000–2100 µm long, non-septate, mostly medium thick-walled, but ranging from very thin- to very thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, diffuse, diffuse-in-aggregates or in fine discontinuous to continuous 1–2(–3)-seriate straight to slightly wavy bands forming a reticulate pattern, 4–8 lines per radial mm, in 6–8(–10)-celled strands. Rays 8–12(–15)/mm, 1–2(–3)-seriate with uniseriate tails, in some species mainly uniseriate, in others mainly multiseriate, up to 900 µm high, heterocellular with (1–)2–5(–8) rows of upright and square marginal cells and procumbent body cells. In some species crystals recorded in chambered axial parenchyma in chains of up to 8 cells. Silica bodies present in ray cells of most species.

Species studied: *P. amboinense*, *P. ellipticum* (Dalzell) Baillon, *P. gutta*, *P. hexandrum*, *P. leiocarpum*, *P. lobbianum*, *P. luzoniense*, *P. maingayi*, *P. microphyllum*, *P. obovatum*, *P. obtusifolium*, *P. polyanthum* (Wallich) Baillon, *P. ridleyi*, *P. rostratum*, *P. semaram*, *P. stellatum*, *P. walsurifolium*, *P. xanthochymum*.



transverse section (×25)



radial section (×75)

tangential section (×75)

Palaquium obtusifolium

Growth and development The few data available show a slow rate of growth. In Peninsular Malaysia the mean annual girth increment for *P. maingayi* and *P. rostratum* is only 1.5 cm and 1.8 cm, respectively; these trees take 100 and 70 years respectively, to attain a diameter of 55 cm. However, a *P. rostratum* tree in an arboretum attained a diameter of 57 cm in 40 years. *P. gutta* has a mean annual girth increment of 3.8 cm and attains about 8 m height in 7 years, 17 m in 23 years and a diameter of about 50 cm in 50 years.

There is usually good natural regeneration, but seedlings are often choked out or retarded in growth by other trees and brush. Fruit is borne abundantly some years, but little of it survives. In many cases flowers do not reach maturity because of attack by insects or because of unfavourable weather conditions. Flowers may remain closed for a long time (up to 18 months), probably waiting for favourable weather conditions for opening. There seems to be no definite and regular periodicity of flowering and fruiting seasons. There are however, certain years, when there is a rather general and heavy seed crop. The ripe fruit is greedily eaten by fruit bats; but not the seeds. There are often large numbers of ripe seeds on the ground underneath bat roosts. Fallen fruits are quickly consumed by squirrels, birds, insects and other animals. Only a small proportion of the seeds thus survives and few seeds have a chance to germinate.

Other botanical information *Palaquium* is distinguished from other *Sapotaceae* genera by its flowers having most commonly 6 sepals (two whorls of 3) and 12 stamens. The leaves show much variation between the different species in shape, size, indumentum and venation. A subdivision of the genus (into subgenera or sections) is not warranted as no discrete groups can be recognized, probably because the species show reticulate relationships.

Ecology Most *Palaquium* species grow in lowland forest. Only occasionally are species found at higher elevations, e.g. *P. regina-montium* in Peninsular Malaysia and *P. rioense* in Borneo. Usually the trees occur scattered in the forest; rarely *Palaquium* species form almost pure stands, e.g. *P. xanthochymum* locally in Peninsular Malaysia. Many species are common in freshwater swamp forests, some grow commonly in peat swamps, e.g. *P. ridleyi* and *P. maingayi*.

Propagation and planting Carefully selected seeds will show a germination rate of 75–85% or more. *Palaquium* can also be grown from cuttings and marcots, but the percentage of success is not high. It is also possible to propagate the tree by layering and by cleavage, but these methods are less successful than the planting of seedlings. Nursery seedlings can be planted in the field when about 20 cm tall. In agroforestry systems, spacing may be 3 m × 2 m.

A plantation of gutta-percha trees was started in the early 1930s on a commercial basis at Cipetir, West Java. The total area of gutta-percha plantations in Indonesia may comprise 4000 ha.

Silviculture and management Natural regeneration of *Palaquium* trees is often plentiful in secondary or logged-over forests. The enrichment planting system ensures sufficient regeneration in natural forests, but the saplings are often poorly competitive. *Palaquium* trees need a considerable amount of light for optimal development. Trees freed by cutting away the overshadowing vegetation show much increased vigour.

Forest with a fair amount of natural regeneration of *Palaquium* can be gradually changed over to an almost pure forest by gradually removing other species.

Diseases and pests *Palaquium* trees are susceptible to the fungus jamur upas (*Corticium salmonicolor*).

Harvesting In timber concession areas in the Riau Archipelago and Sumatra, suntai (*Palaquium burckii*) is placed in the same timber group as meranti (*Shorea* spp.), punah (*Tetramerista glabra* Miq.) and pulai (*Alstonia* spp.).

At 60°C, gutta-percha can be moulded into a desired shape, which is retained on cooling. Gutta-percha is usually transported and traded in vacuum zinc containers.

Genetic resources The gutta-percha plantations in Indonesia are also maintained to secure the supply of seed for future planting.

Prospects Nyatoh has become more important since 1985; trade and export of this timber have been increasing. This is due to intensified logging operations and to the wood properties which are close to meranti, for which there is an increasing demand. More research into silvicultural aspects is urgently needed. It is not known how the timber properties, which vary greatly, correspond to the botanical species, and hence, silviculturists do not know which species they should concentrate on. Clarification of this matter is urgently needed.

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Selection of species

Palaquium amboinense Burck

Ann. Jard. Bot. Buitenzorg 5: 37 (1886).

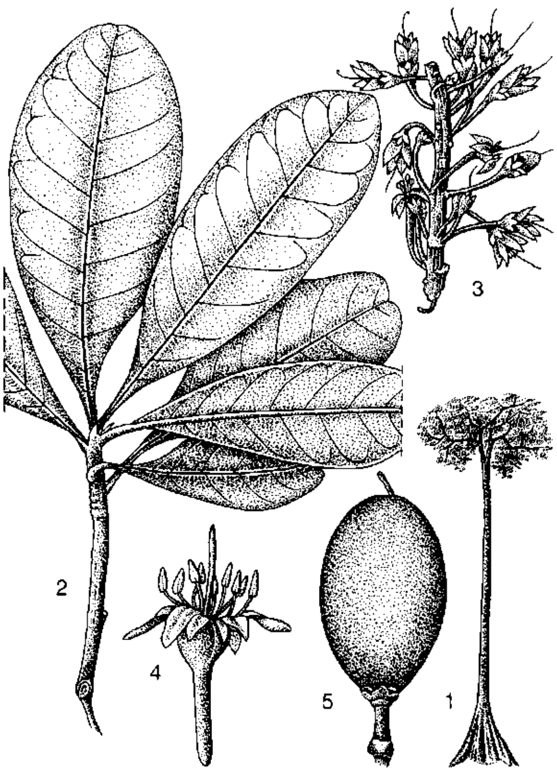
Synonyms *Palaquium javense* Burck (1886), *Isonandra amboinensis* (Burck) Baehni (1965).

Vernacular names Indonesia: kawang (Java), siki ayer, siki batu (Ambon).

Distribution Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and New Guinea (including New Britain and Bougainville).

Uses The timber is used as nyatoh for house construction, boards and simple furniture, but in Central Java also for gamelan musical instruments and fine furniture. A fat can be obtained from the seeds, which is used for cooking or as illuminant.

Observations A medium-sized to large tree, sometimes up to 50 m tall, with straight bole up to 120 cm in diameter; leaves more or less clustered at tips of twigs, elliptical or narrowly obovate to obovate, with tertiary veins transverse to almost parallel to secondary veins, glabrous on both sides; flowers in 1–6-flowered clusters, borne on 4–15(–20) mm long pedicels, yellowish-white; fruit narrowly ovoid to ovoid, 2.5–5 cm long, glabrous. *P. amboinense* occurs in lowland forest, in East Java up to 750 m altitude, in Timor up to 900 m. The timber is fairly light with a density of 450–510 kg/m^3 at 15% moisture content, is not durable and splits easily; it is difficult to saw.



Palaquium amboinense Burck – 1, tree habit; 2, sterile twig; 3, flowering twig; 4, flower; 5, fruit.

Selected sources 35, 36, 318, 461, 743.

Palaquium barnesii Merr.

Bur. Govt. Lab. 6: 13 (1903).

Synonyms *Madhuca barnesii* (Merr.) Baehni (1965).

Vernacular names Philippines: Barnes nato (general), alakaak, palak-palak (Tagalog).

Distribution The Philippines (Luzon, Masbate).

Uses The timber is used as nyatoh for light planking and temporary construction work, and also for cigar boxes and furniture.

Observations A large tree up to 40 m tall; leaves evenly distributed, obovate to spatulate, with inconspicuous and slender transverse tertiary veins, pubescent beneath; flowers in 5–many-flowered clusters, borne on slender, 25–35 mm (–50 mm in fruit) long pedicels; fruit narrowly ovoid to fusiform, 3.5–4 cm long, glabrous. *P. barnesii* is found in primary forests at low and medium altitudes. The timber is grouped together with other *Palaquium* species under 'red nato', which has a density of 450–600 kg/m^3 at 15% moisture content and is reddish-brown.

Selected sources 36, 480, 484, 486, 743.

Palaquium bataanense Merr.

Bur. Govt. Lab. 17: 44 (1904).

Synonyms *Palaquium whitfordii* Merr. (1905).

Vernacular names Philippines: tagatoi, Bataan tagatoi (Tagalog), gasatan (Iloko).

Distribution The Philippines.

Uses The timber is used as nyatoh for cigar boxes and furniture, light planking and temporary construction work.

Observations A large tree up to 45 m tall; leaves more or less clustered at tip of twigs, obovate to spatulate, with slender transverse tertiary veins fairly distinct beneath, initially hairy beneath but glabrescent; flowers 1–3 together, borne on 10–25 mm long pedicels; fruit obovoid, 1–1.7 cm long, glabrous. *P. bataanense* grows in primary forests at low altitudes, particularly in dry hill forests. The timber is grouped together with other *Palaquium* species under 'red nato', which has a density of 450–600 kg/m^3 at 15% moisture content.

Selected sources 480, 486, 743.

Palaquium beccarianum (Pierre) P. v. Royen

Blumea 8: 424 (1957).

Synonyms *Croixia beccariana* Pierre (1890), *Palaquium ferox* H.J. Lam (1925), *Planchonella beccariana* (Pierre) H.J. Lam (1925).

Vernacular names Indonesia: asam babi, binjai babi, nyatu tingang (Kalimantan).

Distribution Borneo.

Uses The timber is used as nyatoh.

Observations A medium-sized tree, about 20 m tall; leaves narrowly obovate to obovate or oblanceolate, with distinct, transverse tertiary veins hairy beneath; flowers in 5–8-flowered clusters, borne on 5–9 mm (–25 mm in fruit) long pedicels; fruit ellipsoid, 2.5–3 cm long, glabrous and greenish. *P. beccarianum* is found in lowland forest and is locally common. The density of the timber is about 600 kg/m^3 at 15% moisture content.

Selected sources 100, 190, 461, 743.

Palaquium burckii H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 57 (1925).

Synonyms *Croixia burckii* (H.J. Lam) Baehni (1965).

Vernacular names Indonesia: suntai hitam (Sumatra).

Distribution Peninsular Malaysia (Johor), Sumatra and the Riau Archipelago.

Uses The timber is used as nyatoh, particularly for making planks for building boats. The fruit is edible. The seeds contain fat which may be used for cooking.

Observations A fairly large tree up to 40 m tall, with straight, cylindrical bole up to 80 cm in diameter; leaves loosely clustered at tip of twigs, obovate, with inconspicuous, closely transverse tertiary veins, velvety beneath; flowers in 4–10-flowered clusters, borne on 15–35 mm long pedicels; fruit ovoid-ellipsoid, 4.5–7.5 cm long, hairy. *P. burckii* grows in marshy forests, often in peat-swamp forest, at low altitudes. The timber is moderately heavy, with a density of 520–760 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 36, 102, 318, 461, 743, 779.

Palaquium clarkeanum King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 191 (1905).

Vernacular names Malaysia: getah getapang, taban ketapang, nyatoh ketiar (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as nyatoh.

Observations A large tree up to 50 m tall, with columnar bole up to 130 cm in diameter and large plank buttresses; leaves clustered at tip of twigs, narrowly obovate to obovate, with slender transverse tertiary veins distinct beneath, densely brownish woolly beneath; flowers in 4–12-flowered clusters, borne on 30–45 mm long pedicels, yellowish-white; fruit oblong, 3.5-5 cm long, glabrous. *P. clarkeanum* is an uncommon tree of primary lowland forest below 300 m altitude; it occurs scattered. The timber is heavy for nyatoh, with a density of about 820 kg/m^3 at 15% moisture content.

Selected sources 102, 190, 581, 743, 779, 792.

Palaquium cochleariifolium P. v. Royen

Blumea 10: 545 (1960).

Vernacular names Brunei: paga. Indonesia: katiau, nyatu yehrong, nyatu temiang (Kalimantan). Malaysia: samundo (Sarawak).

Distribution Borneo.

Uses The timber is used as bitis.

Observations A small to medium-sized tree up to 28 m tall; leaves clustered at tip of twigs, obovate or spoon-shaped, with few transverse tertiary veins usually indistinguishable from the reticulate venation in between, glabrous on both sides; flowers in 5–12-flowered axillary or terminal clusters, borne on 15–35 mm long pedicels, yellowish; fruit ellipsoid or subglobose, 2–2.5 cm long, glabrous and green. *P. cochleariifolium* grows in freshwater swamp (peat-swamp forest) and marshes at low altitudes, sometimes along the sea coast. The timber is heavy, the density is 1070–1120 kg/m^3 at 15% moisture content.

Selected sources 100, 743.

Palaquium dasyphyllum (de Vriese) Pierre ex Dubard

Bull. Soc. Bot. Fr. 56, Mém. 16: 8 (1909).

Synonyms *Palaquium stenophyllum* H.J. Lam (1925), *Madhuca dasyphylla* (de Vriese) Baehni (1965).

Vernacular names Indonesia: bitis nyatu batu, nyatu kelincir (Kalimantan). Thailand: phikun dong (Pattani).

Distribution Peninsular Thailand, the Riau Archipelago and Borneo.

Uses The timber may be used as nyatoh.

Observations A medium-sized tree up to 25 m tall; leaves evenly distributed, obovate to elliptical, with indistinct, slender, transverse tertiary veins, glabrous on both sides except lower side of midrib; flowers in 5–11-flowered clusters, borne on 8–16 mm long pedicels; fruit ovoid to obovoid or ellipsoid, 1–3 cm long, hairy but glabrescent, green. *P. dasyphyllum* grows in primary forest, on soil overlying rocks and limestone; locally it is not uncommon. The density of the timber is 500–760 kg/m^3 at 15% moisture content.

Selected sources 36, 100, 743.

Palaquium gutta (Hook.f.) Baillon

Traité bot. méd. phan., Add.: 1500 (1884).

Synonyms *Palaquium acuminatum* Burck (1886), *Palaquium oblongifolium* (Burck) Burck (1886), *Croixia gutta* (Hook.f.) Baehni (1965).

Vernacular names Gutta-percha tree (En). Indonesia: suntek (Java), balam abang (Sumatra), getah merah (Kalimantan). Malaysia: taban merah, nyatoh taban merah (Peninsular), nyatoh rian (Sarawak). Thailand: chik-nom (Ranong, Satun), saeo (Phatthalung).

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo; cultivated elsewhere, e.g. in Java.

Uses The timber is used as nyatoh, for planks (not exposed to the weather or ground), and furniture. The latex gives the best grade of gutta-percha. The seeds contain a fat used for the manufacture of soap and candles, and sometimes for cooking.

Observations A medium-sized to large tree up to 45 m tall, but generally much smaller (c. 25 m) with columnar bole up to 60 cm in diameter and usually small buttresses; leaves clustered at tip of twigs or evenly distributed, obovate, ovate, elliptical or narrowly elliptical, with transverse or reticulate tertiary veins (sometimes parallel to secondary veins), distinct or inconspicuous, golden-brownish velvety beneath; flowers in 2–7(–10)-flowered clusters, borne on 2–9(–12) mm long pedicels, whitish-green or yellowish; fruit globose, ellipsoid or ovoid, 2–3.5 cm long, finely hairy and green. *P. gutta* is a variable species, especially in its leaves. It occurs scattered in lowland forest, but sometimes up to 1600 m altitude (Sabah). The timber is fairly heavy for nyatoh, with a density of 610–910 kg/m^3 at 15% moisture content, and often shows attractive patterns. Gutta-percha can be obtained by tapping the bark or by extraction from the leaves; it is often blended with gutta-percha of inferior quality from other *Sapotaceae* species. The seeds contain 58–63% fat. See also the table on wood properties.

Selected sources 35, 36, 89, 100, 102, 190, 255, 315, 318, 322, 451, 461, 581, 730, 743, 779, 792.

Palaquium herveyi King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 197 (1905).

Synonyms *Croixia herveyi* (King & Gamble) Baehni (1965).

Distribution Peninsular Malaysia.

Uses The timber is used as nyatoh.

Observations A medium-sized to large tree up to 45 m tall, with columnar bole up to 60 cm in diameter and plank buttresses; leaves fairly densely clustered at tip of twigs, obovate (sometimes elliptical), with slender, inconspicuous, transverse tertiary veins, sparsely puberulous or almost glabrous, but glaucous beneath; flowers in 2–6-

flowered clusters, borne on c. 3 mm long pedicels (c. 10 mm in fruit); fruit globose to ellipsoid, 1–1.5 cm long, glabrous. *P. herveyi* occurs scattered in lowland primary forest up to 350 m altitude and is locally common. The density of the timber is about 700 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 190, 743, 779, 792.

Palaquium hexandrum (Griffith) Baillon

Traité bot. méd. phan., Add.: 1500 (1884).

Synonyms *Croixia hexandra* (Griffith) Baehni (1965).

Vernacular names Indonesia: balam nasih, balam pinang, balam putih (Sumatra). Malaysia: nyatoh jambak (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo.

Uses The timber is used as nyatoh. The latex is sometimes used to adulterate gutta-percha. The fruit is edible but sour. The seed yields a fat that may be used for cooking or as illuminant.

Observations A large tree up to 50 m tall, with columnar bole up to 80 cm in diameter and plank buttresses; leaves loosely clustered at tip of twigs, obovate (particularly in old trees), ovate, elliptical or narrowly elliptical (particularly in young trees), with slender transverse tertiary veins, initially puberulous but soon glabrous beneath; flowers in up to 20-flowered clusters, borne on 4–13 mm long pedicels (up to 22 mm in fruit), greenish-yellow; fruit globose, ovoid or ellipsoid, 2–3 cm long, glabrous. *P. hexandrum* occurs scattered in lowland primary forest and seasonal swamps, rarely up to 1300 m (Peninsular Malaysia). In some places it is very common (e.g. in Perak). The timber has a density of 450–770 kg/m^3 at 15% moisture content and is not durable when exposed to the weather or in contact with the ground; it is reddish-brown. The latex is abundant but glutinous.

Selected sources 36, 102, 190, 318, 461, 581, 743, 779, 792.

Palaquium hispidum H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 63 (1925).

Synonyms *Croixia hispida* (H.J. Lam) Baehni (1965).

Vernacular names Indonesia: mayang serikat (Sumatra). Malaysia: nyatoh tembaga kuning, nyatoh tembaga (Peninsular).

Distribution Peninsular Malaysia, northern Sumatra and Borneo (Sarawak).

Uses The timber is used as nyatoh. An inferior quality of gutta-percha can be obtained from the latex.

Observations A large tree up to 50 m tall, with columnar bole up to 115 cm in diameter and large buttresses; leaves clustered at tip of twigs, ovate, obovate or elliptical, with slender transverse tertiary veins rather distinct beneath, medium-brown to golden-brown hairy beneath; flowers in up to 25-flowered clusters, borne on 15–40 mm long pedicels, whitish; fruit globose or ellipsoid, 2–2.5 cm long, hairy or glabrous. *P. hispidum* occurs scattered in primary forest at low altitudes (up to 500 m). The timber is brown with a density of 650–680 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 36, 102, 190, 318, 743, 779, 792.

Palaquium impressinervium Ng

Gard. Bull. Sing. 24: 7 (1969; '*impressionervium*').

Vernacular names Malaysia: nyatoh surin (Peninsular).

Distribution Southern Thailand and Peninsular Malaysia.

Uses The timber is used as bitis.

Observations A large tree up to 50 m tall, with columnar, frequently fluted bole up to 115 cm in diameter and buttresses; leaves loosely to densely clustered at tip of twigs, elliptical to obovate, with reticulate to parallel-reticulate tertiary veins often sunken above, glabrous on both sides; flowers in c. 6-flowered clusters, borne on 12–20 mm long pedicels (up to 28 mm in fruit); fruit oblong, c. 3 cm long. *P. impressinervium* is locally common in forest on hill slopes below 350 m. The timber is heavy (about 950 kg/m^3 at 15% moisture content) and durable, but it is difficult to saw and bore and has poor nailing properties. It is moderately smooth to finish, it is difficult to peel and shrinks considerably during drying. See also the table on wood properties.

Selected sources 779, 792.

Palaquium kinabaluense P. v. Royen

Blumea 10: 475 (1960).

Distribution Borneo (Sarawak, Sabah).

Uses The timber is used as nyatoh.

Observations A large tree up to 50 m tall, with straight bole up to 120 cm in diameter and high plank buttresses; leaves more or less clustered at tip of twigs, obovate or slightly fiddle-shaped, with slender but distinct, transverse tertiary veins, initially sparsely hairy but glabrescent beneath;

flowers in 1–8-flowered clusters near apex of branches, borne on up to 4 mm long pedicels (up to 10 mm in fruit), cream-coloured; fruit unknown in mature condition. *P. kinabaluense* resembles *P. macrocarpum*, but it differs from the latter species in its larger leaves and stipules and glabrous anthers. This species is locally common in Sabah, in primary forest at medium altitudes (about 1000 m). The density of the timber is about 660 kg/m^3 at 15% moisture content.

Selected sources 100, 743.

Palaquium lanceolatum Blanco

Fl. Filip.: 403 (1837).

Synonyms *Madhuca pacifica* Baehni (1965).

Vernacular names Philippines: palak-palak (general), bagalangit (Tagalog), mikat (Ibanag).

Distribution The Philippines (Luzon).

Uses The timber is used as nyatoh for making cigar boxes, furniture and sometimes ship planking. The fruit is edible.

Observations A medium-sized tree; leaves clustered at tip of twigs, obovate to spatulate, with slender but distinct, transverse tertiary veins, glabrous on both sides; flowers in 5–8-flowered clusters, borne on long (25–38 mm) pedicels; fruit spindle-shaped or ellipsoid, 2.5–3.5 cm long, glabrous. The name *Palaquium lanceolatum* has been used by various authors for other species (e.g. for *P. merrillii* and *P. xanthochymum*). *P. lanceolatum* grows in rain forest at low and medium altitudes. The timber is traded as 'red nato' together with other *Palaquium* species and is available in very limited quantities. The heartwood is pale brown to reddish-brown, with a density of 450–620 kg/m^3 at 15% moisture content.

Selected sources 36, 480, 484, 486, 579. 743, 752.

Palaquium leiocarpum Boerl.

Bull. Inst. Bot. Buitenzorg 5: 24 (1900).

Synonyms *Palaquium molle* Pierre (1902), *Croixia leiocarpa* (Boerl.) Baehni (1965).

Vernacular names Indonesia: jongkang, getah hangkang, hangkang (Kalimantan). Malaysia: nyatoh jangkar, jangkai (Sarawak).

Distribution Borneo and Sulawesi; possibly also Peninsular Malaysia.

Uses The timber is used as nyatoh. The latex gives gutta-percha of rather inferior quality; it is often mixed with superior types of gutta-percha.

Observations 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, with few transverse tertiary veins almost parallel to secondary veins and with a reticulate venation in between, velvety beneath; flowers in 3–6-flowered clusters, borne on 8–15 mm long pedicels (in fruit up to 30 mm), whitish; fruit globose to ellipsoid, 1.5–2.5 cm long, glabrous. In Peninsular Malaysia a *Palaquium* species is found which is close to *P. leiocarpum* or perhaps represents this species. It is a large tree up to 40 m tall with bole up to 75 cm in diameter and large plank buttresses and frequently also stilt roots; locally it is very common in freshwater swamps and on hillsides up to 200 m altitude. In Borneo, *P. leiocarpum* is found in primary forests at low altitudes, but sometimes up to 1000 m. The timber is fairly heavy for nyatoh with a density of 610–790 kg/m^3 at 15% moisture content. The gutta-percha obtained from this species contains much resin (about 70%) and little poly-isoprene (about 30%).

Selected sources 36, 100, 102, 318, 461, 730, 743, 779.

Palaquium lobbianum Burck

Ann. Jard. Bot. Buitenzorg 5: 29 (1886).

Synonyms *Croixia lobbiana* (Burck) Baehni (1965).

Vernacular names Indonesia: tiwiring, tofiri lobi-lobi (Moluccas), tiurring (Irian Jaya).

Distribution The southern Philippines (Mindanao), the Moluccas and Irian Jaya.

Uses The boles of the trees are used for making canoes in the Moluccas.

Observations A small or medium-sized to large tree up to 40 m tall, with straight bole up to 50 cm diameter; leaves more or less clustered at tip of twigs, elliptical to obovate, with inconspicuous, slender, transverse tertiary veins, yellowish to brownish hairy beneath; flowers in 1–10-flowered clusters, often on short leafless branches, borne on 5–10(–15) mm long pedicels; fruit obliquely ovoid, 3–3.5 cm long, glabrous but pubescent at base. *P. lobbianum* grows on clayey or sandy soil in lowland primary forest. The timber is brown and not very durable.

Selected sources 36, 318, 743.

Palaquium luzoniense (Fernandez-Villar) S. Vidal

Revis. pl. vasc. filip.: 176 (1886).

Synonyms *Palaquium ahernianum* Merr. (1903), *Croixia luzoniensis* (Fernandez-Villar) Baehni (1965).

Vernacular names Philippines: nato (general), dolitan (Tagalog), gasatan (Iloko).

Distribution Throughout the Philippines, but probably not in Palawan.

Uses The timber forms the bulk of 'red nato' in the Philippines. It is used for furniture and cabinet making, cigar boxes and ship planking; it is also suitable for veneer and plywood. The latex is used for making gutta-percha.

Observations 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, with transverse to reticulate tertiary venation, minutely hairy beneath; flowers in 1–4-flowered clusters, borne on slender pedicels 20–65 mm long, yellowish-green or whitish; fruit ellipsoid, 3.5–4 cm long, initially minutely hairy but glabrescent, dull green. *P. luzoniense* is fairly common in primary forest at low and medium altitudes. The heartwood is reddish-brown, has a density of 440–670(–770) kg/m^3 at 15% moisture content, is easy to work and moderately durable for interior work. The timber is obtainable in limited quantities. The gutta-percha obtained from this species is of fairly good quality, and the trade was formerly important. See also the table on wood properties.

Selected sources 36, 175, 461, 480, 484, 486, 579, 743.

Palaquium macrocarpum Burck

Ann. Jard. Bot. Buitenzorg 5: 32 (1886).

Synonyms *Croixia macrocarpa* (Burck) Baehni (1965).

Vernacular names Indonesia: pintek kayu, punti kayu, nyatu kayu balam (Sumatra).

Distribution Peninsular Malaysia (rare) and Sumatra; possibly also Sulawesi and the Moluccas.

Uses The timber may be used as nyatoh or bitis. It is used in Sumatra for boats. The fruits are edible.

Observations A medium-sized to large tree up to 45 m tall, with straight cylindrical bole up to 90 cm in diameter but usually much less; leaves more or less clustered at tip of twigs, obovate, elliptical or oblong, with distinct but slender, transverse tertiary veins, sparsely hairy but glabrescent beneath; flowers usually in 5–9-flowered clusters, borne on 5–13 mm long pedicels; fruit ovoid or ellipsoid, large (5–11 cm long), glabrous. *P. macrocarpum* is found in forest, often in freshwater swamps, up to 1000 m altitude. It has probably often been confused with other *Palaquium* species.

Selected sources 36, 102, 318, 743, 779.

Palaquium maingayi (C.B. Clarke) King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 191 (1905).

Synonyms *Croixia maingayi* (C.B. Clarke) Baehni (1965).

Vernacular names Malaysia: nyatoh tembaga, sundik, getah ketapang (Peninsular). Thailand: chik-khao (Chumphon, Surat Thani), chik-nomhin (Pattani), yak-keng (Malay, Pattani).

Distribution Southern Thailand and Peninsular Malaysia (except Perlis, Pinang, Terengganu).

Uses The timber is used as nyatoh. The latex makes gutta-percha of moderate quality, often used as an adulterant for gutta-percha from *P. gutta*.

Observations A fairly large tree up to 40 m tall, with columnar bole up to 115 cm in diameter and usually prominent buttresses; leaves densely to loosely clustered at tip of twigs, obovate or sometimes oblong-elliptical, with distinct, transverse tertiary veins, brownish woolly-hairy beneath; flowers in up to over 30-flowered clusters, borne on 7–15 mm long pedicels (up to 25 mm in fruit), whitish; fruit globose or ellipsoid, 2–3.5 cm long, glabrous. *P. maingayi* is common in lowland forest up to 400 m, sometimes up to 1100 m. The timber has a density of 570–850 kg/m^3 at 15% moisture content, is easy to saw, smooth to finish and the nailing and boring properties are rated as good. It is moderately durable, but has great durability when treated with appropriate preservatives. The gutta-percha contains about 50% resin. See also the table on wood properties.

Selected sources 36, 102, 190, 318, 419, 581, 743, 779, 792.

Palaquium merrillii Dubard

Bull. Mus. Hist. Nat. Paris 15: 381 (1909).

Vernacular names Philippines: dulitan (Tagalog), mikat (Ibanag), bulau-bulau (Panay Bisaya).

Distribution The Philippines.

Uses The timber is used as nyatoh for furniture, cabinet work and cigar boxes.

Observations A medium-sized tree up to 25 m tall; leaves evenly distributed or loosely clustered at tip of twigs, obovate to oblanceolate, with rather distinct, transverse tertiary veins, glabrous on both sides when mature; flowers in 2–4-flowered clusters, borne on 5–12 mm long pedicels (in fruit up to 15 mm); fruit ellipsoid, c. 2 cm long, glabrous. *P. merrillii* grows in primary forests at low and medium altitudes. The timber is traded as 'red nato' together with other *Palaquium* species, and is pale brown to reddish-brown and resembles the timber of *P. barnesii*.

Selected sources 480, 484, 486, 743.

Palaquium microphyllum King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 196 (1905).

Synonyms *Croixia microphylla* (King & Gamble) Baehni (1965).

Vernacular names Indonesia: nyatoh lakis (Bangka), nyatoh merah (Kalimantan). Malaysia: nyatoh pipit (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra, Lingga, the Riau Archipelago and Borneo.

Uses The timber is used locally as nyatoh for house building and furniture.

Observations A fairly large tree up to 35(–45) m tall, with columnar bole up to 85 cm in diameter, with buttresses; leaves more or less clustered at tip of twigs, spatulate, with slender, reticulate tertiary veins often parallel to secondary veins, initially finely hairy beneath but glabrescent; flowers in 1–5-flowered clusters, borne on short (2–5 mm) pedicels; fruit globose to obovoid, 1.2–2.2 cm long, glabrous. *P. microphyllum* occurs very scattered in lowland and swamp forest, usually below 500 m but occasionally up to 1000 m. It is only very locally common, e.g. in Johor (Peninsular Malaysia). The timber is usually fairly heavy for nyatoh, with a density of 530–920 kg/m^3 at 15% moisture content.

Selected sources 36, 100, 102, 190, 318, 461, 581, 743, 779, 792.

Palaquium obovatum (Griffith) Engl.

Bot. Jahrb. Syst. 12: 511 (1890).

Synonyms *Isonandra obovata* Griffith (1854), *Palaquium theoideum* Elmer (1910; *'theoidea'*).

Vernacular names Indonesia: mayang katapong, balam terupuh (Sumatra), siki putih (Moluccas). Malaysia: nyatoh puteh (Peninsular). Philippines: lahas (Subanon). Burma: pinle-byin. Cambodia: sang das, chor ny, chlôr. Thailand: khanun-nok, saang (Chanthaburi), yue-raa-toh (Malay, Pattani). Vietnam: ch[aa]y.

Distribution India, Burma, Indo-China, Thailand, Peninsular Malaysia Sumatra, Lingga, the Riau Archipelago, Bangka, Borneo (Sarawak), Sulawesi, the Philippines (Luzon, Mindoro, Sibuyan, Samar), Flores and the Moluccas.

Uses The timber is used as nyatoh locally for house building. The latex is used as an adulterant for gutta-percha.

Observations 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(-oblong), with distinct, transverse tertiary venation, puberulous or glabrous and glaucous beneath; flowers in 4–12-flowered clusters, borne on (4–)9–20 mm long pedicels, greenish-yellow or greenish-white; fruit globose, ellipsoid to obpyriform, 2–3 cm long, glabrous. 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. *P. obovatum* is a fairly common species of lowland forest, up to 1300 m altitude. The wood has a density of 580–760 kg/m^3 at 15% moisture content. The gutta-percha prepared from the latex is white and of inferior quality. See also the table on wood properties.

Selected sources 36, 102, 190, 235, 318, 451, 480, 486, 578, 581, 642, 643, 743, 779, 792.

Palaquium obtusifolium Burck

Ann. Jard. Bot. Buitenzorg 5: 33 (1886).

Synonyms *Palaquium negrosense* Merr. (1915), *Palaquium ternatense* H.J. Lam (1925), *Madhuca obtusifolia* (Burck) Baehni (1965).

Vernacular names Indonesia: tatahaan, weluan (Sulawesi), tofiri mojui (Moluccas). Philippines: negros nato (general).

Distribution Sumatra, the Lesser Sunda Islands, Sulawesi, the Philippines (Negros, Mindanao), the Moluccas and Irian Jaya.

Uses The timber is used as nyatoh, but only for indoor use; locally it is used for canoes.

Observations A large tree up to 45 m tall, with bole up to 100 cm in diameter, with buttresses; leaves evenly distributed or loosely clustered at tip of twigs, obovate, spatulate or elliptical, with slender, transverse tertiary veins, initially sparsely pubescent beneath but soon glabrous; flowers in 2–5-flowered clusters, borne on 9–15(–32) mm long pedicels, yellowish to brownish; fruit ovoid or obovoid, 3–4 cm long, glabrous and greenish. *P. obtusifolium* is found in lowland primary forest. The timber is moderately light to moderately heavy (density of 390–740 kg/m^3 at 15% moisture content) and not very strong or durable when exposed to the weather or in contact with the ground.

Selected sources 36, 318, 461, 480, 486, 743.

Palaquium ottolanderi Koord. & Valeton

Bijdr. Boomsoorten Java 1: 146 (1894).

Synonyms *Croixia ottolanderi* (Koord. & Valeton) Baehni (1965).

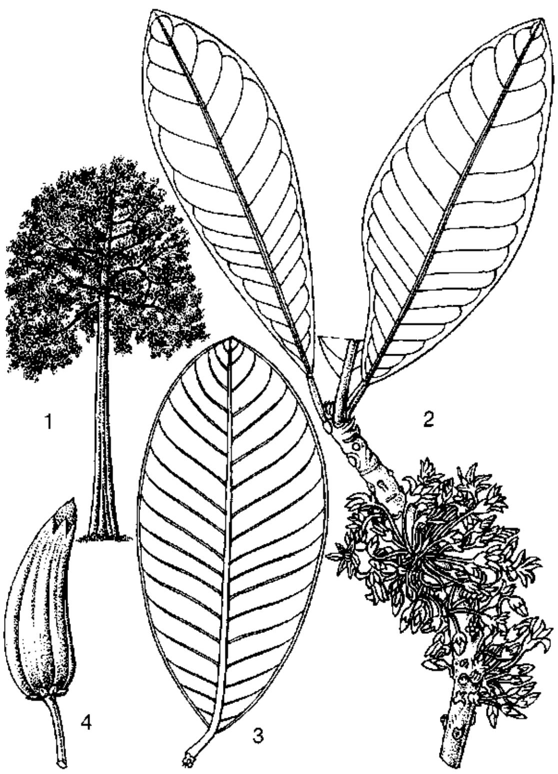
Vernacular names Indonesia: wuru santen, ki bengang (Java).

Distribution Peninsular Malaysia, Sumatra and Java.

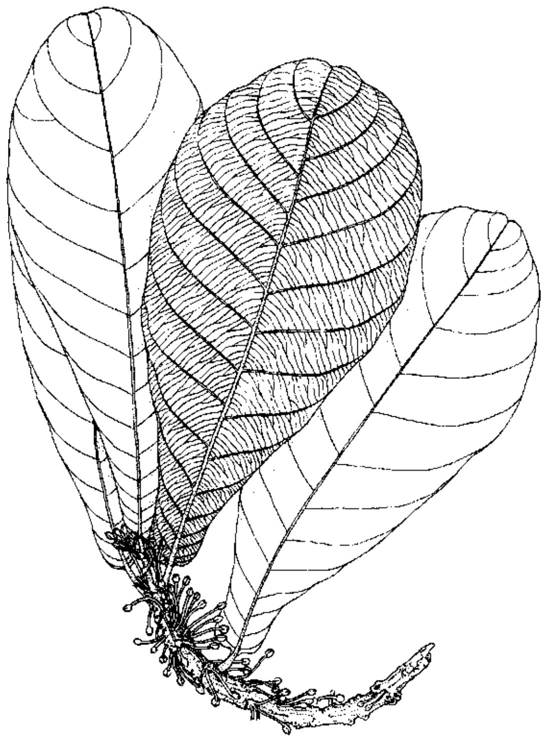
Uses The timber is probably used as nyatoh.

Observations A medium-sized to large tree up to 50 m tall, with columnar bole up to 100 cm in diameter and plank buttresses; leaves densely clustered at tip of twigs, broadly obovate to elliptical, with distinct, transverse tertiary veins, densely woolly beneath; flowers in 5–16-flowered clusters, borne on 20–50 mm long pedicels; fruit narrowly ovoid or more or less gherkin-shaped, 6–10 cm long, glabrous and shining green. *P. ottolanderi* is uncommon to rare throughout its area of distribution, and occurs in primary and secondary forest at low altitudes, up to 800 m.

Selected sources 35, 36, 743, 779.



Palaquium ottolanderi Koord. & Valeton – 1, tree habit; 2, flowering twig; 3, leaf; 4, fruit.



Palaquium philippense (Perrottet) C. Robinson – flowering twig and leaf showing tertiary venation.

Palaquium philippense (Perrottet) C. Robinson

Philipp. Journ. Sc. 3: 304 (1908).

Synonyms *Madhuca philippensis* (Perrottet) Baehni (1965).

Vernacular names Philippines: malak-malak (Tagalog, Pampangan), dalakan (Iloko), manogtalisai (Panay Bisaya).

Distribution The Philippines (Luzon, Leyte, Mindoro, Panay, Negros, Mindanao).

Uses The timber is used as nyatoh for furniture and cabinet making, cigar boxes and ship planking. The fruit is edible. The seeds yield an oil which is used for illumination or for cooking.

Observations A medium-sized tree up to 25 m tall, with bole up to 80(–120) cm in diameter; leaves clustered at tip of twigs, obovate, narrowly obovate to spatulate, with inconspicuous transverse tertiary venation, densely yellowish-brown hairy beneath; flowers in 4–7-flowered clusters, borne on 13–45 mm long pedicels, greenish-yellow or greenish-white; fruit ellipsoid, c. 3 cm long, glabrous and green. *P. philippense* is common in primary forests at low and medium altitudes. The heartwood is reddish-brown, with a density of

440–610 kg/m^3 at 15% moisture content. The timber is traded as 'red nato', together with other *Palaquium* species, and is obtainable in limited quantities; it is moderately strong, easy to work, but very perishable when exposed to the weather or in contact with the ground.

Selected sources 36, 175, 451, 480, 484, 486, 579, 743.

Palaquium pseudocuneatum H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 391 (1927).

Synonyms *Croixia pseudocuneata* (H.J. Lam) Baehni (1965).

Vernacular names Malaysia: nyatoh kelalang, salanglang (Sarawak).

Distribution Borneo (Sarawak, Brunei, Sabah, West Kalimantan).

Uses The timber is used as nyatoh.

Observations A medium-sized to fairly large tree up to 35 m tall; leaves more or less clustered at tip of twigs, spatulate or obovate, with distinct, reticulate tertiary veins more or less parallel to secondary veins, glabrous on both sides; flowers in 2–4-flowered clusters, borne on 5–12 mm long pedicels; fruit globose to ellipsoid, 1.5–2 cm long, glabrous. *P. pseudocuneatum* occurs in lowland forest, particularly in swamps. The timber has a density of about 540 kg/m^3 at 15% moisture content.

Selected sources 36, 100, 743.

Palaquium pseudorostratum H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 393 (1927).

Synonyms *Croixia pseudorostrata* (H.J. Lam) Baehni (1965).

Vernacular names Malaysia: nyatoh batu, nyatoh puntik (Sarawak).

Distribution Borneo (Sarawak, Sabah, Kalimantan); possibly also in the Philippines.

Uses The timber is used as nyatoh.

Observations A large tree up to 45 m tall; leaves evenly distributed, obovate to spatulate, with inconspicuous, laxly reticulate tertiary veins often parallel to secondary veins, glabrous on both sides; flowers in 2–4-flowered clusters, borne on very short pedicels about 1.5(–7) mm long, greenish-yellow or whitish; fruit globose, subglobose or ellipsoid, 1–1.5 cm long, glabrous and green. *P. pseudorostratum* grows particularly in freshwater swamp forest at low altitudes, but sometimes up to 1500 m. The timber is fairly heavy with a density of about 780 kg/m^3 at 15% moisture content.

Selected sources 36, 100, 743.

Palaquium quercifolium (de Vriese) Burck

Ann. Jard. Bot. Buitenzorg 5: 41 (1886).

Synonyms *Palaquium macrophyllum* (de Vriese) Pierre ex Dubard (1909), *Croixia quercifolia* (de Vriese) Baehni (1965).

Vernacular names Indonesia: kerekit, nyatu tinggang (Kalimantan).

Distribution Borneo (Kalimantan, Sabah, Brunei), Sulawesi and the Moluccas; possibly also in Sumatra.

Uses The timber is used as nyatoh. The latex is sometimes made into gutta-percha of inferior quality.

Observations A large tree up to 40 m tall; leaves evenly distributed, narrowly obovate or narrowly elliptical, with slender, transverse tertiary veins, brownish or reddish hairy beneath; flowers in 4–8-flowered clusters, borne on 8–14 mm long pedicels (15–25 mm in fruit); fruit globose, c. 2 cm in diameter, glabrous. *P. quercifolium* is found particularly in primary forest in the lowland. The density of the timber is 460–610 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 461, 743.

Palaquium regina-montium Ng

Gard. Bull. Sing. 24: 9 (1969).

Vernacular names Malaysia: nyatoh gunong (Peninsular).

Distribution Peninsular Malaysia (Perak, Selangor, Pahang).

Uses The timber is used as nyatoh.

Observations A medium-sized tree up to 30 m tall, with columnar bole, sometimes slightly fluted or knobbly, up to 100 cm in diameter; leaves loosely clustered at tip of twigs, obovate (sometimes elliptical), with few, inconspicuous, transverse tertiary veins, velvety beneath; flowers in up to 6-flowered clusters, in some trees exclusively female, borne on c. 12 mm long pedicels; fruit obovoid, c. 2.5 cm long, initially sparsely hairy but glabrescent. *P. regina-montium* is locally very common in montane forest at 1000–1800 m altitude. The trees are deciduous, all individuals in a certain area shedding the leaves at the same time and flowering as the new leaves appear. The timber is fairly heavy, with a density of about 750 kg/m^3 at 15% moisture content.

Selected sources 779, 792.

Palaquium ridleyi King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 196 (1905).

Vernacular names Indonesia: balam rambai, balam seminai (Sumatra), kandole (Sulawesi). Malaysia: bitis paya, mayang (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra, Borneo, the Lesser Sunda Islands, Sulawesi, the Philippines (Luzon, rare) and Irian Jaya; possibly also in Vietnam.

Uses The timber is used as bitis. It is used for beams and posts.

Observations A medium-sized to large tree up to 40 m tall, with columnar, often fluted bole usually up to 50 cm in diameter and buttresses; leaves more or less clustered at tip of twigs, obovate to elliptical, with very fine, transverse tertiary venation, glabrous on both sides; flowers in 5–18-flowered clusters, often along a leafless terminal shoot, borne on slender 3–7(–14) mm long pedicels, greenish-white or greenish-yellow; fruit obovoid, ellipsoid or globose, 1–1.5 cm long, glabrous. *P. ridleyi* usually occurs scattered in swamp forests, sometimes on hills up to 800 m altitude. The timber is purplish or reddish-brown, heavy (875–1120 kg/m^3 at 15% moisture content) and very hard. See also the table on wood properties.

Selected sources 100, 102, 190, 235, 318, 578, 581, 699, 743, 779.

Palaquium rioense H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 89 (1925).

Vernacular names Malaysia: getah keras, ketipei pan (Sabah).

Distribution Borneo (Sabah, East Kalimantan).

Uses The timber is used as nyatoh.

Observations A large tree up to 50 m tall; leaves evenly distributed, obovate, ovate or elliptical, with transverse tertiary veins, appressed-hairy beneath; flowers in 2–4-flowered clusters, borne on (3–)6–16 mm long pedicels (in fruit up to 20 mm), greenish or brownish; fruit obovoid, c. 1.5 cm long, glabrous, dark green. *P. rioense* is most commonly found in primary montane forest at 1200–2000 m altitude. The density of the timber is c. 650 kg/m^3 at 15% moisture content.

Selected sources 100, 743.

Palaquium rostratum (Miq.) Burck

Ann. Jard. Bot. Buitenzorg 5: 39 (1886).

Synonyms *Palaquium bancanum* Burck (1886), *Croixia rostrata* (Miq.) Baehni (1965).

Vernacular names Indonesia: balam bakulo, nyatoh terong (Sumatra), nagasari (Java). Malaysia: nyatoh sidang (Peninsular).

Distribution Southern Thailand, Peninsular Malaysia, Sumatra, Borneo, Java, the Lesser Sunda Islands, Sulawesi and the Moluccas.

Uses The timber is used as nyatoh for indoor construction, flooring, furniture and implements; sometimes also for making boats. The fruits are edible, and the seeds yield a fat suitable for cooking.

Observations A very large tree up to 60 m tall, with columnar bole up to 120(–210) cm in diameter and large plank buttresses; leaves more or less clustered at tip of twigs, obovate, spatulate or sometimes elliptical, with reticulate tertiary venation, often with tertiary veins parallel to secondary ones, glabrous on both sides; flowers in 1–5-flowered clusters, borne on short pedicels 0.5–3(–12) mm long, yellowish or greenish-white to slightly brownish; fruit oblong or ellipsoid, 2–3.5 cm long, glabrous and green. *P. rostratum* usually grows in primary forest at low altitudes, sometimes up to 1500 m, often in swampy forests. It is common in several areas, e.g. in Peninsular Malaysia and Borneo and is one of the most important producers of nyatoh. The timber is reddish-brown with a density of 480–760 kg/m^3 at 15% moisture content and is easy to work. The bark yields scanty latex. The fat in the seed tastes bitter.

Selected sources 35, 36, 89, 100, 102, 190, 318, 481, 581, 743, 779, 792.

Palaquium semaram H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 43 (1925).

Synonyms *Croixia semaram* (H.J. Lam) Baehni (1965).

Vernacular names Indonesia: balam hitam, balam seminai (Sumatra), lakis bukit daun lebar (Lingga). Malaysia: nyatoh semaram, semaram (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Lingga.

Uses The timber is used as nyatoh. The seeds yield a fat which may be used for cooking.

Observations A large tree up to 50 m tall, with columnar bole, often free of branches for over 25 m, up to 90 cm in diameter and with large plank buttresses; leaves densely clustered at tip of twigs, spatulate or obovate, with reticulate tertiary venation, often with tertiary veins parallel to secondary ones, initially woolly on midrib beneath, otherwise glabrous; flowers in 2–9-flowered clusters, borne on 8–20 mm long pedicels, pale yellow; fruit obovoid or ellipsoid, 2.5–3.5 cm long, glabrous (often except at base and apex) and green. *P. semaram* is fairly common in lowland forest (up to 500 m altitude), but occurs scattered in the forest, often in marshy places. The timber is dark brown, with a density of 680–820 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 190, 318, 743, 779, 792.

Palaquium stellatum King & Gamble

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 74(2): 198 (1905).

Synonyms *Bassia watsoni* Ridley (1923), *Madhuca watsoni* (Ridley) H.J. Lam (1925).

Vernacular names Indonesia: balam seminai (Sumatra). Malaysia: bitis bukit, putat bukit (Peninsular).

Distribution Peninsular Malaysia, Sumatra and the Riau Archipelago.

Uses The timber is used as bitis. It is used for planks in house building, but also for beams and posts. The fruit is edible, and the seeds yield a fat used as vegetable butter. The latex may be used as gutta-percha.

Observations A very large tree up to 60 m tall, with bole up to 2.5 m in diameter and large plank buttresses; leaves densely clustered at tip of twigs, obovate to elliptical, with slender but distinct, transverse tertiary veins, glabrous on both sides except midrib which is usually finely hairy on both sides; flowers in 3–6-flowered clusters usually at ends of twigs, borne on 12–22 mm long pedicels, white; fruit ellipsoid or subglobose, 2–2.5 cm long, hairy but glabrescent, green. *P. stellatum* is an uncommon tree of low altitudes, usually below 300 m. The timber is heavy with a density of 820–1050 kg/m^3 at 15% moisture content.

Selected sources 102, 190, 318, 581, 699, 743, 779.

Palaquium sukoei C. Fischer

Kew Bull.: 365 (1933).

Vernacular names Malaysia: nyatoh mayang. Burma: pinle-byin-anti.

Distribution Burma and Peninsular Malaysia.

Uses The timber is used as nyatoh.

Observations A medium-sized to large tree up to 40 m tall, with bole up to 70 cm in diameter and sometimes with small buttresses; leaves usually densely clustered, broadly obovate to elliptical, with laxly reticulate tertiary venation, glabrous on both sides; flowers in 1–4-flowered clusters, borne on 8–22 mm long pedicels, yellowish-white; fruit ellipsoid, 2–5 cm long, densely lepidote-hairy. *P. sukoei* occurs scattered in forest at low and medium altitudes up to 700 m. The timber is heavy for nyatoh, about 820 kg/m^3 at 15% moisture content.

Selected sources 743, 779, 792.

Palaquium sumatranum Burck

Ann. Jard. Bot. Buitenzorg 5: 34 (1886).

Vernacular names Indonesia: balam sudu-sudu, balam pipit (Sumatra), nyato gummy (Kalimantan). Thailand: phikun pa (Trang).

Distribution Southern Thailand, Sumatra, the Riau Archipelago, Belitung, and Borneo (Kalimantan, Sabah).

Uses The timber is used as nyatoh.

Observations A large tree up to 45 m tall, with columnar bole up to 80 cm in diameter; leaves evenly distributed, narrowly elliptical or elliptical to obovate, with distinct, reticulate tertiary veins often parallel to secondary veins, glabrous on both sides; flowers in 2–5-flowered clusters, borne on 5–10 mm long pedicels (up to 22 mm in fruit), greenish or brownish-white; fruit ovoid, obovoid or ellipsoid, 2–5 cm long, glabrous. *P. sumatranum* grows in primary forest in the lowland, sometimes up to 1200 m altitude.

Selected sources 318, 743.

Palaquium tenuipetiolatum Merr.

Bur. Govt. Lab. 17: 45 (1904).

Synonyms *Croixia tenuipetiolata* (Merr.) Baehni (1965).

Vernacular names Philippines: maniknik (general), dulitan-pula (Tagalog), pango (Ibanag).

Distribution The Philippines (Luzon, Mindoro, Masbate, Mindanao).

Uses The timber is used as nyatoh for cigar boxes, furniture and in-house decoration.

Observations A medium-sized to fairly large tree up to 35 m tall; leaves evenly distributed, obovate, lanceolate or oblanceolate, with few, inconspicuous, transverse tertiary veins, initially hairy but soon becoming glabrous; flowers in 1–4-flowered clusters, borne on 3–8 mm long pedicels; fruit ovoid to narrowly ellipsoid, 2.5–3 cm long, glabrous and brownish. *P. tenuipetiolatum* is common in primary forest at low and medium altitudes. The timber is obtainable in limited quantities; it is reddish or purplish-brown and is grouped together with other *Palaquium* species under 'red nato'.

Selected sources 36, 480, 484, 486, 579, 743.

Palaquium walsurifolium Pierre ex Dubard

Bull. Soc. Bot. Fr. 56, Mém. 16: 22 (1909; 'walsuraefolium').

Vernacular names Indonesia: balam putih, balam serindit (Sumatra), nyatoh jangkar (Kalimantan).

Distribution Sumatra and Borneo (Sarawak, Sabah, Kalimantan); possibly also in Peninsular Malaysia.

Uses The timber is used as nyatoh, especially for planks. The latex is sometimes used to adulterate gutta-percha. The fruits are edible. The seeds yield a fat which is used as illuminant.

Observations A medium-sized to fairly large tree up to 37 m tall with bole usually up to 50 cm in diameter and having stilt roots; leaves loosely clustered at tip of twigs, obovate, with inconspicuous, transverse tertiary venation, initially pubescent beneath but soon glabrous; flowers in 2–4-flowered clusters, borne on 3–7 mm long pedicels (in fruit up to 20 mm long); fruit globose or ellipsoid, 1–2 cm long, glabrous. *P. walsurifolium* usually grows in marshy forest or on peaty soils and is locally common. The timber is yellowish-brown, with a density of 560–840 kg/m^3 at 15% moisture content.

Selected sources 100, 190, 318, 461, 743, 779.

Palaquium xanthochymum (de Vriese) Pierre ex Burck

Ann. Jard. Bot. Buitenzorg 5: 30 (1886).

Synonyms *Croixia xanthochyma* (de Vriese) Baehni (1965).

Vernacular names Indonesia: nyatoh renggong (Bangka), nyatu ringkau, nyatu bawui (Kalimantan). Malaysia: nyatoh kabu, nyatoh babi, nyatoh baya (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra, the Riau Archipelago, Lingga, Bangka, Java, Borneo (Kalimantan) and the Philippines (Luzon, rare).

Uses The timber is used as nyatoh, for boards, boats and furniture. The seeds yield fat sometimes used for cooking.

Observations A large tree up to 45 m tall, with bole up to 80 cm in diameter and with buttresses and stilt roots; leaves evenly distributed or loosely clustered at tip of twigs, obovate to spatulate, with inconspicuous, laxly reticulate to transverse tertiary venation, glabrous or sometimes puberulous beneath, drying reddish; flowers in 3–7-flowered clusters, borne on 3–12 mm long pedicels (up to 22 mm in fruit), white; fruit narrowly ellipsoid, 3–5 cm long, glabrous. Several varieties have been distinguished, especially in Sumatra, differing in the stipules, length of the pedicels and texture of the leaves. *P. xanthochymum* occurs scattered in lowland forest, particularly in freshwater swamps and low hillsides. The timber is fairly light with a density of 460–650 kg/m^3 at 15% moisture content.

Selected sources 35, 36, 102, 190, 318, 581, 743, 779, 792.

J. Kartasubrata (general part),
N. Tonanon (properties),
R.H.M.J. Lemmens (properties, selection of species),
R. Klaassen (wood anatomy)

Paraserianthes Nielsen

Bull. Mus. Natn. Hist. Nat., 4e sér., sect. B, Adansonia 5: 326 (1983).

LEGUMINOSAE

$x = 13$; *P. falcataria* subsp. *falcataria*: $2n = 26$

Trade groups Batai: lightweight timber, e.g. *Paraserianthes falcataria* (L.) Nielsen.

Vernacular names Batai. Brunei: puah. Indonesia: jeungjing (general), sengon laut (Java), sika (Moluccas). Malaysia: kayu machis (Sarawak). Papua New Guinea: white albizia. Philippines: Moluccan sau, falcata.

Origin and geographic distribution *Paraserianthes* consists of 4 species. It is native to Sumatra, Java, Bali and Flores, the Moluccas, New Guinea, the Solomon Islands and Australia. Its origin probably lies in the eastern Malesian area as the largest diversity is found here. The peculiar disjunct distribution of the two subspecies of *P. lophantha* (Willd.) Nielsen (south-western Australia and Sumatra, Java, Bali and Flores, respectively), a shrub or small tree, is thought to have originated from a once more continuous distribution, probably during the cooler and less humid glacial periods in the Pleistocene. At present species of this genus are widely planted throughout the tropics.

Uses The comparatively soft wood of batai is suitable for general utility purposes such as light construction, especially rafters, panelling, interior trim, furniture and cabinet work. As the wood is not durable and susceptible to various kinds of insect and fungal attacks, it should be used under cover and not in contact with the ground. It is useful for lightweight packing materials such as packages, boxes, cigar and cigarette boxes, crates, tea chests and pallets. It is a well-known source for matches. Because the wood is fairly easy to cut, batai is also suitable for wooden shoes, musical instruments, toys and novelties, forms and general turnery. Batai is an important source of lightweight veneer and plywood and is very suitable for the manufacture of light- and medium-density particle board, wood-wool board and hardboard and has recently also been used for blockboard. The wood is also fairly extensively used to supply pulp for the manufacture of paper and has been used for the manufacture of viscose rayon. Batai is commonly planted for reforestation and afforestation of vacant and denuded forest lands and for firewood and charcoal production, although it is generally not valued as firewood. Its suitability as a shade tree for tea and other crops is limited because solitary trees are easily damaged by wind.

The leaves are sometimes used as a fodder for chickens and goats. The bark is reported to serve for tanning nets in Ambon, and it is sometimes used locally as a substitute for soap. It is also stripped from the tree and used for packing purposes. The pods have been used as a substitute for peté beans (*Parkia speciosa* Hassk.).

Production and international trade In Japan there is a great demand for batai wood for manufacture of lightweight furniture and furniture components (e.g. drawer sides); the butt log portion is used particularly for these purposes. Timber from natural and plantation-grown trees is imported in Japan, but no statistics are available.

Properties Batai is a lightweight, soft to moderately soft wood. The colour of the heartwood ranges from whitish to pale pinkish-brown or light yellowish- to reddish-brown (in older trees); the heartwood of younger trees is not clearly demarcated from the sapwood (pale coloured), but it is more distinct in older trees. The density is (230–)300–500 kg/m^3 at 12% moisture content. The grain of the wood is straight or interlocked, texture moderately coarse but even.

At 12% moisture content the modulus of rupture is 48–58 N/mm^2, modulus of elasticity 6900–8830 N/mm^2, compression parallel to grain 27(–58) N/mm^2, compression perpendicular to grain 2 N/mm^2, shear 6–9 N/mm^2, cleavage (at 15% moisture content) 33 N/mm radial and 35.5 N/mm tangential, Janka side hardness 1165 N at 15% moisture content and 2000 N at 12% moisture content, and Janka end hardness (at 15% moisture content) 2175 N.

The rates of shrinkage are moderate, from green to 12% moisture content 1.1–2.1% radial and 2.6–4.0% tangential, and from green to oven dry (2.1–)2.5–3.4% radial and (3.6–)5.0–6.5% tangential. Batai wood usually air dries fairly rapidly without serious degrade, and the kiln- drying properties are satisfactory. The most common drying defect is bowing. Boards of 12 mm thick air dry in about one month, but boards of 40 mm thick may take 2.5–3 months to air dry from green to 15% moisture content. Boards of 2.5 cm thick can be kiln dried to 10% moisture content in 4 days, at a temperature of 49–77°C and corresponding moisture content of 79% to 33%. The stability of the wood after drying is good; movement in service is small.

Batai is easy to work with machines and hand tools, but, although the wood is non-siliceous, it is reported to be abrasive to saws due to pinching and subsequent burning of sawteeth as a result of tension stresses relieved in the wood. Sharp knives are needed to produce smooth surfaces in planing; if not, grain may pick up badly after planing, especially on radial surfaces. Best planing results are obtained when a 20° cutting angle is used. The wood moulds and mortises well but tension wood, if present, will give a woolly surface. Boring is usually easy, but the nailing properties are rated as poor. Gluing is no problem. Batai peels and slices easily without pretreatment into veneer of 0.8 mm or 1.6 mm thick; the veneer produced is of good quality, light and smooth, with curly figure, and can be dried easily. Batai is very suitable for low- and medium-density particle boards (density 427–613 kg/m^3). The pulping characteristics of the wood are excellent; batai is listed among the best tropical woods recommended for pulping. The strength properties of kraft and soda pulps are comparable to good-quality eucalypt pulp, and the neutral sulphite semi-chemical process also produces pulp with excellent strength properties. Only minimum bleaching is required to achieve high-quality, white paper, because of the paleness of the wood.

Batai wood is not durable when used outside. Graveyard tests in Indonesia showed an average service life in contact with the ground of 0.5–2.1 years. It is often highly vulnerable to attack by termites, powder-post beetles and fungi. The wood can be treated easily with preservatives by the open tank procedure and using a mixture of creosote and diesel fuel. Stake tests showed an average life in contact with the ground of 15 years under tropical conditions when the stakes had been treated with preservatives.

Sawdust from dry wood may cause allergic reactions and may irritate nose and throat. Batai wood contains 49% cellulose, 27% lignin, 15.5% pentosan, 0.6% ash and 0.2% silica. The solubility is 3.4% in alcohol-benzene, 3.4% in cold water, 4.3% in hot water and 19.6% in a 1% NaOH solution. The energy value of the wood is 19 500–20 600 kJ/kg.

Description Unarmed trees (or shrubs) up to 40 m tall; bole generally straight and cylindrical in dense stands, branchless for up to 20 m and up to 100 cm or sometimes more in diameter; buttresses small or absent; bark surface white, grey or greenish, smooth or slightly warty, sometimes shallowly fissured and with longitudinal rows of lenticels, inner bark white, yellowish, pink or pale red-brown, fibrous; young parts often densely tomentose. Leaves alternate, bipinnate, the rachis and pinnae with extrafloral nectaries; stipules linear or filiform, caducous; leaflets opposite, many. Inflorescence axillary, consisting of pedunculate spikes or racemes, the spikes sometimes arranged in panicles. Flowers bisexual, regular, 5-merous, subtended by bracts; calyx valvate, gamosepalous, tubular to cup- or bell-shaped; corolla valvate, gamopetalous, funnel- or bell-shaped, creamy to yellowish; stamens numerous, the filaments united at base into a tube which is shorter or longer than the corolla, anthers quadrangular, minute, opening by longitudinal slits; ovary solitary, shortly stipitate or sessile, glabrous. Fruit a chartaceous, flat, straight pod, not segmented, dehiscent along both sutures, many-seeded. Seed subcircular to oblong, flat to convex, without aril, with a thick sclerified exotesta, not winged; endosperm absent; cotyledons large. Seedling with epigeal germination; cotyledons stipulate, sessile; first two leaves opposite or arranged spirally, pinnate or bipinnate, subsequent leaves bipinnate.

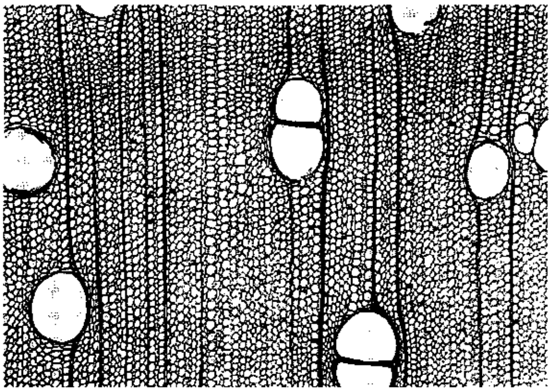
Wood anatomy

– Macroscopic characters:

Demarcation between sapwood and heartwood usually indistinct, heartwood white to pale pink or light reddish-brown, with little figure or no figure at all. Grain usually interlocked, sometimes straight. Texture moderately coarse and even. Growth rings indistinct; vessels readily visible to the naked eye, without deposits; parenchyma paratracheal and sparse, visible with a 10× hand lens as distinct sheaths to the vessels, and diffuse, appearing as small white dots at cross-section; rays fine and visible with a lens at cross-section. Ripple marks absent.

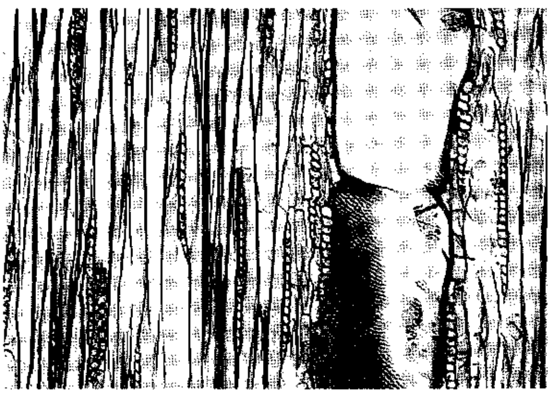
– Microscopic characters:

Growth rings indistinct. Vessels diffuse, 1–3(–4)/



transverse section (×25)

radial section (×75)



tangential section (×75)

Paraserianthes falcataria

mm^2, solitary and in radial multiples of 2(–3), mostly circular to oval, average tangential diameter 160–340 μm, perforations simple; intervessel pits alternate, vestured, round to polygonal, 5–8 μm; vessel-ray and vessel-parenchyma pits similar to intervessel pits, but half-bordered; helical thickenings absent; tyloses absent. Fibres 1200–1500 μm long, non-septate, thin-walled, with simple to minutely bordered pits mainly confined to radial walls, with tendency to storied structure. Parenchyma scanty, paratracheal, vasicentric and diffuse. Rays 6–12/mm, narrow, mainly uniseriate, with some 2-seriate rays (c. 20%), 300–400(–500) μm high, homogeneous. Prismatic crystals in long vertical strands in diffuse parenchyma. Brownish deposits abundant in ray cells.

Species studied: *P. falcataria*.

Growth and development Batai grows so fast that it is sometimes called 'miracle tree'. *P. falcataria* is even mentioned in the Guinness Book of Records as the world's fastest growing tree. On good sites, trees may attain a height of 7 m in a little more than one year. Trees reach a mean height of 25.5 m and a bole diameter of 17 cm after 6 years, 32.5 m high and 40.5 cm diameter after 9 years, 38 m high and 54 cm diameter after 12 years, and 39 m high and 63.5 cm diameter after 15 years. Growth of young trees in a phosphorus-deficient soil is promoted by inoculation with mycorrhizal fungi; *Glomus fasciculatum* and *Gigaspora margarita*, in combination with *Rhizobium* have proved to be effective. Nitrogen-fixing nodules containing leghaemoglobin are found on roots.

Trees may already flower at the age of 3 years. Two flowering periods per year have been observed in Peninsular Malaysia and Sabah. Ripe pods appear approximately 2 months after flowering. The pods dehisce when ripe, often still attached to the tree, scattering the seeds on the ground.

Other botanical information The genus *Paraserianthes* belongs to the tribe *Ingeae* (subfamily *Mimosoideae*) and was recently separated from *Albizia*. Apart from *Albizia*, its closest relatives are *Serianthes* (especially *S. minahassae* (Koord.) Merr. & Perry), and *Archidendropsis* (especially subgenus *Basaltica* Nielsen). These relationships are mainly based on pollen morphology but are often supported by similarities in wood anatomy. The genus *Paraserianthes* is subdivided into 2 sections: section *Paraserianthes* and section *Falcataria* Nielsen. The first section comprises only the species *P. lophantha* and is distinguished by its solitary, axillary, not paniculate racemes and its pollen with costae (pores surrounded by distinct thickenings).

Ecology The four species of *Paraserianthes* occur in a wide variety of habitats generally ranging from sea-level to 1600 m but sometimes up to 3300 m altitude. As they are pioneers, they occur in primary but more characteristically in secondary lowland rain forest, but also in light montane forest, elfin forest and grassy plains or along roadsides near the sea. They are found on sandy and lateritic soils as long as drainage is sufficient. The species are adapted to perhumid to monsoon climates (with a dry season of up to 4 months). In their natural habitat, the annual precipitation may range between 2000–2700 mm or sometimes up to 4000 mm. The optimal temperature range is 22–29°C with a maximum of 30–34°C and and a minimum of 20–24°C. In natural stands in Irian Jaya *P. falcataria* is associated with species such as *Toona sureni* (Blume) Merr., *Terminalia* spp., *Celtis* spp., *Agathis labillardieri* Warb., *Pterocarpus indicus* Willd. and *Diospyros* spp.

When planted, *P. falcataria* is able to grow on comparatively poor sites and to survive without fertilization. However, it does not thrive in poorly drained, flooded or waterlogged areas.

Propagation and planting Batai is strongly light-demanding and regenerates naturally only when the soil is exposed to sunlight. In the forest, wildlings sprout in abundance only when the canopy is open and when the soil is cleared from undergrowth. Wildlings can be successfully collected and potted for planting, but they are delicate and have to be handled carefully.

Seeds are difficult to collect from the ground since they are small. The weight of 1000 seeds is 16–26 g. Usually they are collected by cutting down branches bearing ripe brown pods. The seeds can easily be collected from felled trees if the fruits happen to be in the right condition. Untreated seeds germinate irregularly; germination may start after 5–10 days but sometimes it is delayed for up to 4 weeks from sowing. To hasten germination and to make it more simultaneous, seeds can be treated by soaking them in boiling water for 1–3 minutes, or by immersion in concentrated sulphuric acid for 10 minutes and subsequent washing and soaking in water for 18 hours. The germination rate can be as high as 80% to almost 100%. Seeds of batai are usually sown by broadcasting, pressed gently into the soil, and then covered by a layer of fine sand up to 1.5 cm thick.

For storage, seeds are air dried for 24 hours and then packed in polyethylene bags. When stored at 4–8°C, the germination rate after 18 months may still be 70–90%.

The soil in the seed-bed must be loose and well-drained; application of a surface layer of mulch is advisable and excessive shading should be avoided. The seedlings can be transplanted when they have reached a height of 20–25 cm with a woody stem and a good fibrous root system; this stage can be reached in 2–2.5 months. Container plants are often transplanted into the field when 4–5 months old. The stem is cut back to about 10 cm above the root collar, and the taproot to a length of about 22 cm. The seedlings are usually planted into the field with a spacing of 2 m × 2 m to 4 m × 4 m. The average yearly production of batai seedlings in the Philippines was 2.1 million in the period 1979–1982.

Seed tissue of batai has been successfully used for propagation by tissue culture in the Philippines.

Silviculture and management Batai plantations should be kept weed-free during the first few years. The application of fertilizers may improve the yield; application of 12.5 kg/ha of P was found satisfactory. When the stand (for timber production) is 4–5 years old, it can be thinned to a density of 250 stems/ha, and after 10 years to 150 stems/ha. When the trees are grown for timber production, artificial pruning is necessary, as they have a tendency to fork. The cutting cycle is usually 12–15 years. Trees grown for pulp production have a cutting cycle of about 8 years.

Batai is commonly used in agroforestry systems, usually in a cutting cycle of 10–15 years, in combination with annual crops in the first year and grazing animals in subsequent years. Pure stands give a good protective cover to prevent erosion on slopes, and they are recommended for this purpose in the Philippines on catchment areas sheltered from typhoons. Batai trees coppice fairly well, which is advantageous for pulpwood production, but they are very susceptible to fire.

Diseases and pests In 1988 and 1989 gall rust disease caused by *Uromycladium tepperianum* provoked severe damage in Bukidnon Province (Mindanao, the Philippines). The government banned the transport of logs in and out of Bukidnon Province, and planting was suspended.

Nursery seedlings are susceptible to damping-off caused by fungi of *Rhizoctonia, Sclerotium, Fusarium, Pythium* and *Phytophthora*. Sterilizing the soil before sowing and applying fungicides to soil and seeds may control the disease. The fungus *Corticium salmonicolor* causes a disease known as pink canker or salmon canker. At first, light brown lesions appear on the bark of young trees; they gradually enlarge and develop cracks, the colour turns to pale salmon or pinkish and then mycelium mats appear around the lesions. The disease may seriously damage plantations. Plantations can also suffer from other fungal diseases like red root caused by *Ganoderma pseudoferrum*. An anthracnose seedling disease caused by a *Colletotrichum* species has been observed in Sumatra.

Plantation pests in Malaysia, Indonesia and the Philippines include stem-borers such as the longicorn beetle *Xystrocera festiva* and the red borer *Zeuzera coffea* (a cossid moth). Leaf-eating caterpillars (e.g. *Eurema blanda*, *E. hecabe* and *Semiothesa emersaria*) may attack seedlings and trees. Aphids have occasionally been a problem on seedlings. Insecticides are commonly used to control these pests.

Harvesting Plantations are clear-cut when the cutting age is reached. Usually harvesting is problem-free as the trees are harvested when still comparatively young and consequently have small and lightweight logs which can be yarded and loaded easily. Rapid extraction, conversion and seasoning of batai wood is necessary to prevent insect attack and infection with fungi. The wood is particularly prone to sap-stain attack.

Yield Batai is a fast grower and the yield is often high. In 8–12-year rotations, mean annual volume increments of (10–)25–30(–40) m^3/ha are attained. On fertile soils in Indonesia, mean annual increments of 50–55 m^3/ha have even been reached in plantations of 9–12 years old (120 trees/ha when 9 years old and 76 trees/ha when 12 years old).

Genetic resources Batai is planted on a large scale all over the tropics and the genetic resources are quite comprehensive. *P. pullenii* is endemic to Papua New Guinea, where it occurs very locally and might be liable to genetic erosion or extinction.

Prospects Breeding programmes should be conducted to obtain superior trees in respect to shape of bole (preferably without a tendency to fork and long and straight) and resistance to diseases and pests. Superior trees can be mass produced by tissue culture.

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Selection of species

Paraserianthes falcataria (L.) Nielsen

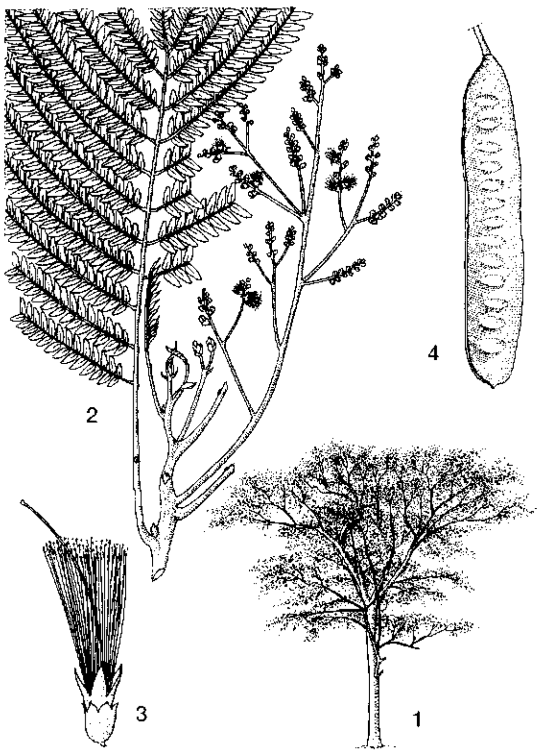
Bull. Mus. Natn. Hist. Nat., 4e sér., sect. B, Adansonia 5: 327 (1983).

Synonyms *Albizia moluccana* Miq. (1855), *Albizia falcata* sensu Backer (1908), *Albizia falcataria* (L.) Fosberg (1965).

Vernacular names Brunei: puah. Indonesia: jeungjing (general), sengon laut (Java), sika (Moluccas). Malaysia: batai (Peninsular, Sabah), kayu machis (Sarawak). Papua New Guinea: white albizia. Philippines: Moluccan sau, falcata.

Distribution The Moluccas, New Guinea, the Bismarck Archipelago and the Solomon Islands. *P. falcataria* is widely planted throughout the tropics.

Uses The timber is used as batai (as given for the genus). In New Guinea native people make various items, including shields, from this wood. *P. falcataria* is planted as an ornamental and shade tree, for reforestation and afforestation or for firewood production. The bark yields kino and has tanning properties and it is also used for packing. The leaves are used to feed chickens and goats.



Paraserianthes falcataria (L.) Nielsen – 1, tree habit; 2, flowering twig with part of leaf; 3, flower; 4, pod.

Observations A medium-sized to fairly large tree up to 40 m tall, bole branchless for up to 20 m and up to 100 cm or sometimes more in diameter; leaves up to 40 cm long, with (4–)8–15 pairs of pinnae, each pinna with (8–)15–25 leaflets, leaflets oblong-falcate, (2–)3–6 mm broad; flowers in paniculate racemes, corolla sericeous all over; pod winged along the ventral suture, puberulous but glabrescent. *P. falcataria* has three subspecies. Subsp. *falcataria* occurs in the Moluccas and New Guinea, subsp. *solomonensis* Nielsen in the Solomon Islands, and subsp. *fulva* (Lane-Poole) Nielsen (synonyms: *Albizia fulva* Lane-Poole and *A. eymae* Fosberg) in the mountains of New Guinea; the latter subspecies has densely puberulous to tomentose pods and a woolly leaf-rachis. *P. falcataria* occurs in primary but more often in secondary forest and on river flood terraces, sometimes in beach forest and regrowth from sea-level up to 2300 m altitude. The density of the wood is (230–)300–500 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 10, 99, 100, 102, 128, 145, 146, 159, 168, 179, 245, 300, 359, 363, 368, 372, 373, 502, 504, 578, 615, 687, 750, 764, 781, 800, 813.

Paraserianthes pullenii (Verdc.) Nielsen

Bull. Mus. Natn. Hist. Nat., 4e sér., sect. B, Adansonia 5: 327 (1983).

Synonyms *Albizia pullenii* Verdc. (1979).

Distribution South-eastern Papua New Guinea.

Uses The timber is probably used as batai.

Observations A medium-sized tree up to 31 m tall, bole not buttressed and up to 55 cm in diameter; leaves up to 13.5 cm long, with (2–)3 pairs of pinnae, each pinna with 5–7 pairs of leaflets, leaflets oblong to trapezoid, 8–25 mm broad; flowers in paniculate racemes, corolla adpressed pubescent outside. *P. pullenii* occurs in hill rain forest on shallow stony soil or gravelly sandy clay at 60–120 m altitude.

Selected sources 750, 751.

J.P. Rojo (general part, wood anatomy, selection of species),
D.S. Alonzo (properties),
J. Ilic (wood anatomy)

Parashorea Kurz

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 39(2): 65 (1870).

DIPTEROCARPACEAE

$x = 7$; *P. densiflora*: $2n = 14$

Trade groups

- White seraya: moderately lightweight to medium-weight hardwood, e.g. *Parashorea malaanonan* (Blanco) Merr., *P. tomentella* (Sym.) Meijer.
- Gerutu: moderately heavy hardwood, e.g. *P. densiflora* v. Slooten & Sym., *P. lucida* (Miq.) Kurz, *P. smythiesii* Wyatt-Smith ex P. Ashton.

Vernacular names

- White seraya: white lauan, Borneo cedar (En). Brunei: urat mata (Malay), perawan, sepit undang (Iban). Indonesia: urat mata, pendan (Kalimantan). Malaysia: urat mata (Sabah). Philippines: white lauan, bagtikan (general), malaanonang (Tagalog).
- Gerutu: heavy white seraya, heavy parashorea (En). Malaysia: meranti gerutu (Peninsular), urat mata batu (Sabah), urat mata bukit (Sarawak). Burma: tavoy wood, thingadu, kaunghmu. Laos: mai si, mai hao, mai nao. Thailand: khaikhieo (peninsular), kian-suai (Surat Thani). Vietnam: ch[of].

Origin and geographic distribution *Parashorea* consists of about 14 species which are widely distributed throughout continental South-East Asia (Burma, Thailand, Laos, southern Vietnam, southern China). Within the Malesian area a total of 10 species occur in Peninsular Malaysia (3 species), Sumatra (3 species), Borneo (6 species) and the Philippines (1 species).

Uses White seraya is a general-purpose timber for light and medium-heavy construction but it is preferred for the manufacture of veneer and plywood. It is also applied for interior finish, light constructional work, cabinet and furniture, flooring for domestic purposes and recently also for the manufacture of fibreboard, particle board and wood-wool cement board. Since the timber is not durable and resists preservative treatment, it is not used in contact with water or the ground. Other applications of the wood are musical instruments, carvings, toys and novelties, turnery, boat planking and framing and ships decking (all under cover), fermentation vats, and for pulp and papermaking (often mixed with other hardwoods).

Like white seraya, gerutu is a general-purpose timber for medium-heavy construction but its main use is for veneer and plywood manufacturing. It is rated as non-durable to fairly durable, is resistant to preservative treatment, and is used mainly under cover and not in contact with the ground. It is best suited for interior construction and is chiefly used for flooring, joinery, cladding, shuttering and for making utility furniture and cabinets. Other applications are for railway sleepers, vehicle bodies, pallets, boxes and crates, poles and piles, staircases and tool handles (non-impact purposes). The wood is also suitable for hardboard and particle board manufacture as well as for pulp and papermaking (often mixed with other hardwoods).

Most of the species yield an oleo-resin which is used only locally for caulking boats and for torches. Probably because of its limited supply no collecting on a commercial scale has been reported.

Production and international trade Most white seraya timber on the world market originates from Sabah and Sarawak. Amounts exported are considerable, e.g. the export of round logs of white seraya from Sabah in 1987 was 1.53 million m^3 with a value of US$ 168 million (average price 110 US$/$m^3$), which makes it the second most important export timber of Sabah after 'red seraya' (light red meranti, *Shorea* spp.). The Philippines exported small amounts of this timber (from *P. malaanonan*): 238 000 kg (with a value of US$ 53 000) in 1986. The majority of white seraya timber goes to Japan; smaller amounts are exported to the United States, European countries, and Korea. At present white seraya is exported from Sabah together with white meranti (*Shorea* spp.); in 1992 the export of logs was 635 000 m^3 in this united trade group and of sawn timber 233 000 m^3 with a total value of US$ 162 million.

The total production of gerutu is small, and the export is negligible. In Indonesia (Kalimantan) white seraya and (to a lesser extent) gerutu are used particularly in plywood production; no figures are available about their contribution to total plywood manufacture. In 1992 the export of sawn gerutu timber from Sabah was only 56 m^3 with a value of US$ 20 000 (US$ 357/m^3).

Properties White seraya is a moderately light to medium-weight hardwood. The heartwood is pinkish or cream-coloured when freshly cut, weathering to straw-coloured or light brown on exposure, sometimes with a pinkish tinge, and not distinctly demarcated from the slightly paler sapwood. The density is 390–670 kg/m^3 at 15% moisture content. The grain of the wood is interlocked, texture moderately coarse.

At 12% moisture content the modulus of rupture is 75–97 N/mm^2, modulus of elasticity 8900–13 950 N/mm^2, compression parallel to grain (31–)42–51 N/mm^2, compression perpendicular to grain 5–7 N/mm^2, shear 7–11 N/mm^2, cleavage 26–51 N/mm radial and 32–52 N/mm tangential, Janka side hardness 2620–4145 N and Janka end hardness 2760–3885 N.

The rates of shrinkage are moderate to high, from green to 12% moisture content 1.1–4.9% radial and 2.6–8.8% tangential. The timber air dries well and rapidly if properly stacked and well-ventilated, but boards may warp, check and stain if not enough care is taken. Boards of 25 mm thick take about 7.5 months to air dry from green to 15% moisture content. The kiln-drying properties are good, with only occasional cupping defects. Boards of 50 mm thick of *P. malaanonan* kiln dry from 75% to 11% moisture content in 22 days. In Malaysia kiln schedule J is recommended. The movement of wood in service is minimal.

White seraya can be worked easily with hand and machine tools. It has little blunting effect on sawteeth and edges. The wood planes easily but quarter-sawn material has a tendency to tear. A cutting angle of 20° should be used to obtain the best results. A clear finish is obtained in most operations, provided the cutters are sharp. White seraya requires care in moulding to prevent arrises breaking away. The wood nails, glues, screws, chisels and turns very satisfactorily, and it polishes and varnishes well after filling. White seraya is not suited for steam bending. It can be sliced readily for veneer, and the veneer can be glued easily to give good-quality plywood. It can be chipped cleanly to produce hardboard of high quality. Wood dust may cause dermatitis.

White seraya is rated as non-durable in the tropics in exposed conditions or in contact with the ground, but as moderately durable in temperate climates. It is durable under cover and in dry conditions. The wood is susceptible to attack by pinhole borers, termites and marine borers, and the sapwood is also susceptible to powder-post beetles. The heartwood is resistant to impregnation with preservatives due to the presence of tyloses in the vessels, but the sapwood is permeable. For *P. malaanonan* heartwood an absorption of 21–115 kg/m^3 has been obtained using the open tank process, for *P. tomentella* 6–53 kg/m^3.

Gerutu is a medium-weight hardwood. The heartwood is very light brown to light bronze with a pinkish or yellowish tinge, darkening on exposure to deeper brown, distinctly demarcated from the light yellow-brown sapwood. The density is 640–865(–1050) kg/m^3 at 15% moisture content. The grain of the wood is interlocked, texture coarse but even. Planed surfaces are slightly glossy and the radial surface has a stripe figure.

At 12% moisture content the modulus of rupture is c. 114 N/mm^2, modulus of elasticity 14 200 N/mm^2, compression parallel to grain 62 N/mm^2 and shear 15 N/mm^2.

The rates of shrinkage are moderate to high, from green to 12% moisture content 1.6–4.1% radial and 3.3–7.1% tangential, and from green to oven dry 4.1–5.1% radial and 6.6–8.1% tangential. Gerutu wood seasons easily but slowly without much degrade or distortion. The kiln-drying properties are rated as good, sometimes with slight cupping. In Malaysia kiln schedule C is recommended. The sapwood is susceptible to stain if not properly and carefully dried.

The working properties are more or less comparable to white seraya, but gerutu is less suited for veneer and plywood manufacture, as it is denser.

The durability is slightly better than white seraya because of the greater density, but gerutu is rated as non-durable in exposed conditions or in contact with the ground under tropical conditions. The heartwood is extremely resistant to preservative treatment.

Description Large evergreen trees of 35–50 (–60) m tall; bole tall, straight and cylindrical, branchless for 20–25 m and with a diameter of 100(–200) cm; buttresses large, rounded, slightly concave, hardly branched; bark surface distinctly mauve grey to purplish with narrow shallow fissures, with broad, smooth or flaking flat ridges, and numerous conspicuous large, pale, corky lenticels in the cracks, outer bark usually dark-coloured with brittle layers, inner bark yellow-brown or pinkish-brown grading to pale yellow at the cambium, sapwood pale yellowish, sometimes with a pink tinge; resin scanty, dirty cream to yellowish, exuding from rows or resin canals on cut surfaces; crown dense, becoming dome-shaped or hemispherical; main branches several to many, usually radiating from the bole apex, branches with alternating series of long and short internodes, twigs usually crowded to the ends of the branches; young parts and lower leaf surface usually pubescent. Leaves alternate, simple, broadly oblong-ovate, shortly acuminate, with an entire or wavy margin, pinnately veined; veins scalariform, usually straight, running in an acute angle from the midrib, with subpersistent plicate folding, no intermediate veins; young leaves white or glaucous beneath; petiole sometimes slightly swollen at base; stipules linear-lanceolate to hastate, early caducous, leaving short to amplexicaul scars. Inflorescence terminal or axillary, lax or dense, racemose (cymose in *P. macrophylla*); bracts paired, small or large. Flowers secund or distichous, bisexual, actinomorphic, scented, nodding, ovate to subglobose in bud; calyx persistent, the 5 calyx lobes free down to the receptacle, in bud more or less equal, very narrowly imbricate; corolla 5-merous, contorted, petals falling separately (except in *P. stellata*), oblong to broadly elliptical, white or yellow; stamens 15, much longer than the ovary; ovary (2–)3-locular, small, ovoid, glabrous or pubescent, style filiform, glabrous, sometimes thickened at base into a slender stylopodium, with a small, simple or slightly dilately truncate stigma. Fruit a large, ovoid to globose, pubescent, short-pedicelled, verrucose-lenticellate nut, free from the calyx; fruit calyx lobes enlarged, more or less equal and shorter than the nut or subequal, with 3 somewhat larger than the other 2 and spatulate, thickened and saccate at the valvate base; style remnant short, indistinct. Seedling with epigeal germination; with fleshy equal or subequal, deeply bilobed cotyledons well above soil level; seedling leaves long-petioled, often linear, in some species aciculate and unique for the family; first two leaves opposite, subsequent ones arranged spirally; older seedlings with subpeltate leaves.

Wood anatomy

– Macroscopic characters:

Heartwood light greyish-brown with a pinkish tinge, usually with irregularly spaced concentric dark (black or violet) stripes, often at intervals of 5–10 cm, not distinctly demarcated from the paler sapwood. Grain interlocked. Texture coarse; pale concentric bands, with white dots, distinct to the naked eye, irregularly spaced in cross-section. Growth rings indistinct.

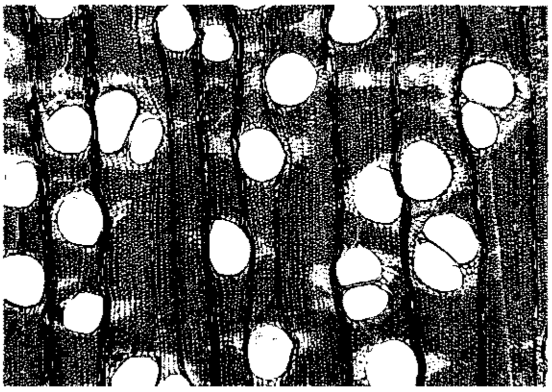
– Microscopic characters:

Growth rings indistinct. Vessels diffuse, 2.5–7/mm^2, solitary and in radial multiples of 2(–3), maximum tangential diameter 300–350 μm; perforations simple; intervessel pits alternate, vestured, 6–8 μm; vessel-ray and vessel-parenchyma pits simple, round or oval or elongated; tyloses present, sometimes abundant. Vasicentric tracheids present. Fibres 1.3–2.1 mm long, thick-walled (2–5 μm), with small pits confined to the radial walls. Parenchyma vasicentric and confluent, with short wings, and abundantly apotracheally diffuse; also in irregularly spaced concentric bands surrounding the axial intercellular canals. Rays 5–8/mm or 3–5(–6)/mm (*P. smythiesii*), 1–7(–8) cells wide, up to 2500 μm high, heterocellular with one and occasionally more rows of square and/or upright marginal cells (Kribs type heterogeneous III and II). Prismatic crystals present, in chambered axial parenchyma cells, in long chains of over 20 chambers, and in procumbent and chambered marginal ray cells. Axial canals of the concentric type distinct and surrounded by tangential parenchyma bands; horizontal canals found in fusiform rays (*P. smythiesii*).

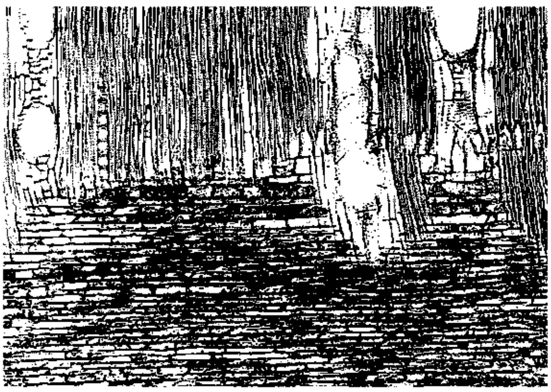
Species studied: *P. malaanonan*, *P. smythiesii*.

White seraya and gerutu can be distinguished from white meranti (*Shorea* spp.) by the presence of crystals in parenchyma and rays and the absence of silica, by the reddish-brown parenchyma and rays (yellow in white meranti) and by the more greyish wood colour with pink tinge.

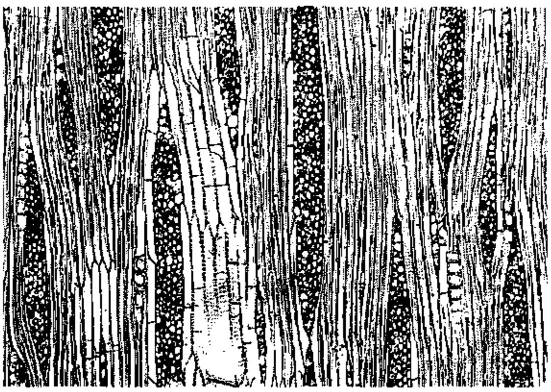
Growth and development Seedlings develop a strong taproot soon after germination, forming a few fibrous lateral roots later on. When the tap-



transverse section (×25)



radial section (×45)



tangential section (×45)

Parashorea lucida

root is obstructed from penetrating the soil, forking or splitting results.

White seraya trees are fast growers. Planted trees of *P. malaanonan* may reach a bole diameter of 90 cm in 40 years, but growth is usually slower. The average time for *P. tomentella* trees to reach 75 cm diameter in forest in Sabah is estimated at 72 years. When, after selective logging, the non-commercial tree species are poisoned, the average diameter increment of *P. tomentella* can be as much as 1.3 cm/year. Gerutu trees grow more slowly. The maximum bole diameter for planted *P. densiflora* trees after 40 years is 54 cm, which still makes it a moderately fast grower. Growth rates in the forest, however, are considerably lower.

As in most dipterocarps, *Parashorea* trees flower at irregular intervals; flowering does not occur annually. In Peninsular Malaysia seed years occur every 2–5 years. Flowering and fruiting seasons last longer in wet and intermediate climatic regions than in the dry ones. As in many other canopy trees, the young trees do not flower at all until their sympodial crown is developed in direct sunlight. The winged fruits may be dispersed for comparatively small distances by wind, but most fruits fall within 60 m of the parent tree.

Other botanical information *Parashorea* is a small, homogeneous, but widely distributed genus, which is closely related to and superficially hardly distinguishable from *Shorea*. The characteristic large corky lenticels at the base of the bole and buttresses differ from the small and usually inconspicuous ones of the latter. The tendency of glaucescence of most of the lower leaf surfaces, the acute angle of the main veins with the midrib, the globose lenticellate nuts and the subequal fruit wings are other characteristics of *Parashorea*.

Embryo and seedling characters provide novel insights into the relationship and distinction of genera of *Dipterocarpaceae*. On this basis, the genus *Parashorea* seems to be most closely related to the former subgenus *Rubroshorea* Meijer of *Shorea*, which currently comprises the sections *Rubella* P. Ashton, *Brachypterae* Heim, *Pachycarpae* Heim, *Mutica* Brandis and *Ovalis* P. Ashton. Diagnostic characters within the genus *Parashorea* are the number of lateral leaf veins, pubescence of the leaf and length of the fruit wings and petiole.

The wood of white seraya is often confused with and used as a substitute for white meranti (*Shorea* spp.).

Ecology *Parashorea* spp. occur scattered and locally or sometimes abundantly and gregariously in a wide variety of forest habitats ranging from evergreen to semi-evergreen and dry deciduous dipterocarp forests in lowlands or hills and ridges up to 1400 m altitude. The habitats may be subject to occasional inundation, or be well-drained and even dry and rocky. Most species have a preference for clay soils. *Parashorea* spp. constitute one of the climax species in a dipterocarp rain forest.

In Sabah seven forest types (five in the lowlands and two in the hills) have been distinguished. White seraya abounds in three of the lowland types. These are: (1) *Parashorea malaanonan* forest where this species tends to single dominance; (2) *P. tomentella / Eusideroxylon zwageri* Teijsm. & Binnend. forest where the first species is abundant; (3) *P. malaanonan / Dryobalanops lanceolata* Burck forest where the first is one of the typical species. *Parashorea* spp. also occur in other forest types in Sabah, either reasonably commonly or rarely. In Sabah *P. malaanonan* is locally the predominant timber species, sometimes accounting for almost 70% of the commercial trees in the forest. In natural forest in northern Sumatra *P. lucida* may constitute 25% of the total number of trees.

Propagation and planting Seeds are collected immediately after fruit fall. They should be properly packed in a moisture-holding medium such as moss, coconut fibre, sawdust or pulverized charcoal. The seeds should be sown rapidly as their viability is short. However, seeds of *P. densiflora* can be stored in bags for 50–60 days. Fresh seeds of *P. tomentella* may have a germination rate of 97%. Germination starts 2–20 days after sowing, with a peak at 10–12 days.

Wildlings are generally used for enrichment planting. They are collected in the forest and planted in polyethylene bags and kept in the nursery for about 8 weeks. Planting is usually done at the onset of the rainy season. Partial shade is needed while the plants are still young, i.e. from seedling to pole stage. Seedlings with a stem diameter of 1–2 cm and a height of 40–60 cm survive the best. *P. tomentella* seedlings used for enrichment planting in Sabah showed a survival rate of 58% after 2 months. Spacing is often 4 m × 4 m. In tests in the Philippines, *P. malaanonan* could not be propagated successfully by air layering and shoot cuttings.

Silviculture and management The overall management and development strategies for a dipterocarp forest also apply to white seraya and gerutu, although some white seraya species have faster growth rates than meranti and are more light demanding. A general forest management plan is prepared for this purpose incorporating the various components such as a logging plan, the annual allowable cut, cutting cycle and silvicultural treatment. At present, timber stand improvement and other silvicultural techniques in selectively logged dipterocarp forest with *Parashorea* are not applied or are limited to cutting of vines and removal of small defective trees and weeds. Enrichment planting is carried out on a very limited scale.

White seraya is locally abundant, in some areas of Sabah 25 trees/ha can be found, and seedlings of white seraya are there more abundant than any other tree species. In undisturbed forest, 17% of the initial number of seedlings was found to survive after 4 years. Seedling mortality is slightly higher after logging, but growth increases after opening of the canopy. White seraya usually regenerates sufficiently in logged-over forest.

Diseases and pests Seedling diseases include root rot caused by fungi such as *Fomes applanatum* and damping-off caused by fungi of the genera *Phytophthora, Pythium, Diplodia, Rhizoctonia* and *Fusarium*. Root rot is often caused by stress of young plants and may be controlled by fertilization, prevention of root injuries, and by using fungicides. Damping-off can be controlled by not using heavy soil as potting medium, sterilizing soil, removing infected seedlings, and gradually exposing seedlings to full sunlight.

Beetles of the genus *Adoretus* (family *Scarabaeidae*) feed on seedlings, adults on leaves and tender shoots and larvae on roots and underground parts of the stem. Spraying with malathion 50EC or sevin WP (1.6 ml/l) can solve the problem. Attack of the bark engraver *Xyleborus ursus* can be controlled by injecting a solution of dieldrex 15 into the tunnels. The borer *Hoplocerambix spinicornis* may cause severe damage to logs of living and felled trees. Snails feed voraciously on seedlings, being active at night and during rainy and cloudy days. A bait consisting of calcium arsenate, metaldehyde and fine rice bran (5 : 2 : 100), moistened by water, has been found very effective.

Harvesting Trees are usually recommended to be felled according to selective logging systems, as commonly practised in dipterocarp forest. Mature and over-mature trees are cut and removed from the forest, and uninjured, healthy residuals are left. A tree marking system is used, whereby the trees to be felled are marked by arrows showing the direction of the fall, and the trees to be re-

tained are marked by numbers and bands. A formula for determining the allowable cut is followed. Felling rules and yarding techniques are prescribed and implemented to insure a good balance of satisfactory log production and an adequate number of residual trees for the next felling operation on a prescribed cutting cycle. However, the selective logging system has to be proven economically and silviculturally workable in mixed dipterocarp forest in South-East Asia.
Brittle heart is often present in the logs to some extent. In general, logs of white seraya can be transported by river, but gerutu logs sink in water. The timber should be extracted rapidly from the forest to prevent severe damage by pinhole borers.

Genetic resources The supply of white seraya is still abundant, particularly in Sabah, Sarawak and parts of Indonesia. Gerutu, however, appears to be limited and scattered. Continued exploitation of gerutu will make it prone to genetic erosion and possible extinction.

Prospects White seraya may be well suited for felling under selective cutting systems. Its natural regeneration is satisfactory, and prospects for sustained yield are good. Growth rates are comparable to those of red and white meranti, which often co-occur with white seraya in the forest. This could make it easier to manage forests for an optimal production of white seraya and meranti. Appropriate forest management techniques that aim at sustained yield through natural or artifical regeneration are of major concern.

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Selection of species

Parashorea aptera v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 8: 377, f. 3 (1927).

Vernacular names Indonesia: balau tembalun (general), meranti horsik (eastern Sumatra), meranti merebu (western Sumatra).

Distribution Sumatra.

Uses The timber is used as gerutu.

Observations A medium-sized tree up to 32 m tall, bole straight, cylindrical, branchless for up to 24 m and with prominent buttresses; leaves ovate-lanceolate, 7–17 cm × 2.8–6 cm, dull and more or less silvery stellate puberulent beneath, secondary veins 6–9(–10) pairs, petiole 9–18 mm long, stipule scars short; fruit calyx lobes shorter than the nut, linear-lanceolate, subequal, up to 14 mm × 3 mm, nut subglobose, up to 2.5 cm in diameter, densely verrucose. *P. aptera* occurs locally abundantly and scattered or sometimes gregariously on flat or hilly country and usually on well-drained, sandy but sometimes on periodically inundated and clayey soils up to 350 m altitude. The density of the wood is 725–1090 kg/m^3 at 15% moisture content.

Selected sources 258, 738, 746, 748.

Parashorea densiflora v. Slooten & Sym.

Gard. Bull. Str. Settl. 10: 373, pl. 24 (1939).

Synonyms *Parashorea aptera* Foxw. (1932) non v. Slooten.

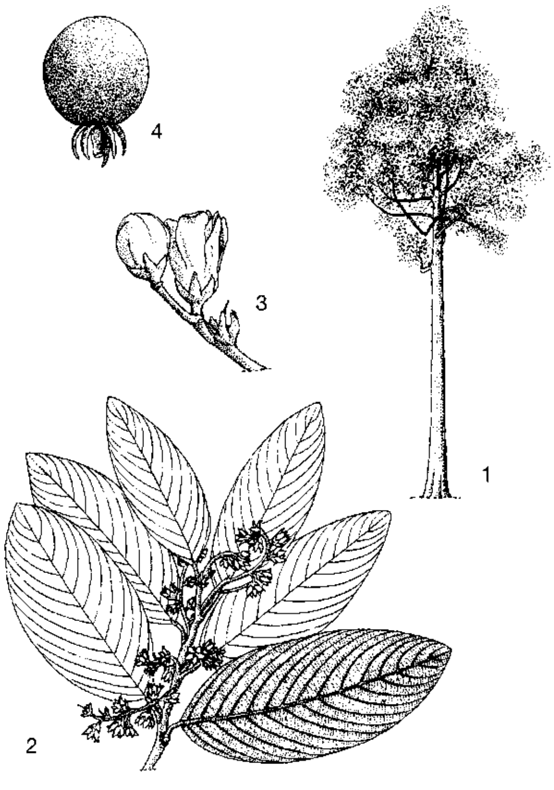
Vernacular names Malaysia: meranti pasir, gerutu pasir (general), tengkawang jantong (Pahang, Trengganu).

Distribution Peninsular Malaysia.

Uses The timber is used as gerutu for general utilities.

Observations A medium-sized to large tree up to 50 m tall, bole tall, branchless for up to 28 m and with a diameter of up to 145 cm, buttresses tall to short and stout or almost absent, outer bark dark, brittle, inner bark yellow-brown or dull brown, sapwood yellow-brown; leaves elliptical to ovate, 7–15 cm × 3–6.5 cm, more or less densely lepidote at least on the 10–20 pairs of secondary veins beneath, petiole 9–12 mm long, stipules linear, the scars short and horizontal; fruit calyx shorter than nut, the lobes reflexed, subequal, up to 12 mm × 3 mm, nut subglobose, to 3 cm in diameter. *P. densiflora* occurs scattered in lowland dipterocarp forest in undulating or hilly country below 500 m altitude. The density of the wood is 650–875 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 138, 253, 258, 514, 677, 748, 811.



Parashorea densiflora v. Slooten & Sym. – 1, tree habit; 2, flowering twig; 3, flowers; 4, fruit.

Parashorea lucida (Miq.) Kurz

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 39(2): 66 (1870).

Synonyms *Shorea lucida* Miq. (1862), *Shorea subpeltata* Miq. (1862).

Vernacular names Indonesia: damar tyirik ayam, katuko, (damar) suranthi (western Sumatra). Malaysia: gerutu-gerutu, meruyun (Sarawak).

Distribution Sumatra and Borneo (Kalimantan, Sarawak).

Uses The timber is used as gerutu. The resin is used for illumination.

Observations A medium-sized to fairly large tree up to 40 m tall, buttresses short, bark surface deeply and longitudinally grooved, inner bark yellow, sapwood yellowish-white, heartwood pale yellow; leaves ovate-lanceolate to elliptical, 6–14 cm × 2.5–6.5 cm, beneath dull and more or less silvery stellate, secondary veins 9–12 pairs, petiole 10–15(–20) mm long, stipule scars short; fruit calyx longer than the nut, 3 larger fruit calyx lobes up to 8 cm × 1.7 cm, 2 shorter ones up to 7.5 cm × 0.8 cm, nut subglobose or ovoid, up to 2.5 cm in diameter, densely verruculose. *P. lucida* occurs in mixed dipterocarp forest on hills up to 700 m altitude. The density of the wood is 570–850 kg/m^3 at 15% moisture content.

Selected sources 31, 258, 318, 638, 738, 748.

Parashorea macrophylla Wyatt-Smith ex P. Ashton

Gard. Bull. Sing. 19: 262, pl. 5 (1962).

Vernacular names Brunei: peran (Malay), bilat (Iban). Malaysia: peran (Sarawak).

Distribution Northern Borneo (not in Sabah).

Uses The timber is used as white seraya.

Observations A large tree up to 50 m tall, bole tall, cylindrical but frequently slightly crooked, up to 110 cm in diameter, buttresses up to 2.5 m tall, bark surface pale mauve-brown, fissured, outer bark hard, dark brown, inner bark hard, pale yellow-brown, sapwood yellow; leaves oblong-elliptical, 30–50 cm × 16–24 cm, silvery to white tomentose below, secondary veins 28–36 pairs, petiole 30–50 mm long, stipules linear; fruit calyx much longer than the nut, the lobes unequal, 3 larger ones 22 cm × 1.8 cm, 2 shorter ones up to 12 cm × 0.7 cm, nut ellipsoid, to 2.5 cm × 1.2 cm, densely buff tomentose. *P. macrophylla* occurs locally abundantly on moist clay-rich soils in valleys and gulleys, on and near river banks in inland areas, up to 600 m altitude. The density of the wood is 610–720 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 89, 258, 474, 748.

Parashorea malaanonan (Blanco) Merr.

Sp. Blanc.: 271 (1918).

Synonyms *Shorea malaanonan* (Blanco) Blume (1852), *Parashorea plicata* Brandis (1895).

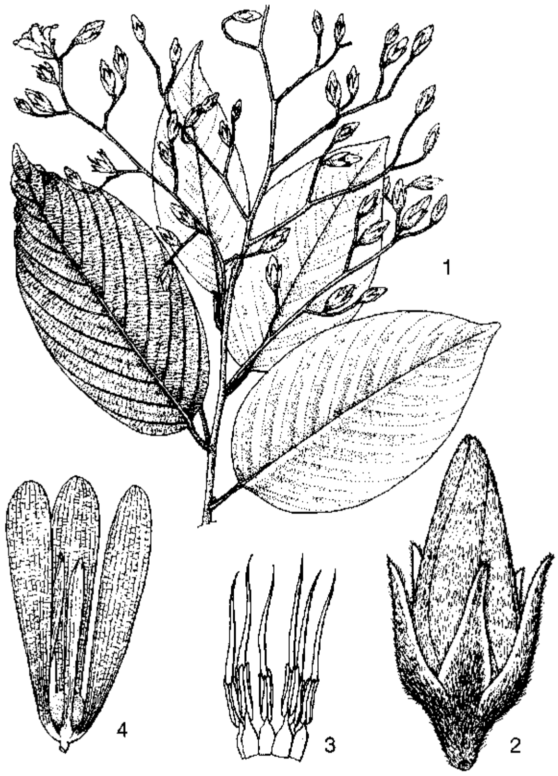
Vernacular names Brunei: urat mata (Malay), anyit (Murut). Malaysia: urat mata daun lichin (Sabah). Philippines: bagtikan, white lauan (general), malaanonan (Tagalog).

Distribution Northern Borneo and the Philippines.

Uses The timber is used as white seraya and *P. malaanonan* is the most important commercial tree from northern Borneo. The wood is mainly used for the manufacture of plywood.

Observations A very large tree up to 60 m tall, bole straight, cylindrical, branchless for 20–25 (–30) m and with a diameter of up to 100(–200) cm, buttresses large, up to 4.5 m high, bark surface grey or nearly black, outer bark yellowish-brown, inner bark reddish-brown, sapwood pale yellowish; leaves elliptical to ovate, 9–12.5(–15) cm × 3.5–5(–7.5) cm, adult leaves glabrous on both sides, secondary veins 9–10(–14) pairs, petiole 12–20 mm long, stipule scars amplexicaul; fruit calyx much longer than the nut, 3 larger lobes up to 16 cm × 1.7 cm, 2 shorter ones up to 10 cm × 0.7 cm, nut ellipsoid, up to 1.7 cm × 1.4 cm, verrucose. *P. malaanonan* is locally abundant and sometimes gregarious in primary lowland forest in the Philippines and Sabah (more rare in other parts of Borneo) and occurs up to 500(–1300) m altitude. The density of the wood is 435–675 kg/m^3 at 15% moisture content. Wood from the northern Philippines resembles gerutu timber in properties. See also the table on wood properties.

Selected sources 10, 30, 31, 89, 98, 100, 112, 115, 175, 249, 254, 258, 408, 423, 476, 479, 483, 514, 579, 608, 680, 738, 748, 815.



Parashorea malaanonan (Blanco) Merr. – 1, flowering twig; 2, flower bud; 3, stamens; 4, fruit.

Parashorea parvifolia Wyatt-Smith ex P. Ashton

Gard. Bull. Sing. 19: 264 (1962).

Vernacular names Brunei: urat mata bukit. Malaysia: urat mata daun kechil (Malay, Sabah), lantan kuning (Iban, Sabah).

Distribution Northern and eastern Borneo.

Uses The timber is used as gerutu, sometimes as a substitute for teak for ship decks and flooring.

Observations A large to very large tree up to 60 m tall, bole straight, cylindrical, up to 145 cm in diameter, buttresses tall, up to 2.5 m high, bark surface dark brown, bark with a conspicuous black line between outer and inner bark, greenish-yellow at the cambium; leaves elliptical to ovate, 6–9 cm × 3–4.5 cm, glabrous, secondary veins 8–10 pairs, curved, petiole 1–1.8 cm long, stipule scars slightly amplexicaul; fruit calyx much longer than the nut, the lobes unequal, 3 larger ones up to 8.5 cm × 1.7 cm, 2 shorter ones up to 7.5 cm long, nut globose, 1.5 cm × 1.3 cm, strongly lenticelled, buff tomentose. *P. parvifolia* occurs scattered and locally in mixed dipterocarp forest, often on clay-rich soil, on ridges up to 1350 m, rarely on river banks. The density of the wood is 640–880 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 100, 258, 476, 748.

Parashorea smythiesii Wyatt-Smith ex P. Ashton

Gard. Bull. Sing. 19: 266, pl. 7 (1962).

Vernacular names Brunei: urat mata daun puteh. Malaysia: urat mata batu (Sabah), meruyun (Iban, Sarawak).

Distribution Borneo.

Uses The timber is used as gerutu, sometimes as a substitute for teak for ship decks and flooring.

Observations A large tree up to 55 m tall, bole up to 195 cm in diameter, plank buttresses up to 3.5 m high, bark surface smooth to flaky, grey, inner bark dull brown with a black line between inner and outer bark, yellow at the cambium; leaves elliptical to ovate, 6–9 cm × 3–4.5 cm, scabrid pubescent on the veins beneath, secondary veins 8–10 pairs, curved, petiole 10–18 mm long, stipule scars short; fruit calyx much longer than the nut, 3 larger lobes up to 8 cm × 1.7 cm, 2 shorter ones up to 7.5 cm long, nut ellipsoid, up to 13 mm × 9 mm, densely fulvous tomentose. *P. smythiesii* occurs scattered but locally abundant in mixed dipterocarp forest at damp places near rivers, on clayey hillsides, or less often on steep well-drained hillsides up to 700 m altitude. The density of the wood is 625–865 kg/m^3 at 15% moisture content.

Selected sources 30, 31, 100, 258, 476, 748.

Parashorea stellata Kurz

Journ. As. Soc. Beng. pt. 2, Nat. Hist. 39(2): 66 (1870).

Synonyms *Shorea cinerea* Fischer (1926), *Parashorea poilanei* Tardieu (1942).

Vernacular names Malaysia: gerutu gerutu (Peninsular), kobe (Pattani, Peninsular). Laos: mai hao. Thailand: khaikhieo, pat lang khieo, takhian-samphon (Thai, peninsular). Vietnam: ch[of] chai, ch[of] lao, l[af]ng v[ij]t.

Distribution Southern Burma, Laos, Vietnam, Thailand and Peninsular Malaysia.

Uses The timber is used as gerutu.

Observations A medium-sized to large tree up to 45 m tall, bole tall, but frequently twisted, branchless for up to 27 m and up to 145 cm in diameter, buttresses stout, up to 185 cm high or sometimes more, bark surface dark grey with lighter patches, outer bark dark, bordered on the inner side by a black layer, inner bark dull reddish-brown, sapwood dull, yellow; leaves lanceolate, 6–16 cm × 2.3–7 cm, base cuneate, more or less silvery lepidote beneath, secondary veins 8–12 pairs, petiole 10–12(–30) mm long, stipule scars short; fruit calyx much longer than the nut, the lobes subequal, up to 11 cm × 1.8 cm, nut ellipsoid, up to 2 cm × 1.5 cm, glabrescent. *P. stellata* occurs frequently in lowland and hill evergreen dipterocarp forest in seasonal climates, especially in valleys, up to 650 m altitude. The density of the wood is 520–930 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 138, 189, 235, 253, 258, 318, 628, 641, 677, 738, 748.

Parashorea tomentella (Sym.) Meijer

Acta Bot. Neerl. 12: 320 (1963).

Synonyms *Parashorea malaanonan* (Blanco) Merr. var. *tomentella* Sym. (1938).

Vernacular names Malaysia: urat mata beludu (Sabah).

Distribution Borneo (Sabah).

Uses The timber is used as white seraya; in some localities *P. tomentella* is the most common timber tree. It is an important export timber of Sabah, used mainly for plywood manufacturing. Locally the timber is used for ship decks, flooring, joinery, cladding, shuttering and utility furniture.

Observations A very large tree up to 60 m tall, bole straight, cylindrical, occasionally branchless for more than 30 m, with a diameter of up to 190 cm, buttresses large, up to 4.5 m high, bark surface grey or nearly black, outer bark yellowish-brown, inner bark reddish-brown, sapwood pale yellowish; leaves elliptical to ovate, 10–17(–20) cm × 5–7(–10) cm, lower surface persistently pale tawny pubescent, secondary veins 11–13 pairs, petiole 15–25 mm long, stipule scars amplexicaul; fruit calyx much longer than the nut, 3 longer lobes up to 20 cm × 2.3 cm, 2 shorter ones up to 10 cm × 0.8 cm, lorate, acute, nut subglobose, up to 2 cm in diameter, verrucose. *P. tomentella* is common in mixed dipterocarp forest on flat and undulating land below 200 m altitude. The density of the wood is 385–675 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 117, 118, 249, 250, 258, 424, 474, 476, 748, 790.

W.M. America (general part, selection of species),
D.S. Alonzo (properties),
S. Sudo (wood anatomy)

Payena A.DC.

Prodr. 8: 196 (1844).

SAPOTACEAE

x = unknown

Trade groups

- Nyatoh: lightweight to medium-heavy hardwood, e.g. *Payena acuminata* (Blume) Pierre, *P. lanceolata* Ridley, *P. lucida* (Wallich ex G. Don) A.DC., *P. maingayi* C.B. Clarke, *P. obscura* Burck (partly).
- Bitis: heavy hardwood, e.g. *P. leerii* (Teijsm. &

Binnend.) Kurz, *P. obscura* Burck (partly).

Vernacular names

- Nyatoh: padang (En). Indonesia: nyatuh. Malaysia: guttah, mayang (Peninsular), riam (Sarawak). Philippines: nato. Burma: kanzwe. Thailand: phikun-pa (Narathiwat), phikun-nok (Surat Thani), phikun-thuan (Surat Thani).
- Bitis. Malaysia: nyatoh batu (Sabah, Sarawak).

Origin and geographic distribution *Payena* consists of about 15 species and is distributed from Burma and the Andaman Islands east to the southern Philippines and Borneo and south to Sumatra and Java. The genus seems to be of western Malesian origin. Most species are found in Peninsular Malaysia, Sumatra and Borneo. *P. acuminata*, *P. leerii* and *P. lucida* are the most widespread species, occurring almost throughout western Malesia.

Uses Nyatoh is a general-purpose timber with properties similar to those of mixed consignments of red meranti. It is much used for the manufacture of fine furniture, decorative doors and panelling. The wood is suitable for moulding, skirting, cabinet making, joinery, interior finishing and flooring. It makes good-quality veneer which is used in the production of plywood. The nyatoh-producing species with lighter wood which usually belong to *Palaquium* and *Madhuca* are preferred, as they are less difficult to work. The timber is generally reported as moderately durable; it is perishable when exposed to the weather or in contact with the ground and is not very well suited for outdoor purposes.

Bitis is much more durable and is used for heavy constructional work, paving blocks, agricultural implements and turnery and also for heavy-duty flooring, posts, and door and window frames. Although *Madhuca utilis* (Ridley) 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.

The latex of several *Payena* species (especially *P. leerii, P. obscura*), called gutta-percha, has been used to insulate submarine cables, in dentistry, in orthopaedics for fracture splints, for the manufacture of surgical instruments and for covering golf balls, and also to haft knives and to make blowpipe mouthpieces, and as a substitute for chewing gum. At present, its main application is in dental clinics where it is used as filler for people who are allergic to synthetic fillers. However, the most important gutta-percha producing species is *Palaquium gutta* (Hook.f.) Baillon.

The fruits of some species (*P. leerii, P. acuminata* and *P. lowiana*) are edible but there is little flesh on them. They taste slightly like the fruits of *Manilkara zapota* (L.) P. v. Royen. The roots of *P. lucida* are used in local medicine; a decoction is given to women after childbirth.

Production and international trade Timber from *Payena* trees is not traded separately. It is not generally available in commercially important quantities. The timber is usually mixed with that of other *Sapotaceae* genera and collectively traded as nyatoh. The export of nyatoh sawn timber from Peninsular Malaysia decreased from 16 500 m^3 (with a value of US$ 2.1 million) in 1981 to 9500 m^3 (with a value of US$ 1.3 million) in 1986. From 1986 onward the export increased to 32 500 m^3 (with a value of US$ 6.1 million) in 1990, but in 1992 only 8000 m^3 was exported with a value of US$ 2.8 million. Large amounts of nyatoh are also exported from Sarawak and Sabah; the export of round logs from Sabah was 65 000 m^3 (worth US$ 6.3 million) in 1987, and in 1992 the export of logs was 14 000 m^3 and that of sawn timber 8500 m^3 with a total value of US$ 4.4 million.

Timbers of the bitis class are usually converted to scantling sizes, and sold unclassified. The bulk of the 'seriah' sold in Singapore consists of logs of *Palaquium* and *Payena* and probably other sapotaceous trees imported from Indonesia.

P. leerii was an important species for the production of gutta-percha, which was principally collected from trees growing in the wild. However, by 1980 the exports of gutta-percha had declined to less than 50 t annually, and it is still declining, due to the replacement by synthetic plastics.

Properties A general description of nyatoh and bitis is given here. The timber of *Payena* species is traded in these trade groups which also include *Palaquium*, *Pouteria* and *Madhuca* species. *Payena* timber, with its density of 580–1070 kg/m^3 at 15% moisture content, can be classified as belonging to the heavier nyatoh timbers and occasionally (*P. leerii, P. obscura*) to the lighter bitis timbers. Nyatoh and bitis are not well demarcated groups of timber, showing much overlap. The arbitrary limit lies at 850 kg/m^3. In East Malaysia, bitis is not accepted as a separate group.

Nyatoh is a light to medium-weight, moderately hard to hard red meranti-like wood. The heartwood is pinkish-brown to reddish-brown and only moderately distinct from the lighter sapwood. The density is (420–)550–800(–850) kg/m^3 at 15% moisture content; that of the majority of the commercial supply is 600–700 kg/m^3. The grain is shallow-

ly interlocked, texture moderately fine and even.
At 15% moisture content the modulus of rupture is 70–130 N/mm^2, modulus of elasticity 10 000–18 000 N/mm^2, compression parallel to grain 28–54 N/mm^2, compression perpendicular to grain 2.5–7 N/mm^2, shear 8.5–11(–17) N/mm^2, cleavage 39–77 N/mm radial and 49–87 N/mm tangential, Janka side hardness 3700–7000 N and Janka end hardness 3900–7600 N.

The recorded rates of shrinkage of nyatoh are moderate, from green to 15% moisture content 1.3–3% radial and 2.3–4% tangential, from green to oven dry about 4.1% radial and 7.6% tangential. Air drying of 40 mm thick boards takes approximately 4 months, 25 mm thick boards about 2 months. The timber can be satisfactorily dried by using kiln schedule E (Malaysia). Form stability is medium to good when dry.

The sawing properties are variable, probably depending on the species, but variation may also be large within species. Some nyatoh-producing species contain silica, which makes the timber difficult to work (e.g. *P. endertii* and *P. lucida*). Gum may accumulate on cutters. Nyatoh is easy to polish when the grain is properly filled. The wood is easy to turn. Pre-boring for nails and screws is advised because of easy splitting. Gluing gives no problems. The fine grain and colour make it suitable for veneer; it can be peeled at a 91° peeling angle without pretreatment. Sometimes the wood is figured and then the veneer can be very attractive, especially when radially sliced. Peeling is reported as easy to fairly difficult, and a good plywood can be made from the timber.

Nyatoh is rated as only moderately durable. Graveyard tests with wood of *P. acuminata* in Indonesia showed an average service life in contact with the ground of only 1 year. It is prone to termite attack and susceptible to fungal attack, but not to powder-post beetles. Treated nyatoh timber can be very durable. However, the heartwood is very resistant to preservative treatment. The sapwood is less difficult to impregnate.

Bitis comprises heavier timber, with density of 850–1150 kg/m^3 at 15% moisture content. The heartwood is reddish-brown to dark brown, and clearly differentiated from the lighter sapwood. The grain is fairly straight, texture moderately fine and even. Bitis is very hard and strong, and much more durable than nyatoh.

At 15% moisture content the modulus of rupture is 105–170 N/mm^2, modulus of elasticity 10 000–23 800 N/mm^2, compression parallel to grain 65–90 N/mm^2, compression perpendicular to grain 9–12.5 N/mm^2, shear 10–17 N/mm^2, cleavage c. 86 N/mm radial and 67 N/mm tangential, and Janka side hardness 14 400–14 900 N.

Bitis is difficult to dry; shrinkage rates are rather high (from green to 15% moisture content 3.0% radial and 4.0% tangential), and there is a tendency to surface checking. A mild kiln schedule (B in Malaysia) should be used.

Bitis is difficult to work, rapidly blunting saws and cutters due to the presence of silica, but it produces a smooth surface in planing and takes stain and polish satisfactorily. The timber tends to split in boring and mortising. Bitis is not suitable for veneer and plywood because it is difficult to peel.

Bitis timber is rated as durable and is resistant to termite and wood-rotting fungi attack. It is very difficult to impregnate.

Freshly felled wood often has a sour smell and a bitter taste. It lathers freely when rubbed with water. Dust from sawn nyatoh and bitis timber may cause irritation to skin and mucous membranes.

Wood of *P. leerii* contains 49% cellulose, 28% lignin, 17% pentosan and 0.5% ash. The solubility is 2.3% in alcohol-benzene, 1.7% in cold water, 3.6% in hot water and 11.4% in a 1% NaOH solution. Dry distillation of the wood produces 31% charcoal, 12% settled tar and 43% piroligneous liquor.

The latex from the inner bark of the tree absorbs oxygen and becomes brittle. Gutta-percha is the purified, coagulated latex. It is a whitish-grey to yellowish-brown tough substance, consisting essentially of gutta hydrocarbon with some resin. It is pliable at 25–30°C, plastic at 60°C, and it melts at 100°C with partial decomposition; it is insoluble in water and resistant to acids. At 60°C gutta-percha can be moulded into a desired shape, which is retained on cooling. It is defined as a transisomer of rubber. The quality of gutta-percha depends on the ratio of poly-isoprene and resin; the best quality contains about 80% poly-isoprene, inferior quality much less, sometimes only 20%. *P. leerii* provides a gutta-percha of fairly good quality, containing 43–49% resin and 51–57% poly-isoprene. However, the quality is less than the gutta-percha from *Palaquium gutta*. The resin contains ß-amyrineacetate. The seeds of some species are reported as poisonous; extracted kernels of *P. lucida* contain about 30% saponin.

Description Medium-sized to large trees, with latex, up to 45(–50) m tall, with usually columnar, cylindrical or fluted and buttressed bole, up to 100 cm in diameter; outer bark smooth, irregularly cracked, fissured or scaly, grey to brown, inner bark soft and fibrous, pink, red or reddish-brown; twigs slender and terete, usually hairy or scurfy. Leaves alternate on branch shoots, spiral on leader shoots, simple and entire, mostly acuminate, usually glabrous above and more or less pubescent beneath when mature; midrib generally prominent on both sides, secondary veins straight, curving towards apex and joined near leaf margin, tertiary veins mostly descending from marginal conjunctions of secondary veins and ramifying towards the midrib; petiole of even thickness throughout its length; stipules early caducous. Inflorescence a small, axillary (sometimes pseudo-terminal) fascicle, 1–many-flowered. Flowers bisexual; sepals 4, 2 outer ones thick and fleshy, 2 inner ones thinner; corolla (7–)8(–9)- lobed, with short tube, glabrous, white or yellowish; stamens 13–20(–30), inserted at the throat of the corolla tube, with short filaments and acute anthers; pistil 1, with globose or conoidal (4–)6–8(–9)-celled ovary and long style. Fruit a berry with persistent and incrassate sepals and style and fleshy pericarp, 1(–2)-seeded. Seed with a thin crustaceous testa and long narrow hilum; endosperm abundant, cotyledons thin and flat. Seedling with epigeal germination, with strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves spiral and soon similar to leaves of adult trees.

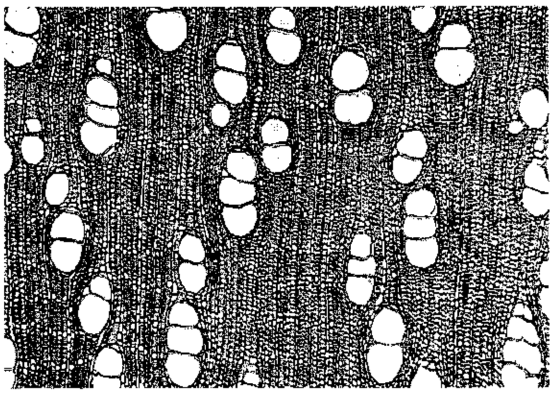
Wood anatomy

– Macroscopic characters:

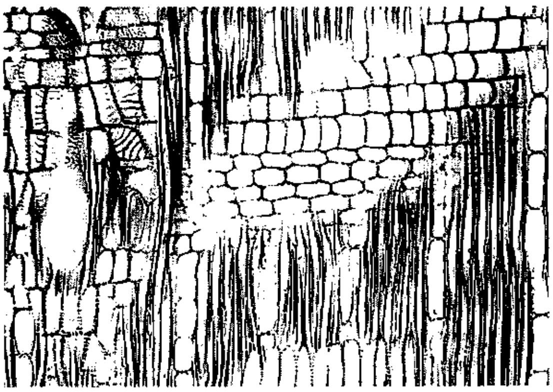
Heartwood deep pink, red, red-brown or purple-brown, sometimes with dark streaks, distinctly to indistinctly demarcated from the pale red sapwood. Grain shallowly to moderately interlocked, sometimes wavy. Texture moderately fine to slightly coarse; wood dull, sometimes with a sour smell when freshly sawn. Growth rings indistinct to the naked eye; vessels and parenchyma indistinct to barely visible to the naked eye; rays not distinct without a lens.

– Microscopic characters:

Growth rings faint or absent, if present marked by differences in spacing of tangential parenchyma bands, and in fibre wall thickness on either side of the ring boundary. Vessels diffuse, (4–)6–14(–25)/ mm^2, mainly in radial multiples of 2–5(–8), in a radial or radial to oblique pattern, round to oval, average tangential diameter 100–190 μm; perforations simple; intervessel pits alternate, round, 5–7 μm; vessel-ray pits mainly confined to the upright and square cells, mostly large and simple, horizontally to vertically elongated or round, partly



transverse section (×25)



radial section (×75)

tangential section (×75)

Payena lowiana

half-bordered, scarce in procumbent cells; helical thickenings absent; gum-like deposits and tyloses sometimes present. Fibres c. 1200–1800 µm long, non-septate, mostly medium thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, diffuse, diffuse-in-aggregates or in fine discontinuous to continuous 1–2-seriate wavy to straight bands forming a reticulate pattern, 4–8 lines per radial mm, in 6–9-celled strands. Rays 12–15/mm, 1–2(–3)-seriate, up to 800 µm high, heterocellular with (1–)2–5 marginal rows of upright and square cells and procumbent body cells. Crystals absent. Silica bodies often present in ray cells.
Species studied: *P. acuminata, P. leerii, P. lowiana, P. lucida, P. maingayi, P. obscura.*

Growth and development Water shoots often have unusually large leaves. There seems to be no definite time for flowering and fruiting. Flowering and fruiting trees can be found throughout the year, and sometimes a single tree bears flowers and fruits at the same time. In plantations of *P. leerii* on Java, with initial planting distances of 2 m × 2 m, the canopy closed after 10–12 years. The trees then reached 6–13 m in height. They flower and fruit already at an age of about 7 years.

Other botanical information There used to be much confusion about the genera of *Sapotaceae*. This has recently been largely clarified. However, in the timber trade no distinction is made between timber from several *Sapotaceae* genera and species. Data on nyatoh timber given in literature can only rarely be linked to individual genera and species. It is not surprising that nyatoh is known as a variable timber, as many species and several genera are involved.
Payena is generally included in the tribe *Madhuceae*, and is considered as closely related to *Madhuca*. Unlike *Madhuca, Payena* does not vary much in floral characters (4 sepals, 8 petals, 16 stamens, 8 ovary cells, rarely otherwise), but the shape of the leaves and stamens, and the number of seeds per fruit may vary. *Payena* is often recognized easily by the tendency of the leaves to be arranged alternately on the twigs and by the tertiary veins of the leaves descending from the marginal conjunction of secondary veins. However, it is sometimes difficult to identify herbarium specimens of *Payena*, especially sterile ones, even to the genus. Some species are apparently very closely related and may cause problems in identification, e.g. *P. acuminata* and *P. maingayi, P. leerii* and *P. obscura*. The most deviating species is *P. dasyphylla* with its woolly red pubescence and possibly purplish-red flowers; it is often placed in a separate section *Purpureopayena* v. Bruggen. The remaining species cannot be subdivided into groups as they show interwoven relationships and are placed in the section *Payena*, having a less dense pubescence and always whitish flowers.
The wood properties of nyatoh are close to those of makoré (*Tieghemella* spp.) from western and central Africa.

Ecology *Payena* trees are most commonly found in primary mixed dipterocarp forest, but occasionally also in secondary forests and at forest edges, e.g. along rivers. They occur from the lowland up to 1500(–2000) m altitude, on a variety of soils, from peat swamps to podzols, and from clayey to sandy soils, rarely on limestone. *Payena* trees generally belong to the middle or uppermost storey of the forest, but are not emergents. Locally, *Payena* species are not uncommon, although they usually occur scattered, e.g. *P. acuminata* in Java and Borneo, *P. leerii* in Sumatra and Borneo, *P. lucida* in many areas, and *P. obscura* in Peninsular Malaysia.
For plantations of *P. leerii*, high-rainfall areas at medium altitudes and loamy soils are preferable.

Propagation and planting *P. leerii* is usually propagated by sowing seed in a nursery. Fresh seed should be used, as viability declines rapidly. Seeds of *P. lucida* are 2–3 cm long and germinate in 2–5 weeks. When sown within a week of harvesting, up to 80% of the seeds may germinate. Saplings are planted at a spacing of 2 m × 2 m in the field. Mature trees usually provide fruits abundantly. Some species (*P. acuminata, P. maingayi*) occasionally produce fruits with more than 1 seed, but these seeds are reported to be less viable.

Silviculture and management In young plantations of *P. leerii* for gutta-percha production, *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. When the canopy has closed 10–12 years after planting, weeds are shaded out completely, and the ground is covered with fallen leaves.
For timber production, pure stands of *Payena* are probably not a good management target. It is better to plant dipterocarp species with more valuable timber. Natural regeneration is usually plentiful in logged-over forests.

Diseases and pests Nyatoh trees are reported susceptible to the fungus *Corticium salmonicolor*. In Peninsular Malaysia, a large species of longhorn beetle has been reported to attack living nyatoh trees. The larvae bore long tunnels, especially at the base of the trunk, and may severely damage the timber.

Harvesting No information is available on the harvesting of *Payena* timber. The logs have few defects.
The gutta-percha of planted trees of *P. leerii* can be harvested for the first time after about 12 years. Usually a vertical herring-bone cut is made in the inner bark in the early morning. The latex hardens to a sticky mass. The trees must be allowed to rest for about 1.5 year before the next harvest. Vigorous tapping can easily cause the trees to die. Methods have been developed to extract the leaves instead of the bark. An excellent product can be obtained, but the process is very labour-intensive. Gutta-percha is usually traded and transported in vacuum zinc containers. Gutta-percha from *P. leerii* is often mixed with the products from other *Sapotaceae* trees.

Yield No information is available on the yield of *Payena* timber. The annual yield of gutta-percha from *P. leerii* is not high; in Java (Indonesia) much less than 1 kg of dry latex per average tree (about 20 m tall), usually even less than 200 g. A big tree in Perak (Peninsular Malaysia) was reported to produce about 200 g annually. These figures are much lower than those for *Palaquium gutta*.

Genetic resources At the end of the 19th Century, the latex from *Sapotaceae* trees, including *Payena*, was important. Trees were often felled to obtain gutta-percha; this resulted in the destruction of such trees over wide areas. In Peninsular Malaysia, *P. leerii* and other species producing gutta-percha were protected a century ago. However, in many places trees were felled on a large scale well into the 20th Century for gutta-percha and for timber. Many *Payena* species occur scattered in the forest which makes them liable to genetic erosion and hence extinction.

Prospects Nyatoh is a valuable but silviculturally neglected timber. It has good properties for indoor uses, and is in demand for furniture and plywood. However, nyatoh is variable in its properties, because it covers many species from several genera. *Payena* species have only very rarely been subjected to tests. Tests on properly identified logs are desirable, as well as research on all silvicultural aspects. The relation between timber properties and species urgently needs to be clarified, so that silviculturists will know which species to concentrate on.
Although gutta-percha still enters commerce in small quantities, the main product of *Payena* species including *P. leerii*, is probably timber. Prospects for gutta-percha do not seem to be very promising, as it is being replaced by synthetic plastics. The trees have a very low annual yield of gutta-percha per ha and procedures for collection are very labour-intensive.

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Selection of species

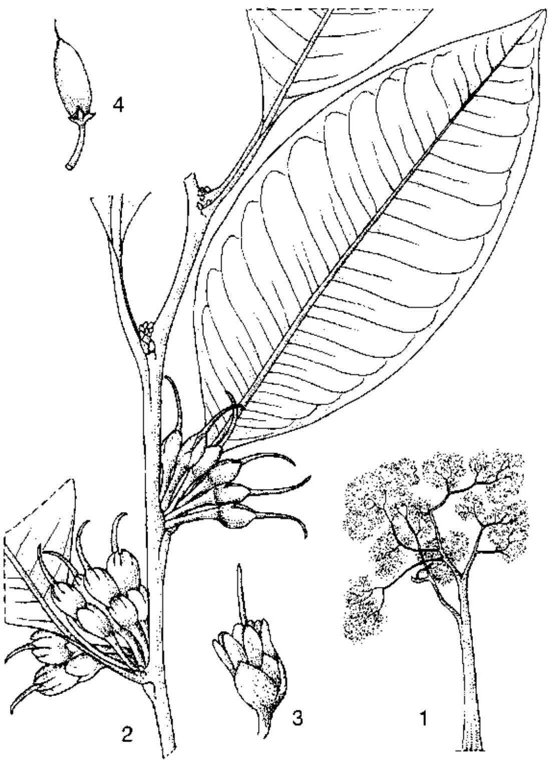
Payena acuminata (Blume) Pierre

Bull. Mens. Soc. Linn. Paris: 528 (1885).

Synonyms *Payena sericea* (Blume) H.J. Lam (1925) non Miq. (1859), *Madhuca acuminata* (Blume) Baehni (1965).

Vernacular names Indonesia: jengkot (Java), balam, balam durian (Sumatra). Malaysia: nyatoh durian. Thailand: cha-kun, phikun-pa (Narathiwat).

Distribution Thailand, Peninsular Malaysia,



Payena acuminata (Blume) Pierre – 1, tree habit; 2, flowering twig; 3, flower; 4, fruit.

Sumatra, Simeuluë, Java and Borneo (Kalimantan, Sabah).

Uses The timber is used as nyatoh. The latex is used to adulterate gutta-percha. The fruits are edible.

Observations A medium-sized to fairly large tree up to 40 m tall, but usually much less, with straight bole up to 90 cm in diameter; leaves usually elliptical, densely pubescent beneath; flowers small, up to 1 cm long, white; fruit ovoid or narrowly ovoid, 3–3.5 cm long. *P. acuminata* resembles *P. maingayi* but has smaller flowers. Two varieties are distinguished: var. *acuminata* and var. *pulchra* (Burck) H.J. Lam, the latter having broader leaves with more prominent secondary veins below and occurring only in Sumatra, Java and Kalimantan. *P. acuminata* is locally common (e.g. in Peninsular Malaysia), elsewhere it occurs scattered (e.g. in Java), and grows up to 1300 m altitude. The density of the timber is 580–880 kg/m³ at 15% moisture content. The latex supplies gutta-percha of very inferior quality.

Selected sources 35, 36, 100, 318, 461, 727, 779.

Payena dasyphylla (Miq.) Pierre

Bull. Mens. Soc. Linn. Paris: 527 (1885).

Synonyms *Bassia caudata* Ridley (1923), *Madhuca caudata* (Ridley) H.J. Lam (1925).

Vernacular names Indonesia: balam kerang, nyato kerah (Sumatra). Malaysia: nyatoh ekor (Peninsular). Thailand: phikun-dong (Pattani).

Distribution Peninsular Malaysia, Sumatra; possibly also Thailand.

Uses The timber is used as nyatoh. The latex is collected locally for gutta-percha in Sumatra.

Observations A medium-sized to fairly large tree up to 35 m tall, with columnar bole up to 100 cm in diameter, and steep buttresses; leaves usually elliptical, densely ferruginous and woolly pubescent beneath; flowers up to 1.7 cm long, recorded as white and purplish-red; fruit ovoid or obovoid, 1.8–2.5 cm long, densely ferruginous pubescent. *P. dasyphylla* occurs in lowlands and mountains up to 1400 m altitude, and is not common. The timber is heavy for nyatoh (about 840 kg/m³ at 15% moisture content).

Selected sources 102, 581, 727, 779, 792.

Payena endertii H.J. Lam

Bull. Jard. Bot. Buitenzorg, sér. 3, 7: 144 (1925).

Synonyms *Madhuca lamii* Baehni (1965).

Vernacular names Indonesia: balam terung (Sumatra), nyato burung beitis (Kalimantan).

Distribution Sumatra and Borneo (Kalimantan, Sabah).

Uses The timber is used as nyatoh, possibly also as bitis.

Observations A large tree up to 40 m tall with bole up to 80 cm in diameter; leaves ovate-oblong, pubescent beneath; flowers rather small, 1–1.2 cm long, white; fruit rounded-ovoid to spherical, 2.2–2.3 cm long, glabrous. *P. endertii* is closely related to *P. leerii, P. lucida* and *P. obscura,* but it can be distinguished by the long apex of the connective of the stamens and by the typical shape of the fruit. The timber is reported as medium-weight to heavy: in Sabah its density is reported as about 600 kg/m³ at 15% moisture content, in Indonesia 760–1070 kg/m³.

Selected sources 36, 100, 727.

Payena lanceolata Ridley

Journ. Roy. As. Soc. Straits Br. 79: 93 (1918).

Synonyms *Payena lancifolia* H.J. Lam (1925), *Isonandra lancifolia* (H.J. Lam) Baehni (1965).

Vernacular names Indonesia: balam (Sumatra). Malaysia: nyatoh ekor, ekor, beliau (Peninsular). Thailand: kun, cha-kun, phikun-nok (Surat

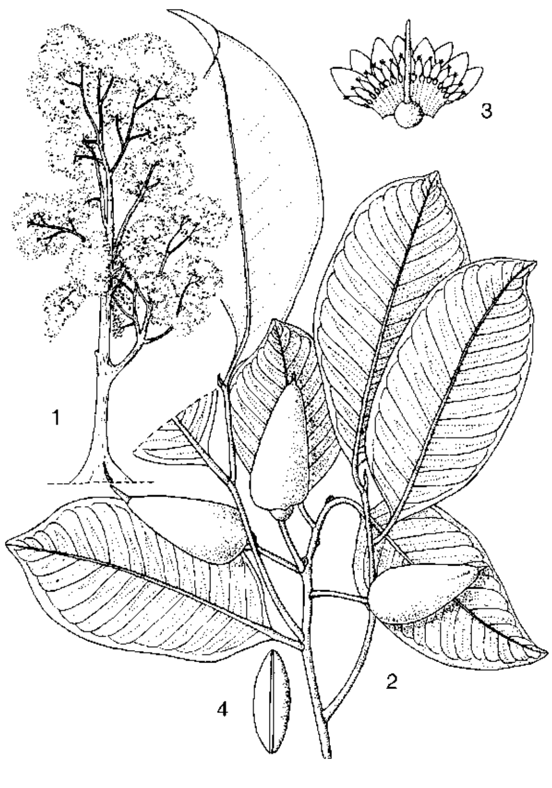
Thani). Vietnam: cata (Phan Rang).

Distribution Southern Vietnam, Thailand, Peninsular Malaysia and western Sumatra.

Uses The timber is used as nyatoh.

Observations A large tree up to 43 m tall, with columnar to fluted bole, up to 65 cm in diameter, and thin buttresses; leaves lanceolate to ovate-lanceolate, glabrous on both sides; flowers small, up to 0.7 cm long, white or pale yellow; fruit ovoid, 3–4.5 cm long, usually with a long apical beak. A distinct variety occurs in Vietnam: var. *annamensis* (Lecomte) v. Bruggen (synonym: *Payena annamensis* Lecomte); it differs from var. *lanceolata* in having narrower sepals, a sometimes 7-lobed corolla, longer and more slender stamens, a sometimes 6–7-lobed ovary, and a thinner fruit-wall. In Peninsular Malaysia *P. lanceolata* occurs in lowlands and hills up to 300 m altitude. The density of the timber is high for nyatoh, about 830 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 235, 581, 727, 779, 792.



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

Payena leerii (Teijsm. & Binnend.) Kurz

Journ. As. Soc. Beng. 40: 69 (1871).

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).

Distribution Peninsular Malaysia, Sumatra, the Riau Archipelago, Bangka, Borneo and the southern Philippines (Palawan, Mindanao, Sulu Archipelago); cultivated in Java, rarely also in tropical Africa and South America.

Uses The timber is used as bitis, sometimes as nyatoh. The latex was formerly important as gutta-percha. The fruits are edible.

Observations A medium-sized to fairly large tree up to 40 m tall, with columnar bole up to 80 cm in diameter, buttressed; leaves broadly ovate to oblong-lanceolate, glabrous on both sides; flowers very small, up to 0.5 cm long, white or yellowish-white; fruit cone-shaped or narrowly so, with a flat broad base, 2.5–5 cm long, glabrous or subglabrous. *P. leerii* is closely related to *P. obscura* and is most commonly found in primary forests, up to 1000 m altitude. The timber is usually heavy with a density of 760–1060 kg/m^3 at 15% moisture content. The gutta-percha is of good quality, but the yield is generally low.

Selected sources 35, 36, 100, 102, 255, 315, 318, 322, 451, 461, 486, 581, 727, 730, 779.

Payena lowiana Pierre

Bull. Mens. Soc. Linn. Paris: 525 (1885).

Synonyms *Payena glabra* H.J. Lam (1925), *Madhuca lowiana* (Pierre) Baehni (1965).

Vernacular names Indonesia: mayang rata (Sumatra), sau uding (Simeuluë), simpur (Kalimantan).

Distribution Peninsular Malaysia (only once collected), Sumatra, Simeuluë and Borneo (Kalimantan).

Uses The timber is used as nyatoh. The fruits are edible.

Observations A medium-sized to large tree up to 42 m tall, with bole up to 65 cm in diameter, buttressed; leaves ovate to ovate-lanceolate, glabrous or subglabrous beneath; flowers small, up to 0.8 cm long, white; fruit ovoid or ellipsoid, 2.5–3.5 cm long, shortly pubescent to glabrous. *P. lowiana* resembles *P. lucida*, but can be distinguished by the more prominent secondary veins of the leaves and longer styles. *P. lowiana* grows in the low-

lands, in marshy as well as in drier forests.
Selected sources 36, 318, 581, 727, 779.

Payena lucida (Wallich ex G. Don) A.DC.

Prodr. 8: 197 (1844).

Synonyms *Payena glutinosa* Pierre (1885), *Payena dasyphylla* (Miq.) Pierre var. *glabrata* King & Gamble (1905), *Madhuca lucida* (Wallich ex G. Don) Baehni (1965).

Vernacular names Indonesia: kalimangong (Sumatra), baringin jiput, nyatu hitam (Kalimantan). Malaysia: nyatoh bunga, mayang bukit (Peninsular). Thailand: phikun-thuan (Surat Thani).

Distribution Burma, Thailand, Peninsular Malaysia, Sumatra, Bangka and Borneo.

Uses The timber is used as nyatoh. The latex is used to adulterate gutta-percha. A decoction of the roots is used medicinally after childbirth.

Observations A medium-sized tree up to 30 m tall, but usually much less, with cylindrical bole up to 60 cm in diameter, buttressed; leaves narrowly elliptical to narrowly obovate, pubescent to glabrous beneath; flowers small, up to 0.8 cm long, whitish; fruit ovoid to ellipsoid, 1.5–4 cm long, pubescent to subglabrous. *P. lucida* is closely related to *P. lowiana*. It is a fairly common understorey tree, usually found in the lowland, but sometimes up to 1600 m altitude. The density of the timber is 670–830 kg/m^3 at 15% moisture content.

Selected sources 36, 100, 102, 461, 581, 727, 779, 792.

Payena maingayi C.B. Clarke

Hook.f., Fl. Brit. India 3: 547 (1882).

Synonyms *Payena grandiflora* Ridley (1912), *Madhuca maingayi* (C.B. Clarke) Baehni (1965).

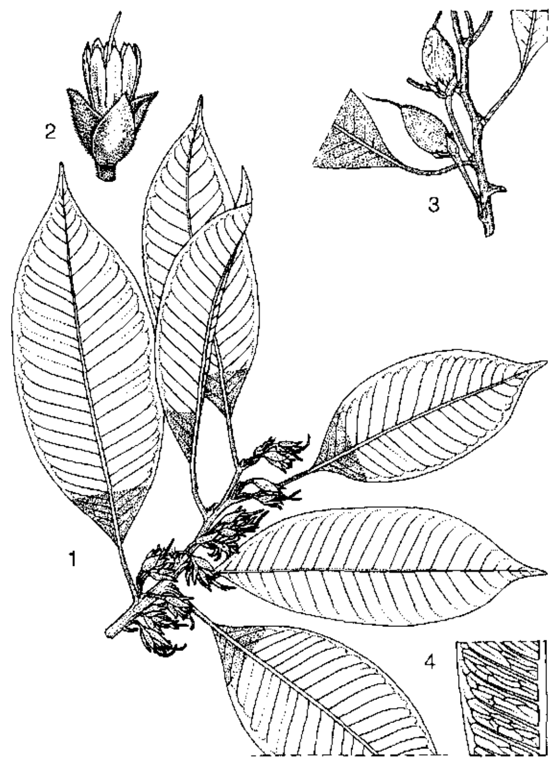
Vernacular names Malaysia: nyatoh durian, mayang, nyatoh paya (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as nyatoh.

Observations A medium-sized to large tree, up to 35(–50) m tall, with columnar bole up to 80 cm in diameter, buttressed; leaves oblong to lanceolate, densely pubescent beneath; flowers up to 1.6 cm long, white to pale yellow; fruit ellipsoid, 2–3.5 cm long, shortly pubescent. *P. maingayi* is closely related to *P. acuminata*. It occurs scattered in lowland forest below 300 m altitude, occasionally in swampy forest. The timber is fairly heavy for nyatoh with a density of about 750 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 581, 727, 779, 792.



Payena maingayi C.B. Clarke – 1, flowering twig; 2, flower; 3, twig with fruits; 4, detail of leaf showing tertiary venation.

Payena obscura Burck

Ann. Jard. Bot. Buitenzorg 5: 60 (1886).

Synonyms *Payena havilandii* King & Gamble (1905).

Vernacular names Indonesia: balam kadidie (Sumatra), nyatoh enkelit, nyatoh riau (Kalimantan). Malaysia: nyatoh sundek, getah sundek (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra, the Riau Archipelago and Borneo (Sabah, Sarawak, possibly Kalimantan).

Uses The timber is used as nyatoh or bitis. The latex gives a gutta-percha of fairly good quality.

Observations A medium-sized to large tree up to 43 m tall, with columnar bole up to 80 cm in diameter, buttressed; leaves elliptical, elliptical-ovate or elliptical-obovate, glabrous or subglabrous beneath; flowers rather small, up to 1 cm long, white or yellowish; fruit ovoid, 2–4 cm long, acuminate, pubescent or glabrous. *P. obscura* is closely related to *P. leerii*, but differs particularly in the shape of the fruits. It occurs in lowlands and on mountain slopes to 1000 m altitude; locally it is common (e.g. in Peninsular Malaysia). The timber is fairly heavy to heavy with a density of 680–1010 kg/m^3 at 15% moisture content.

Selected sources 100, 102, 318, 581, 727, 779, 792.

R.H.M.J. Lemmens (general part, properties, selection of species),
N. Tonanon (properties),
R. Klaassen (wood anatomy)

Pericopsis Thwaites

Enum. Pl. Zeyl.: 413 (1864).
LEGUMINOSAE
x = unknown

Trade groups Pericopsis: heavy hardwood, a single species within South-East Asia, *Pericopsis mooniana* (Thwaites) Thwaites, Enum. Pl. Zeyl.: 413 (1864), synonyms: *Ormosia villamilii* Merr. (1915), *Pericopsis ponapensis* (Hosok.) Hosok. (1943).

Vernacular names Pericopsis: nandu wood, nedun tree (En). Indonesia: kayu kuku (general), kayu besi papus (Sulawesi), nani laut (Irian Jaya). Malaysia: kayu laut (Peninsular, Sabah), merbau laut (Peninsular). Philippines: makapilit (Bisaya).

Origin and geographic distribution *Pericopsis* consists of 5 species, 4 of which are confined to tropical Africa. *P. mooniana* has a large area of distribution and is found in Sri Lanka, Peninsular Malaysia, southern Sumatra, eastern Borneo (Sabah, East Kalimantan), the Philippines (Mindanao), Sulawesi, the Moluccas, New Guinea and Micronesia (Jap, Palau, Ponape).

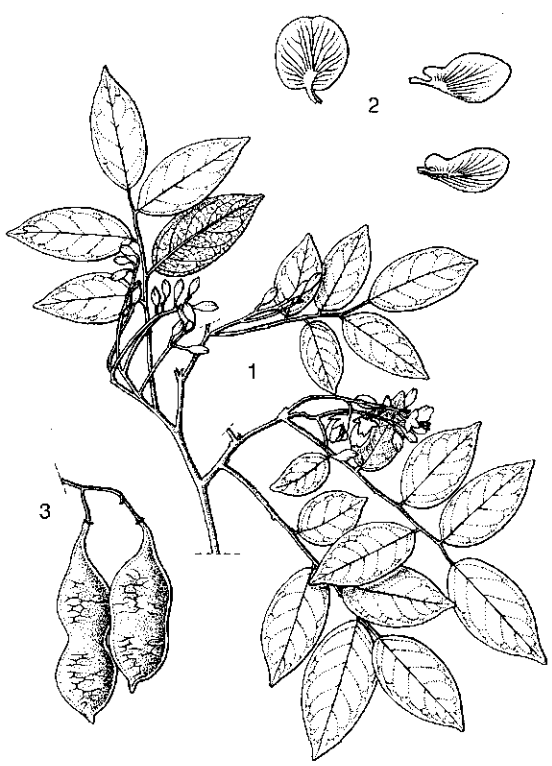
Uses *Pericopsis* timber is very handsome. It has decorative uses and is used as a substitute for teak for cabinet work, furniture, turnery, high-quality joinery, parquet flooring, shop fittings, panelling and veneer. It is also suitable for heavy construction purposes, and is used in ship building (especially for rails and decks), for bridges, door and window frames, vehicle bodies and in freshwater engineering. The wood can probably be used successfully in saltwater harbour works, but resistance to teredos has not yet been tested experimentally.

Production and international trade This decorative wood is very valuable. It fetches high prices on the world market and is ranked in Indonesia among other fancy woods such as sandalwood (*Santalum album* L.), ebony (*Diospyros celebica* Bakh.) and sawo kecik (*Manilkara kauki* (L.) Dubard). However, supplies of this timber are very limited, and trade and export are negligible. Export from Indonesia is probably mainly to Japan.

Properties The wood is moderately heavy to heavy and hard. The heartwood is yellowish-brown when fresh, turning to golden brown to dark brown upon exposure, usually with irregular darker streaks. The sapwood is light yellowish-brown, distinctly demarcated from the heartwood. The density is (650–)780–900 kg/m^3 at 12% moisture content. The grain is interlocked, texture fine to moderately coarse.

At 12% moisture content, the modulus of rupture is 151 N/mm^2, modulus of elasticity 16 100 N/mm^2, compression parallel to grain 90 N/mm^2, compression perpendicular to grain 10–12 N/mm^2, shear 14–15 N/mm^2, Janka side hardness 8900–9000 N, and Janka end hardness 10 600 N. See also the table on wood properties.

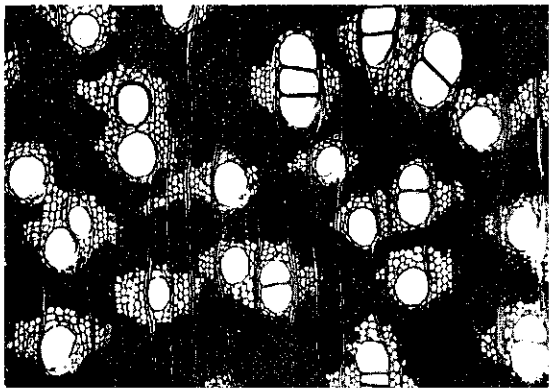
Pericopsis wood should be dried slowly and carefully. Close stacking during air drying is advised.



Pericopsis mooniana (Thwaites) Thwaites – 1, flowering twig; 2, flower parts; 3, pods.

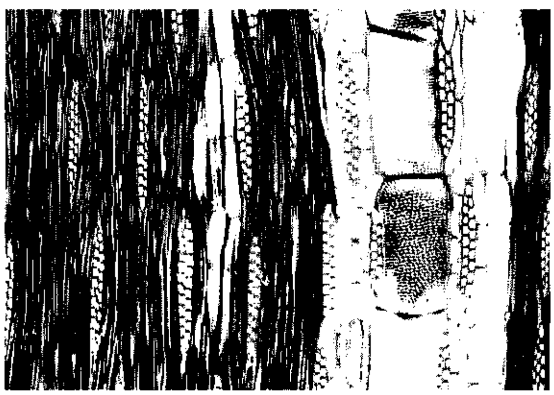
Shrinkage rates are medium (from green to 12% moisture content 2–4% radial and 4–7% tangential, from green to oven dry 3–5% radial and 5–8% tangential). Deformation during drying is slight, however. The timber kiln dries satisfactorily. Once dry, the wood is rated as stable.
The wood is fairly easy to work, although sharp saws are needed. There is a slight tendency to picking up of grain, but this can be obviated by cutting at an acute angle. When the grain is properly filled, the wood polishes and turns well. The holding power of nails and screws is good, but pre-boring is advisable as the wood is hard and is liable to splitting. Gluing gives no problems. Surfaces may have patchy discolorations; treating with synthetic oils and varnishing, or painting, solves this problem (the wood takes varnish and paint well).
The timber is durable, also in contact with the ground or when exposed to the weather. It is rated, however, as slightly susceptible to powder-post beetles. Laboratory tests in Indonesia showed that the wood is moderately resistant to dry-wood termites and that the resistance to wood-rotting fungi varies from poor to very good. It is moderately easy to treat with preservatives, the sapwood more easily than the heartwood. The average retention of heartwood is 226 l/m^3 to creosote oil, 182 l/m^3 to coppernaphtenate, and 16 kg/m^3 to 4% sodiumfluoride.

Description Medium-sized to fairly large trees, up to 40 m tall, with bole straight or twisted, branchless for up to 20 m but often less, up to 80(–100) cm in diameter, shallowly grooved or slightly fluted at base; bark soft and thin, reddish, flaking in thin plates. Leaves alternate, imparipinnate, 5–8-foliolate; leaflets alternate or rarely subopposite, ovate to elliptical, 4–9 cm × 2.5–5 cm, rounded at base, acute to broadly acuminate at the top, glabrous, with about 7 pairs of secondary veins; stipules early caducous, stipels minute or absent. Inflorescence racemose or paniculate, axillary or terminal, bracts and bracteoles minute, very early caducous. Flowers bisexual, about 2 cm long; calyx bell-shaped, about 15 mm long, appressed pubescent outside, tomentellous inside, with 5 acute lobes, two slightly shorter than the other three, and connate for most of their length; corolla papilionaceous, keel petals partly connate, wings auriculate, glabrous, dark purple; stamens 10, equal, free, anthers small, ellipsoid to oblong, dorsifixed; ovary stipitate, 1–6-ovuled, pubescent along the margin, style with a hooked apex and a small terminal stigma; disk present at base of



transverse section (×25)

radial section (×75)



tangential section (×75)

Pericopsis mooniana

ovary. Fruit a slightly woody, oblong pod, flat, indehiscent, stipitate with a narrow base, beaked at the tip, winged along margin, glabrous, sometimes constricted near the middle. Seeds large, flat, rounded to elliptical, reddish-brown, with apical orbicular hilum. Seedling with epigeal germination.

Wood anatomy

– Macroscopic characters:

Heartwood yellowish-brown when fresh, turning to brown, dark brown or dark golden brown upon exposure, usually with irregular darker streaks, demarcated distinctly from the light yellowish-brown sapwood; white coloured deposits in vessels often visible. Grain distinctly interlocked. Texture fine to moderately coarse. Growth rings often vaguely discernible; ripple marks distinct but fine.

– Microscopic characters:

Growth rings, if discernible, marked by marginal, interrupted parenchyma bands and/or a slight difference in vessel diameter and/or in fibre wall thickness on either sides of the ring boundary and/or periodical variation in the length of confluent parenchyma from early to late wood. Vessels diffuse, (6–)8–13/mm^2, usually solitary and in radial multiples of 2–3(–4), rarely in clusters, 108–160 μm in tangential diameter; perforations simple; intervessel pits alternate, vestured, 6–8 μm in diameter; vessel-ray and vessel-parenchyma pits usually almost similar to intervessel pits, rarely palisade-like and simple; tyloses infrequent. Fibres 1.0–1.7 mm long, thick-walled (walls c. 3.5 μm thick), pits infrequent, with minute borders, confined to the radial walls. Parenchyma winged-aliform to confluent, connecting a few vessels, apotracheally diffuse-in-aggregates, and sometimes in interrupted bands at the ring boundary, usually in 2–3(–4)-celled strands. Rays 7–9/mm, (1–)2–3(–4)-seriate, 100–280 μm high, homocellular (Kribs type homogeneous). Prismatic crystals present in chambered axial parenchyma, in long chains sometimes of more than 20 chambers; aliform and confluent parenchyma usually containing crystals in their outer layers. All elements storied.

Growth and development Seedlings grow slowly; in nurseries a total growth of 2 cm is reported for the first two months of growth in the shade and only 0.5 cm per month in the open. After 4 years, the average height of plants grown from seeds from Sri Lanka in the Philippines was 1.9 m. Trees grown in West Java, also from seeds from Sri Lanka, started to flower and bear fruits when 10 years old. They do not flower and fruit every year. The flowering time in West Java is December to February and the fruits ripen from April to July. *P. mooniana* is known to nodulate well, and its ability to supply its own nitrogen gives the tree a notable advantage.

Other botanical information *Pericopsis* was considered to be a monotypic South-East Asian genus until it was pointed out that the African genus *Afrormosia* should be merged with the former. Others prefer to keep the two genera separated on the basis of the stipels being absent in *Pericopsis* and present in *Afrormosia*. Stipels are, however, present in collections of *Pericopsis mooniana* from Sri Lanka and Sumatra. The merging of the two genera is consolidated by phytochemical research.

The genus *Pericopsis* s.l. is closely related to *Ormosia* from tropical South-East Asia and tropical America, and to *Haplormosia* from tropical Africa. It differs from the first by the presence of a disk and auriculate wings and keel, and from the second by the dorsifixed anthers and also the auriculate wings and keel.

Ecology *P. mooniana* grows primarily scattered in coastal forests, but can be found along river banks and in periodically inundated forest up to 200(–350) m altitude. It occurs in evergreen or semi-deciduous forest, primarily on sandy regosols which are relatively infertile. The species requires an annual rainfall of 750–2000 mm and occurs in more seasonal conditions with 3–4 dry months (monthly precipitation less than 60 mm). In south-eastern Sulawesi *P. mooniana* is found in association with *Actinodaphne glomerata* Nees, *Calophyllum soulattri* Burm.f., *Dehaasia curtisii* Gamble and *Metrosideros petiolata* Koord.

Propagation and planting Seeds have no dormancy period, and germinate well (about 87%) when sown soon after collection. The seeds quickly lose viability and cannot be stored for more than 3 months unless they are stratified, which may prolong storage of viable seeds up to 6 months. *P. mooniana* can also be propagated easily from stem cuttings.

Application of growth hormones may increase the growth of seedlings; a GHB solution of 3 ml/l water gives good results. Seedlings are usually planted from the nursery into the field when 16–20 cm high and having 5–7 leaves. Usually, all the leaves are stripped off and the leader shoot and taproot are cut back before the seedlings are transplanted. When using wildlings, the best results have been obtained with plants 30–40 cm tall.

Diseases and pests Seedlings often suffer from damping-off disease. In nurseries, seeds are reported to be damaged by the large cricket species *Brachytrypes portentosus*.

Harvesting In Indonesia trees are harvested according to the Indonesian selective felling and planting system, with a diameter limit of 50 cm. The logs are sinkers, so cannot be floated down the river. Wood dust may irritate eyes and throat. Potentially hazardous sharp splinters may be released from the wood during sawing.

Genetic resources *P. mooniana* is an uncommon species. Since natural regeneration is scarce and large-scale exploitation has not been followed by replanting, this species is at risk of being endangered. In many areas it is rare and considered vulnerable, e.g. in Peninsular Malaysia, Kalimantan, Sulawesi and Sri Lanka. Only locally are there stands of at least some importance, e.g. in western Irian Jaya, western Papua New Guinea and South Sulawesi. In 1962 the standing volume in western Irian Jaya was estimated at 600 000 m^3.

Prospects *P. mooniana* yields a valuable timber. However, the species urgently needs protection. It was proposed in 1992 for inclusion in Appendix II of the CITES convention. All trade of species included in Appendix II must be registered. Plantations may be established fairly easily, but more research on silvicultural aspects is urgently needed.

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Other selected sources 168, 182, 231, 251, 266, 318, 333, 365, 371, 550, 726, 772.

K. Sidiyasa (general part),
I. Soerianegara (general part),
A. Martawijaya (properties),
S. Sudo (wood anatomy)

Peronema Jack

Malayan Misc. 2(7): 46 (1822).
VERBENACEAE
x = unknown

Trade groups Sungkai: lightweight hardwood, a single species, *Peronema canescens* Jack, Malayan Misc. 2(7): 46 (1822), synonym: *Peronema heterophyllum* Miq. (1860).

Vernacular names Sungkai: false elder, kurus (En). Indonesia: jati sabrang (general), jati londo (Java), kurus (Kalimantan). Malaysia: sukai, cherek (Peninsular). Thailand: sangkae (Surat Thani), khoeilai (Chumphon, Ranong), sakae (Malay, Narathiwat).

Origin and geographic distribution *Peronema* is a monotypic genus and is native in Peninsular Malaysia, Sumatra, the Riau Archipelago, West Java and Kalimantan (especially the centre). It is cultivated in Indonesia, Malaysia and Thailand. It may have been introduced into Java from Sumatra but it is now fully naturalized.

Uses The lightweight, non-durable timber is used for pillars in houses, interior finishes, and especially for roof trusses on account of its lightness and strength. It has been used to make carts, and bridges for light traffic. The attractive linear figure makes it suitable for furniture and cabinets as well as for decorative veneer. In Kalimantan and the Riau Archipelago small-scale furniture factories are often supplied with sungkai, which is used as raw material for external frames.

The tree is often planted in hedges. In traditional medicine the bitter juice of the leaves and a decoction of the bark are used against fever. Boiled leaves are used in a poultice against ringworm, and in a mouth-wash against toothache.

Production and international trade The wood of sungkai is mostly used locally. It can be obtained in fairly large quantities and is regularly available. The current price in Java is US$ 90/m^3 and sungkai is classified as a luxurious timber. In Indonesia, export to Japan is becoming important.

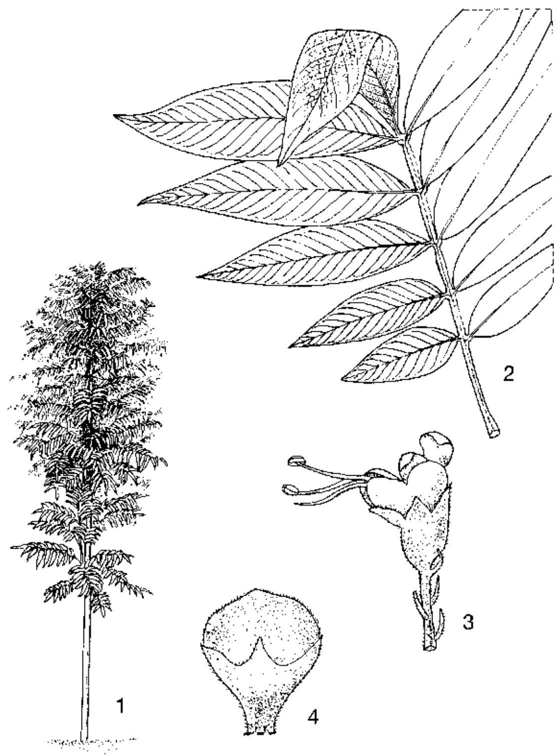
Properties Sungkai is a light to medium-weight and moderately hard wood, with some resemblance to teak. The heartwood is cream-coloured to light yellow or light brown, and not clearly demarcated from the sapwood. The density is (360–)520–730 kg/m^3 at 15% moisture content. The wood surface is moderately glossy, and the radial surface shows a figure of distinct and straight lines. The grain of the wood is straight, but sometimes slightly wavy, texture moderately fine to moderately coarse and often rather uneven.

At 15% moisture content the modulus of rupture is 56–67 N/mm^2, modulus of elasticity 8000–8400 N/mm^2, compression parallel to grain 31–34 N/mm^2, shear 4–7 N/mm^2, cleavage c. 61 N/mm radial and 64 N/mm tangential, Janka side hardness 2530 N and Janka end hardness 2960 N. See also the table on wood properties.

Sungkai dries fairly rapidly without serious defects, but cracking may occur. Boards of 25 mm thick take about 2 months to air dry.

The working qualitites are rated as moderately easy, but the presence of silica in the wood may blunt saws. Planing, shaping and turning give moderate results. Boring and sanding give good results. Good veneer can be made at a peeling angle of 92°30′, and the veneer can be glued with urea-formaldehyde to produce good-quality plywood.

Sungkai is rated as moderately durable; it has an average service life in contact with the ground of about 3 years. It is moderately resistant to dry-wood termites, is resistant to powder-post beetle attack, but is readily attacked by pinhole borers.



Peronema canescens Jack – 1, habit of young tree; 2, leaf; 3, flower; 4, fruit.

The wood is not discoloured by sapwood-staining fungi. It is easy to treat with preservatives.

The wood contains 49% cellulose, 16.5% pentosan, 1.6% ash and 0.4% silica. The solubility is 4.0% in alcohol-benzene, 1.1% in cold water, 5.3% in hot water, and 11.3% in a 1% NaOH solution. The energy value is 20 150 kJ/kg.

Description An evergreen or deciduous shrub or small to medium-sized tree up to 20(–30) m tall; bole straight or slightly flexuous, branchless for up to 9(–15) m, up to 70 cm in diameter, usually with small buttresses; root system superficial, with a short taproot; bark surface dirty grey or light buff, smooth to fissured and fibrous or scaly; crown ovoid; twigs 4-angled, densely short-hairy. Leaves opposite, imparipinnate, purplish tinged when young; petiole and rachis winged, together (16–)30–90 cm long; leaflets in 3–11 opposite or subopposite pairs, sessile or shortly stalked, lanceolate, up to 35 cm × 7.5 cm, base cuneate and slightly unequal, acute to acuminate at the top, the upper leaflets increasing in size, margin entire (serrate in saplings), densely pubescent and pale whitish beneath, lateral veins 20–30 pairs, parallel, prominent below; stipules absent. Inflorescence paniculate, terminal or in the axils of the upper leaves, large and widely branched, erect, 25–60 cm long, densely shortly grey tomentose. Flowers bisexual, small, subsessile, 5-merous; calyx densely pubescent outside, about 2.5 mm long but slightly enlarged in fruit, the lobes slightly shorter than the tube; corolla bilabiate, with a short bell-shaped tube, white or greenish-white, appressed pubescent outside, upper lip bifid, lower lip 3-fid, longer than the upper, with a large median lobe of 2.5 mm long; stamens 2, inserted at the base of the widening part of the corolla tube, far exserted, filaments glabrous; ovary 4-celled, the cells 1-ovuled, densely pubescent, style far exserted, with a subulate top. Fruit drupaceous, dry, globose, small, 3–3.5 mm in diameter, densely pubescent, splitting into 4 parts, with many pendulous seeds. Seedling with epigeal germination; cotyledons equal, petiolate, ovate with an emarginate apex, entire or coarsely 2–4-dentate; first leaves pinnately lobed, subsequent ones imparipinnate.

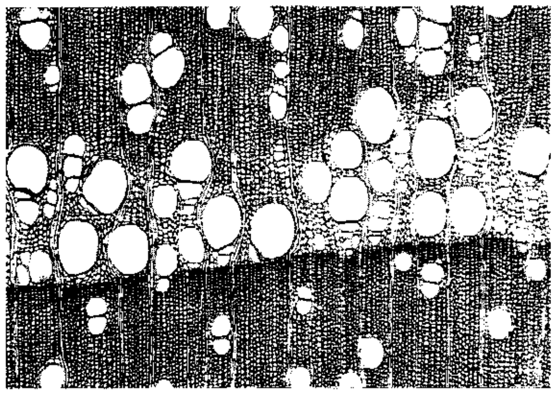
Wood anatomy

– Macroscopic characters:

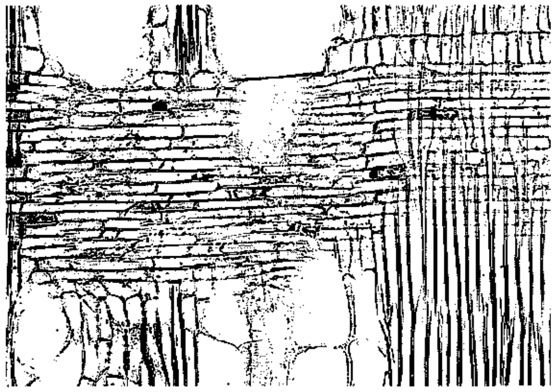
Heartwood cream-coloured to yellowish or light brown, often with a light red tinge, not clearly distinct from the sapwood. Grain straight, sometimes slightly wavy. Texture moderately fine and even or moderately coarse and uneven. Growth rings conspicuous on all surfaces; wood ring porous, pore rings producing dark lines on longitudinal surfaces, vessels visible with a lens, in pore rings medium-sized to moderately small; parenchyma and rays only visible with a lens; ripple marks and intercellular canals absent.

– Microscopic characters:

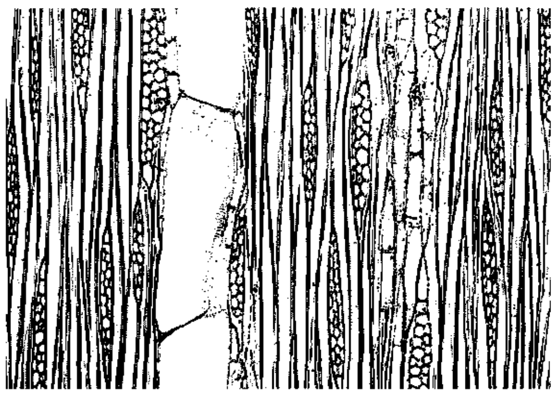
Growth ring boundaries marked by difference in vessel frequency and vessel size. Vessels 5–8/mm^2, in pore rings in radial or oblique rows of 2–3 and 180–260 μm in tangential diameter, in latewood mostly solitary but occasionally in radial pairs, 100–170 μm in tangential diameter; perforations simple; intervessel pits alternate, minute; vessel-ray pits similar to intervessel pits, but occasionally simple. Fibres 900–1600 μm long, with an average diameter of 19 μm, non-septate, moderately thick-walled (3.5–4 μm), with simple to minutely bordered pits. Parenchyma moderately abundant, paratracheal, aliform, mainly vasicentric, forming complete or incomplete borders to the vessels, and tending to form discontinuous confluent layers; terminal parenchyma present at the borders of the growth rings. Rays 4–7(–12)/mm, usually



transverse section (×25)



radial section (×75)



tangential section (×75)

Peronema canescens

4–10-seriate, 200–800 μm high, 40–60 μm and 1–3 cells wide, heterogeneous (Kribs type heterogeneous II and III). Crystals absent, silica bodies often present in ray cells.

Growth and development Sungkai trees need much light for optimal growth. At first, growth is reasonably rapid in full light, but slows down later, even on fertile soils. Seedlings grow fast when fully exposed, but when shaded, even lightly, the stems become very slender and brittle. Mean annual growth increments in trial plots in a logged-over area in East Kalimantan were 120 cm in height and 0.8 cm in diameter for saplings, and 114 cm in height and 1.5 cm in diameter for pole-sized trees. In East Java 7-year-old trees had an average height of 9.5 m and an average diameter of 10.3 cm.

First flowering occurs when trees are about 5 m high, in Java at an age of approximately 5 years. Flowering season in Java is in June/July, in South and East Kalimantan in January/February. Fruiting occurs about 2 months after flowering. The seeds are dispersed by wind and water.

On dry sites the tree may be deciduous but in wet sites it may be evergreen.

Other botanical information The genus *Peronema* is assigned to the subfamily *Caryopteridoideae* on the basis of its cymose inflorescence and its drupaceous, 4-parted fruit. Its closest relatives probably belong to the genus *Glossocarya*, which differs in having 4 stamens and a narrow fruit with basally winged seeds. Sungkai resembles elder (*Sambucus* spp.), hence the name false elder. However, the leaves of sungkai are not foetid when crushed, its flowers are not fragrant and the large panicles with small dry fruits and winged petioles are quite distinctive.

Ecology Sungkai is common in secondary forest, forest clearings, river banks, along roads and railways, and in open country. It does not occur in primary forest and it grows best in moist to wet sites, even if they are flooded seasonally; it does not withstand very dry conditions well. Sungkai occurs naturally from sea-level up to 600(–900) m altitude.

Luxuriant natural regeneration occurs in open, disturbed places such as logged-over areas, making sungkai one of the species that benefit from disturbance of the forest.

Propagation and planting Seeds germinate soon under full light, but collected seeds do not germinate well. The weight of 1000 seeds is 3.5–4 g.

The common method of propagation is by stem cuttings taken from straight trees. Experiments in Indonesia showed that cuttings 1.5–2 cm in diameter and 20–25 cm long give the best rooting results. The application of growth hormones to promote rooting may result in 100% rooted cuttings of juvenile material within 8 days. Trees from stem cuttings will finally develop a superficial root system similar to that of trees grown from seed. Cuttings placed directly in the soil may develop rot, especially at the base if thick. The planting medium commonly used in nurseries consists of topsoil and green manure (7 : 2), sometimes with some additional sand.

After 4–6 months the young plants may be transplanted. Planting distance in Indonesia is usually 3 m × 1 m, but spacings of 3 m × 2 m and 4 m × 2 m are also used. In plantations the canopy closes after about 8 years.

Silviculture and management Sungkai is unsuitable for planting in mixtures with other species, but it may be used as first cover for the planting of dipterocarp species. Self-pruning does not occur sufficiently. Artificial pruning is necessary; wounds caused by artificial pruning heal fast and seldom cause rot.

Diseases and pests Seedlings under shade are often attacked by leaf rust. Shoot-boring insects that tend to attack the tops may deform trees, but the damage is not serious.

Harvesting In Palembang it has been found that long-term storage of the wood in running water is beneficial, and petrifies the wood in 6 years. Sunkai is usually clear felled when the trees have reached an average diameter of 20 cm or more. Fresh logs should not be debarked and both ends should be treated to prevent ambrosia beetle attack. Logs protected this way can remain in the forest for 30 days.

Yield Mean annual volume increment was about 10 m^3/ha in a 15-year-old stand, planted at a spacing of 3 m × 1 m in Gadungan (Indonesia).

Genetic resources In Indonesia sungkai supplies from natural forests are becoming depleted, but as natural regeneration is often abundant in disturbed areas, there seems to be no direct danger of threat to *P. canescens*. There are plantations of several hundreds of ha in Central and East Java and in logged-over concession areas of East Kalimantan.

Prospects The planting of sungkai offers bright prospects, and more plantations are already planned in Indonesia. Sungkai is able to grow on very poor soils, and even stems with a small diameter can be used. More reliable information is needed, especially on the silviculture and management of plantations.

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N.R. de Graaf (general part),
J.W. Hildebrand (general part),
R.P. van der Zwan (properties),
J.M. Fundter (wood anatomy)

Pinus L.

Sp. pl. 2: 1000 (1753)
PINACEAE
$x = 12$; $2n = 24$ (for the vast majority of species)

Trade groups Pine: medium-weight timber, e.g. *Pinus kesiya* Royle ex Gordon, *P. merkusii* Junghuhn & de Vriese.

Vernacular names Pine: pitch pine, deal (En). Pin (Fr). Indonesia: tusam. Malaysia: pokok pine. Burma: tinyu tinshu. Cambodia: sral. Thailand: son-sambai, son-songbai, sonkhao (central). Vietnam: th[oo]ng.

Origin and geographic distribution The genus consists of slightly more than 100 species. The evolutionary origin of the genus 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, while 3 others are planted locally.

Uses Pine is a good general-purpose timber, although in woodworking and finishing aspects its resinous nature requires special attention. The wood of species grown in Malesia is moderately hard to hard, but the heartwood is not very durable. It can be put to a great number of uses such as both light and heavy constructional work, joinery (window frames, doors, weatherboarding, etc.), boxes and crates, posts and poles, pencils and furniture. It may be used for flooring in rooms subject to light pedestrian traffic, and for ship and boat building. It is recommended for treated sleepers and for blockboard manufacturing. It makes an acceptable quality of veneer and plywood. The suitability of the wood of individual species for the different specific end-uses is mainly determined by its density and resinous nature. The wood of Caribbean pine (*P. caribaea*) is usually less heavy and it also exudes much resin, which makes it less suitable for certain uses e.g. joinery and flooring.

Pine wood is used for making particle board. Benguet pine (*P. kesiya*) in particular yields high-quality board. The pine species grown in the Malesian region are usually of an inferior quality with regard to their pulping characteristics. In general, they have comparatively thick tracheid walls which makes paper less flexible, but the addition of small amounts of this pulp to pulp of other wood leads to a higher tear strength.

When tapped, pine yields an oleoresin which is distilled to give turpentine and rosin which is

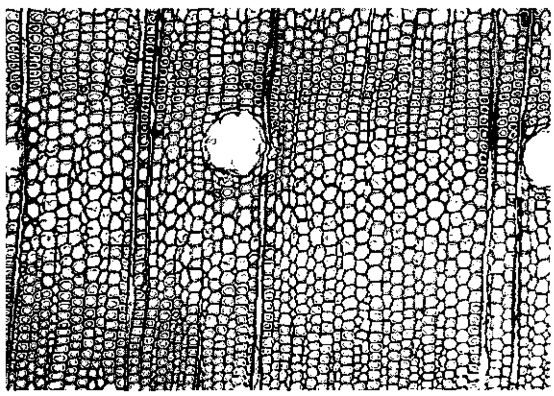
used in e.g. paint and batik industries. Large-scale production takes place in several localities within Malesia.
Pine-leaf oil is sometimes used for medicinal baths, and the seeds may be consumed locally.
Several pine species have been tested for their usefulness in shading out alang-alang (*Imperata cylindrica* (L.). Raeuschel) with fairly good results.

Production and international trade Pine is important for the production of timber, pulp and turpentine. No figures on trade and export are available, partly because the timber is often used locally, and the pulp is often mixed with pulp of other woods. The total production of turpentine in Indonesia was about 5.3 million t in 1989. The export value of gum turpentine increased from US$ 113 500 in 1983 to US$ 790 000 in 1987.

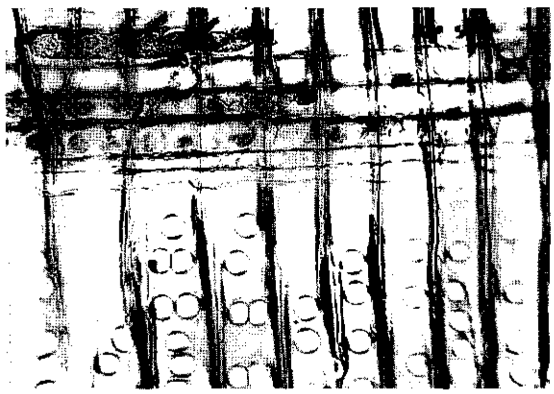
Properties Pine is a medium-weight, moderately hard wood. The colour of the heartwood is yellowish-brown to red-brown, depending on the resin content (more resin yields darker wood). The sapwood is yellowish-white to light reddish-yellow, and sharply defined from the heartwood. The density of heartwood of *P. merkusii* from Sumatra is 565–750 kg/m^3 at 15% moisture content. The density of timber of the same species grown in Burma and Indo-China is normally less: 480–530 kg/m^3. Timber of *P. kesiya* from the Philippines and Burma has an average density of 560 kg/m^3 at 12% moisture content, and plantation-grown Caribbean pine (*P. caribaea*) 410 kg/m^3. The grain of pine wood is even to finely interlocked, texture coarse.
At 15% moisture content the modulus of rupture is 41–83 N/mm^2, modulus of elasticity 4600–12 500 N/mm^2 (up to 15 500 N/mm^2 at 12% moisture content in *P. kesiya* wood from the Philippines), compression parallel to grain 24–44 N/mm^2, shear 8–10 N/mm^2 (in *P. caribaea* usually slightly less), cleavage 38–42 N/mm radially and 46–55 N/mm tangentially, and Janka side hardness 2760–3800 N (slightly less in *P. caribaea*).
The rates of shrinkage of pine are medium, 3.9–4.9% radial and 6.4–8.3% tangential from green to oven dry. Seasoning properties of *P. merkusii* timber are good and no serious difficulties are encountered, provided stock is converted soon after felling and protected during drying. Kiln-drying properties are rated as good, but resin and staining may cause problems. High-temperature drying (at 115°C) takes 24 hours for boards 2.5 cm thick and 48 hours for boards 5 cm thick; no serious defects develop. The wood of *P. kesiya* seasons well without serious degrade when the timber is well piled and closely stacked. Kiln drying is easy, but it is advised to use a mild schedule; fast drying at high temperature may result in serious splitting and excessive resin exudation. For wood of *P. merkusii* in Indonesia, a drying temperature of 54–82°C and a corresponding relative humidity of 76% to 30% is recommended. Plantation-grown material of *P. caribaea* from Fiji seasons satisfactorily provided it is under cover, well stacked with closely spaced stickers, and weighted to prevent distortion. Boards of 30 mm thick require about 6 weeks for air drying from green to 20% moisture content. Conventional kiln drying is successful for both 25 mm thick material (which takes 3–4 days to dry to 12–14% moisture content) and 50 mm thick material. High temperature drying has proved successful for framing sizes. Boards of 30 mm thick timber of plantation-grown *P. caribaea* may be dried in a solar kiln from 145% to 12% moisture content in 40 days.
The green wood is normally easily worked both by hand and machine, although light damage may occur due to the presence of resin. Sawing very resinous material is usually classified as difficult. This can be cured by spraying the sawteeth with paraffin. The timber works easily when air-dried, but it is liable to produce a rough finish. It nails, tongues and grooves in a perfect fashion, and generally glues and takes paint and varnish without difficulty. To glue resinous material the surfaces must be freshly planed or sanded, and then treated with a cleaning fluid (e.g. white spirit). Resinous wood is sometimes difficult to paint and varnish properly because the resin may exude again under the coating layer. The timber of *P. kesiya* is easy to cut into smooth, tight veneer of uniform thickness at a cutting temperature of 50–70°C. During drying the veneer shows slight to moderate shrinkage and warping, and is usually split-free. To obtain an acceptable quality of veneer it is often necessary to patch or fill imperfections in the wood due to the presence of knots and localized raised grain, and then to sand the surface.
Pine timber is only moderately durable, and often prone to termite attack. It is also susceptible to blue stain, ambrosia beetles and dry-wood borers. Graveyeard tests on *P. merkusii* in Indonesia showed a service life in contact with the ground of 1–4.5 years. Heartwood of *P. merkusii* can be impregnated with CCA preservative quite well; it is classified as 'permeable'. Heartwood of *P. caribaea* is rated as moderately resistant to impregnation.
Pines give a long-fibred pulpwood. The wood is

suitable for making wood-wool boards.
Wood of *P. merkusii* contains 55% cellulose, 24% lignin, 14% pentosan, 1.1.% ash and 0.2% silica. The solubility is 6.3% in alcohol-benzene, 0.4% in cold water, 3.2% in hot water and 11.1% in a 1% NaOH solution. The energy value of the wood is 20 300–23 200 kJ/kg.
The oleoresin is a pale yellow, clear and sticky mass, which becomes brittle on evaporation. It is a hydrophobic substance soluble in neutral, non-polar organic solvents such as dry ethyl ether, hexane, and other petroleum solvents, and it mainly consists of terpenoids, hydrocarbons, and neutral compounds. On distillation it produces gum rosin and gum turpentine in a ratio of 4–6 : 1. Pine bark contains tannin; from the bark of *P. caribaea*, for instance, about 10% tannin can be extracted; it can be dried to a reddish powder soluble in water. Ethyl alcohol extracts of *P. merkusii* showed anticancer activity in tests in the Philippines.

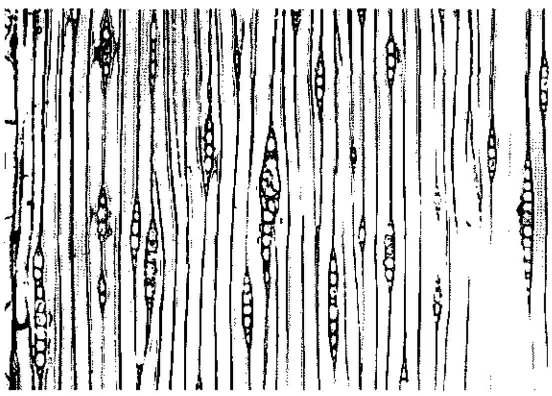
Description Usually medium-sized, monoecious evergreen trees of 15–35(–45) m tall, usually with a straight bole which in dense stands is free of branches for 10–25 m and has a diameter of up to 100(–140) cm; bole non-buttressed but distinctly broadened at base in solitary trees; bark usually thick, rough and deeply furrowed though variable, sometimes even within the same species; branches disposed 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 in their axils the short shoots, and needle-like leaves, in clusters of 2–4(–5) (depending on the species), the latter persistent for two or more years, either semi-circular 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, spirally arranged scales, each with 2 inverted pollen sacs. Female cones usually terminal or sub-terminal, very variable in outline, consisting of spirally arranged scales which are thickened at the apex (called the apophysis), and which bear 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 fine roots near the soil surface and near the root tip.



transverse section (×25)



radial section (×150)



tangential section (×75)

Pinus merkusii

Wood anatomy

– Macroscopic characters:

Sapwood merging into heartwood except in old trees; sapwood whitish or creamy white, heartwood yellow or yellowish-red to orange-brown. Grain straight to uneven. Texture coarse. Darker streaks present due to latewood bands and darker lines like scratches seen on longitudinal surfaces due to axial resin canals. Growth rings distinct but irregular in width, wood resinous; rays very fine, indistinct to the naked eye.

– Microscopic characters:

Growth rings distinct with prominent latewood bands. Tracheids coarse, arranged in prominent radial rows 35–45 μm wide in the latewood, squarish rectangular to hexagonal in the earlywood, tracheids less aligned in the earlywood, cell wall thickness 3–5 μm, transition from earlywood to latewood fairly abrupt; tracheids 3–10 mm (average 7 mm) long; inter-tracheid pits opposite in 1–2 rows, prominent on radial walls of the earlywood cells; pits absent from tangential walls of last few latewood tracheids. Axial resin canals irregularly distributed but mostly in the middle or outer portion of the growth ring, with thin-walled epithelial cells; canal diameter 170–190 μm; horizontal resin canals in rays with thin-walled epithelial cells 45–55 μm in diameter. Parenchyma absent. Rays 4–7/mm, very fine; uniseriate and fusiform rays present, approximately 10–15 cells high, ray tracheids present with one to several marginal cells occasionally interspersed, dentate; crossfield pitting single large window-like in the earlywood.

Species studied: *P. kesiya, P. merkusii.*

Distinguishing characteristics: *P. merkusii* is typically a hard pine anatomically; the wood is more dense, the transition from earlywood to latewood more abrupt and vertical resin ducts are larger than in *P. kesiya.*

Growth and development Young trees of mainland provenances of *P. merkusii* pass from 3–5 years through a so-called 'grass stage' characterized by densely clustered needles and short shoots and minimal height growth. However, Sumatran provenances of the same species have no 'grass stage' and they grow quickly upwards. This improves their chances in the competition with weeds which grow vigorously in the moist climate. Mycorrhizae are required for successful growth and allow seedlings to survive in more adverse sites. The normal architecture of pines is Rauh's model. The trunk is monopodial and grows rhythmically, and develops tiers of branches; the formation of cones does not affect shoot construction. Sometimes 'foxtails' occur, plants without branching and without growth rings in the wood, e.g. in *P. caribaea* and *P. merkusii*. Foxtailing is a reaction to off-site planting. Locally, e.g. in East Kalimantan, 40–50% foxtailing has been recorded in plantations of *P. caribaea*. For *P. caribaea*, bole straightness generally improves from the subtropics towards the tropics.

In early stages of growth, trees of *P. kesiya* are prone to fire damage. *P. caribaea* is rated as moderately fire resistant.

In plantations, trees of *P. merkusii* reach sexual maturity when about 20 years old. They bear cones every year, although seed production varies. Trees of *P. caribaea* planted in Peninsular Malaysia and East Kalimantan and of *P. oocarpa* planted in East Kalimantan do not produce seed, due to unsynchronized production of male and female cones. Seeds needed to establish new plantations must be derived from elsewhere.

The annual growth rate of Benguet pine (*P. kesiya*) in the Philippines is 0.8–1.9 cm in diameter and 54–142 cm in height. Caribbean pine grows in the Philippines on average 2.8 cm/year in diameter and 2.7 m/year in height.

Pollination and seed dispersal is by wind. Sometimes the birds, rodents and people who gather the seeds for food, also disperse them.

Other botanical information The genus *Pinus* is often divided into 2 subgenera, i.e. *Haploxylon* (Shaw) Mirov and *Diploxylon* (Shaw) Mirov, based among other things on the number of vascular bundles in the leaves (one and two, respectively). The first subgenus comprises species with soft wood, the second species with generally heavier wood. The species occurring in Malesia belong to the subgenus *Diploxylon*.

The most commonly planted pines (not indigenous) in South-East Asia are *P. caribaea, P. oocarpa* and *P. patula*. Some other species are much less commonly cultivated in plantations: *P. elliottii* Engelm. (e.g. Kalimantan), *P. radiata* D. Don, *P. occidentalis* Swartz and *P. massoniana* Lambert (e.g. Sabah), *P. cubensis* Grisebach, *P. strobus* L. (e.g. Sarawak), *P. taeda* L. (e.g. Papua New Guinea) and *P. montezumae* Lambert (e.g. Java).

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 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 are increasing 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.

P. merkusii occurs in areas with mean annual rainfall of 1000–2800(–3500) mm, a mean annual temperature of 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.

The species planted in South-East Asia demand light- to medium-textured, neutral to acid soils (optimum pH 5–6) which are well-drained. They may sometimes tolerate shallow soils (*P. oocarpa*) or seasonally waterlogged soils (*P. caribaea*). *P. caribaea* tolerates salt winds and hence may be planted near the coast.

Propagation and planting Successful natural regeneration 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. The weight of 1000 seeds of *P. caribaea* is 14–19 g, of *P. kesiya* 16–18 g, of *P. oocarpa* 18–24 g, of Sumatran *P. merkusii* about 17 g, and of continental provenances of *P. merkusii* 25–33 g. The seeds can be stored for several years, provided they are kept dry, cold and in an airtight container. However, seeds of *P. merkusii* are reported to have a rather short viability; seeds from Sumatra can be stored dry for only 1–2 years, and those from continental Asia during even shorter periods.

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. Seedlings need ectomycorrhizae for optimal growth. Natural injection may occur locally, but a reliable method of inducing seedlings to form mycorrhizal associations is to expose them to saplings 30–80 cm tall which are already mycorrhiza carriers. 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*, *Cenoccoccum graniforme* and *Rhizopogon* sp. After about 8 months the seedlings of *P. merkusii* in nursery beds are 20–25 cm tall and ready for planting into the field. Seedlings of *P. caribaea* and *P. kesiya* may already be suitable for transplanting after 4–6 months. Field planting is carried out at spacings of 4 m × 4 m (for resin production) or 3 m × 1–2 m (for timber production). Experiments in Indonesia showed that scions of *P. caribaea*, and particularly *P. oocarpa*, grafted onto *P. merkusii* grow faster in height than controls of the stock species.

Propagation by tissue culture is possible. Suspensor, root tissue and hypocotyl segments of 2-week-old seedlings of *P. merkusii* have been used, and they all readily yield callus when cultured on a Murashige and Skoog mineral formulation supplemented with naphthalene acetic acid (0.25–0.65 ppm) and benzylamino purine (1.0–2.0 ppm).

In the Philippines Benguet pine is recommended as a shade tree for coffee plantations. It is planted at a spacing of 3 m × 3 m, and after 5–7 years, when the pines have reached a height of at least 4 m, young coffee is planted. Weeding is necessary for about 3 years until the canopies of the growing pine and coffee have completely overtopped the grasses. Another viable agroforestry system in the Philippines is raising goats in forest of *P. kesiya* at a stocking rate of 4 goats/ha. In Indonesia *P. merkusii* has been successfully intercropped with Irish potatoes.

Silviculture and management In plantations of *P. merkusii* the first thinning is usually carried out in the 9th or 10th year, and about every 5 years thereafter. Rotation cycles of 30 years are needed for optimal timber production and have been stipulated by the Indonesian forestry administration. For the production of pulpwood, a cutting cycle of 15 years is usually practised.

Weeding operations depend on the species, site and priority. *P. merkusii* and *P. kesiya* require

more weeding than *P. caribaea* and *P. oocarpa*. In Thailand weeding in *P. kesiya* plantations is carried out 4 times a year. The prolonged 'grass stage' often present in young trees of *P. merkusii* means increased weeding requirements when compared to *P. caribaea, P. oocarpa* and *P. kesiya*.
The total area of natural pine forest in Thailand has been estimated at 228000 ha. *P. kesiya* is the preferred species for reforestation on highland sites in Thailand. In trials in the Philippines at 350 m and 750 m altitude, *P. caribaea* and *P. oocarpa* showed better growth and/or survival rate than *P. kesiya, P. merkusii, P. elliottii, P. radiata* and *P. patula*.
P. caribaea responds well to low levels of nitrogen fertilization, but trials in the Philippines showed no response to either phosphorus or potassium.

Diseases and pests Damping-off is the most common nursery disease, associated with *P. caribaea* in particular. Regular spraying with fungicides, careful monitoring of the moisture level in the nursery beds and potting media, and sterilization of the nursery medium may reduce damping-off substantially.
Pines in plantations are fairly susceptible to shoot moth and needle blight attack. In the Philippines bark beetles (*Ips calligraphus*) may cause problems in plantations of *P. kesiya*, and pine shoot moths (*Dioryctria rubella*) in stands of *P. kesiya* and *P. caribaea*. Pine shoot moth is effectively controlled by using the insecticides fenitrothion (0.1%) and fenvalerate (0.2%). 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. In Malaysia termites are reported as the main pest in plantations of *P. caribaea*.

Harvesting Several methods of harvesting the resin are practised. The resin is found in the intercellular canals in the wood (especially sapwood) and products are often termed 'naval stores' because of their historic use for ship caulking. Living pine trees are tapped (wounded), the first cut of about 1.3 cm wide and 30 cm long being made 30–40 cm from the ground, followed by a series of chippings until breast height. A sulphuric acid solution (usually 40–60%) is applied immediately after chipping. This process yields the 'gum naval stores', still the major source of the worlds supply of rosin and turpentine. 'Wood naval stores' can be obtained by solvent extraction of stumps of old trees; the resin obtained in this manner is less pure. Turpentine and wood resin can also be obtained as by-products from the kraft (sulphate) pulping of pines. Turpentine is removed from the chip digester during the initial steaming and condensed from the relief gases. This method gives 'kraft naval stores'.

Yield On suitable sites pines can achieve a mean annual increment of up to 28(–40) m^3/ha up to the 13th year. For an average site quality (4) the mean annual increment of *P. merkusii* is 22.4 m^3/ha in a 25-year rotation, but it may reach 30 m^3/ha for better site quality (6) in a 20-year rotation. In Sumatra 30-year-old stands of *P. merkusii* trees (with an average diameter of 58.5 cm) may have a standing volume of 397 m^3/ha with a total yield of 814 m^3/ha. The target volume in pine plantations in East Kalimantan is 200–300 m^3/ha with a cutting cycle of up to 20 years. The yield of resin from *P. merkusii* is 420–750 kg/ha. Trees of *P. kesiya* are sometimes commercially tapped for resin prior to harvesting of the main product, which is timber. Trees in the Philippines older than 20 years yield an average of 1800–2450 g of resin per tree.

Genetic resources and breeding 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 species in Malesia are comparatively small, and for this reason, protection of natural stands should be guaranteed.
Seeds of *P. caribaea* are often imported from Fiji, Queensland (Australia) or Honduras (Central America), whereas seeds of *P. oocarpa* come from Belize (Central America).
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 Commonwealth Forestry Institute of Oxford (UK).
In Thailand, trials of provenance hybrids of *P. merkusii* showed that hybrids of Thailand and Papua New Guinea provenances had better survival and length-growth than local provenances. *P. merkusii* seed orchards have been established in Indonesia.

Prospects Pines are much planted trees because of their fast growth, ability to grow on comparatively poor soils and at high altitudes, and because of the detailed information available on their silviculture. The quality of the wood is, however, often very poor. The production of better quality wood from pine plantations should be a research priority.

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Selection of species

Pinus caribaea Morelet

Rev. Hort. Côte d'Or 1: 107 (1851).

Vernacular names Caribbean pine, pitch pine, Nicaragua pine (En).

Distribution Central America, Cuba and the Bahama Islands; planted throughout the tropics, e.g. in Malaysia, Indonesia and the Philippines.

Uses The comparatively low density of the wood limits the uses as a timber. The timber is most often used for light construction, light flooring, fruit boxes and toys. The woodpulp is used for the manufacture of paper, fibreboard and chipboard. The trees produce a good quality of oleoresin.

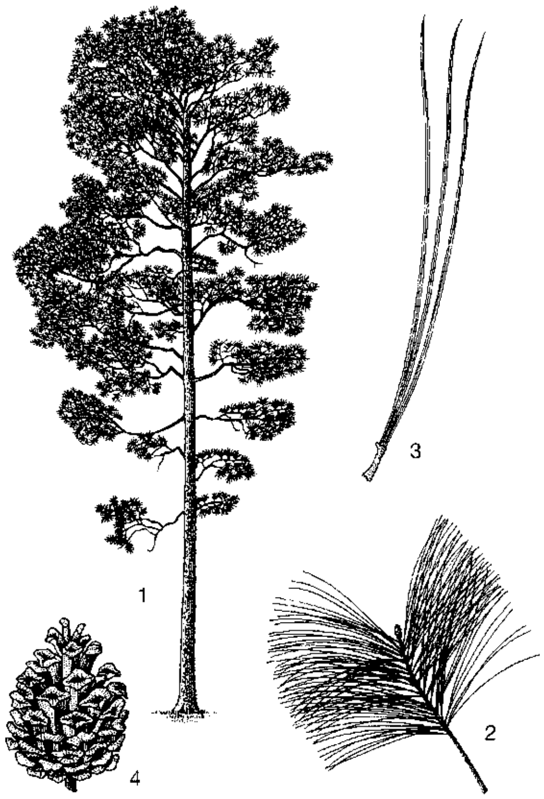
Observations A large tree up to 45 m tall, but in plantations usually much smaller, with a straight and cylindrical bole, deeply fissured bark, and orange-brown twigs later turning grey-brown; needles in bundles of (2–)3(–5), 15–25 cm long, in whorls at the end of the shoots and soon shed, most of them in the second year; cones solitary, ovoid, 4–14 cm long, readily shed from the branches. Caribbean pine is often divided into 3 varieties: var. *hondurensis* Barrett & Golfari (Honduras pine) is most commonly planted in South-East Asia, var. *caribaea* and var. *bahamensis* Barrett & Golfari much less so. The latter variety is reported to have some tolerance to shoot moth attack. *P. caribaea* has often been mistaken for *P. elliottii* in the past. In Malesia it often does not produce seeds. See also the table on wood properties.

Selected sources 68, 153, 156, 157, 163, 224, 225, 288, 295, 359, 393, 417, 471, 488, 546, 764.

Pinus kesiya Royle ex Gordon

Loudon, Gard. Mag. 16: 8 (1840).

Synonyms *Pinus insularis* Endl. (1847), *Pinus khasya* Hook.f. (1888).



Pinus kesiya Royle ex Gordon – 1, tree habit; 2, sterile twig; 3, bundle of needles; 4, mature female cone.

Vernacular names Benguet pine, Khasya pine (En). Pin à trois feuilles (Fr). Philippines: saleng (general), tapulao (Zambales). Burma: tinyu. Laos: khoua, mai hing. Thailand: son-sambai (central), chuang, kai-plueak-daeng (northern). Vietnam: th[oo]ng ba l[as], x[af] nu.

Distribution Eastern India, Burma, Laos, Cambodia, Vietnam, southern China, northern Thailand and the Philippines (northern Luzon); planted throughout the tropics, in South-East Asia in Thailand, the Philippines, Malaysia and Papua New Guinea.

Uses Benguet pine is a general purpose timber. It is also used for the manufacture of particle board and pulp, but its usefulness depends on the quality of the wood. Oleoresin of good quality is tapped from the trees.

Observations A large tree up to 45 m tall with a bole free of branches for 15–20 m and up to 100 cm in diameter, a thick, reticulately and deeply fissured bark, and often pruinose branchlets 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, 1.5–2.5 cm long wing. 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. Benguet pine is locally common in northern Luzon, often occurring in open pure stands on steep slopes at elevations of 300–2700 m. See also the table on wood properties.

Selected sources 28, 153, 157, 163, 178, 224, 225, 295, 359, 417, 488, 517, 534, 548, 579, 748, 764.

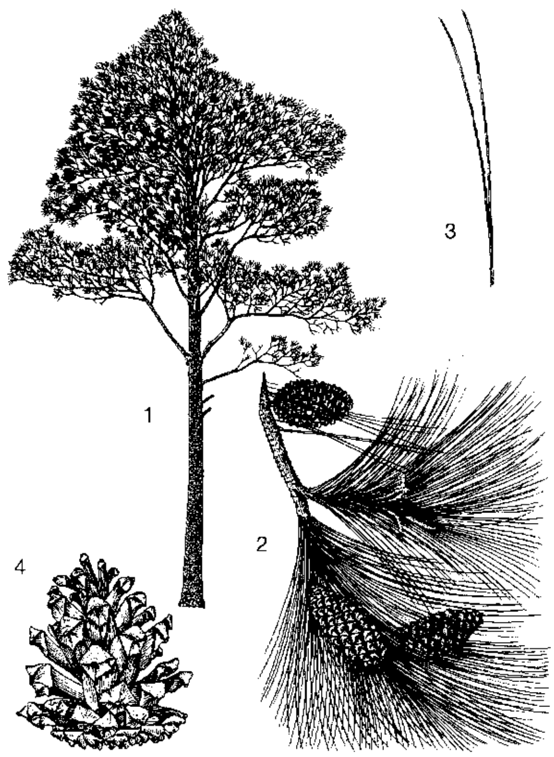
Pinus merkusii Junghuhn & de Vriese

Pl. Nov. Ind. Bat. Or.: 5, t. 2 (1845).

Synonyms *Pinus sumatrana* Junghuhn (1846), *Pinus merkusiana* Cooling & Gaussen (1970).

Vernacular names Merkus pine, Mindoro pine, Sumatran pine (En). Indonesia: damar batu, damar bunga, uyam (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].

Distribution Eastern Burma, Indo-China, southern China, northern Thailand, the Philippines (Mindoro, western Luzon), Sumatra (Aceh, Tapanuli, Kerintji mountain); commonly planted in South-East Asia.



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

Uses Merkus pine is a general-purpose timber; it can also be used for construction work, flooring and boat building as it is fairly durable and heavy. Good quality oleoresin is collected from this species, often on plantation scale. The tree is used to shade out alang-alang grass with fairly good results.

Observations A large tree up to 50(–70) m tall with a straight and cylindrical bole free of branches for 15–25 m and an average diameter of 55 cm, but occasionally up to 140 cm, thick bark which forms plates and is grey-brown underneath, but scaly and more reddish tinged upwards, and heavy horizontal or ascending branches; 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 c. 2.5 cm long. Merkus pines of the Asian mainland and the Philippines differ slightly from those of Sumatra: the seedlings have a 'grass stage', the needles are slightly longer, the cones are less cylindrical, and the seeds nearly twice as heavy. *P. merkusii* is locally common in northern Sumatra up to 2000 m altitude. It is the southernmost occurring pine of all pines, and the only one whose natural distribution extends into the southern hemishpere. See also the table on wood properties.

Selected sources 10, 102, 145, 149, 153, 157, 159, 163, 224, 225, 230, 283, 284, 288, 318, 330, 359, 396, 417, 462, 464, 487, 488, 517, 519, 579, 660, 722, 748, 764.

Pinus oocarpa Schiede ex Schlechtendal

Linnaea 12: 491 (1838).

Distribution Central America from Mexico towards Nicaragua; planted in Borneo, Peninsular Malaysia and the Philippines.

Uses The wood is used as a general-purpose timber and for pulp. *P. oocarpa* is planted to shade out alang-alang grass.

Observations A medium-sized tree up to 20(–30) m tall with a usually straight and cylindrical bole, a wide and open crown, rough and scaly bark, and long, flexible branches, curved upwards; needles in bundles of (3–)4–5, 20–30 cm long, bluish or light green; cones often in groups of 2–3, usually ovoid, 5–7 cm × 3–5 cm, with hard scales which are tuberculose at apex and have a pointed umbo. *P. oocarpa* is a variable species; 5 well-distinguished varieties can be recognized. In South-East Asia plantation-grown trees often do not produce viable seed, and since propagation is through seeds these must be obtained elsewhere.

Selected sources 157, 163, 216, 224, 288, 291, 294, 295, 487, 488, 764.

Pinus patula Schlechtendal & Chamisso

Linnaea 6: 354 (1831).

Synonyms *Pinus subpatula* Roezl ex Gordon (1862).

Vernacular names Spreading-leaved pine, Mexican weeping pine, Jelecote pine (En).

Distribution Mexico; planted in South-East Asia, particularly in Papua New Guinea.

Uses The wood is used for light construction work, boxes, ceilings, joinery and flooring, and for paper production.

Observations A medium-sized, slender tree up to 30(–40) m tall, but in plantations often much shorter, usually with a straight and cylindrical bole, sometimes forked, rough and deeply fissured bark, scaly with papery sheets curling upwards, and branches horizontal or turned upwards at their tips; needles in bundles of (2–)3–4(–5), very slender, 15–30 cm long, persistent for 2–4 years; mature cones in groups of 3–6, 4–12 cm × 2.5–4 cm, often curved, shortly stalked, pale glossy grey or brown; seed 3–5 mm long with a wing of c. 10 mm long, brownish-black.

Selected sources 157, 163, 224, 488, 803.

Suhardi (general part),
M.S.M. Sosef (general part, selection of species),
P.B. Laming (properties),
J. Ilic (wood anatomy)

Pometia J.R. Forster & J.G. Forster

Charact. Gen. Pl.: 55, t. 55 (1775).
SAPINDACEAE
x = unknown

Trade groups Kasai: medium-weight timber, particularly *Pometia pinnata* J.R. Forster & J.G. Forster.

Vernacular names Kasai: taun, matoa, megan (general). Indonesia: leungsir (Java), tawan (Moluccas), ihi mendek (Irian Jaya). Malaysia: sibu (Sarawak). Papua New Guinea: taun. Philippines: malugai (Tagalog). Burma: paga-nyet-su ava. Laos: chieng dong, kwaang. Thailand: sai (Yala), daengnam (northern). Vietnam: tr[uw][owf]ng m[aaj]t, s[aa]ng, m[aws]c ken.

Origin and geographic distribution *Pometia* consists of 2 species and is native from Sri Lanka and the Andaman Islands, throughout South-East Asia, towards Fiji and Samoa. It is rare in mainland South-East Asia and in Taiwan. Kasai is sometimes cultivated for its fruits within its natural area of distribution.

Uses Kasai is a good general-purpose wood for interior construction. The wood is suitable for domestic flooring, mouldings, joinery, ship and boat building, spars, tool handles, agricultural and sporting implements, interior trimming, blockboard, and tight cooperage. It is well accepted for making boxes and crates. On the export market kasai is recommended for joinery (windows, solid doors, framing, weather-boarding) and flooring for both light and medium pedestrian traffic. In outdoor constructions contact with the ground must be prevented as the wood is then not durable. The timber is used for furniture and cabinet work but must be dried to a sufficiently low moisture content. It is suitable for hardboard and particle board and as pulpwood. The wood makes a good-quality veneer which has potential to be used as decorative veneer and is very suitable for core and outer layers of plywood. Kasai may produce a good charcoal for domestic or industrial purposes.

The arillode of the fruit of trees cultivated for fruit production is eaten fresh and tastes like rambutan; it is of local interest only, e.g. in the Sentani Lake region of Irian Jaya, where especially purplish fruits are preferred and selected. The roasted seeds of kasai are also edible. A decoction of the leaves or bark is used medicinally against fever and sores. In Papua New Guinea kasai is sometimes planted in a cycle of shifting cultivation and its leaves are used as a mulch and green manure in yam cultivation.

Production and international trade Although kasai is frequently mentioned as a promising timber for export, little information is available on harvested and traded volumes. In 1978 the export of logs from Irian Jaya was 35 000 m^3 with a value of US$ 1.4 million. In 1979 the export increased considerably to 194 000 m^3 with a value of US$ 17 million. Export from Irian Jaya was mainly to Japan, Taiwan and Korea. It is also exported in fairly large amounts to Japan from Papua New Guinea and the Solomon Islands. In Papua New Guinea kasai is ranked in MEP (Minimum Export Price) group 1, and fetched a minimum export price of US$ 75/m^3 for saw logs in 1992. Considerable standing volumes are present especially in the eastern part of the area of distribution. Small amounts of kasai timber are exported from Sabah: in 1992 340 m^3 of logs and 70 m^3 of sawn timber with a total value of US$ 36 000.

Properties Kasai is a medium-weight timber; it is not hard, and faintly resembles meranti and mahogany. The heartwood is light to dark red, medium dark red-brown, or sometimes purplish, with a glossy surface; radial and tangential sections sometimes show dark coloured ribbons. The sapwood is pink or buff-coloured, on average 3 cm wide, and not always well demarcated from the heartwood.

Wood properties of kasai vary widely over the various provenances and regions. Hillside trees are better than lowland trees in wood quality, and wood near the heart of the log is reported to be lighter, softer and less strong than the outer wood. The density of kasai from Malaysia is 735–915 kg/m^3 at 15% moisture content, but that from Papua New Guinea is less: 625–700 kg/m^3 at 12% moisture content. The overall density range is 390–860 kg/m^3 at 12% moisture content. The grain of the wood is straight or slightly interlocked, texture rather coarse but even.

Wood tested in Malaysia at 21% moisture content showed the following figures for mechanical properties: modulus of rupture 106 N/mm^2, modulus of elasticity 17 000 N/mm^2, compression parallel to grain 49–54 N/mm^2. Tests in Indonesia at 15% moisture content gave the following figures: modulus of rupture 77–100 N/mm^2, modulus of elasticity 8900–14 000 N/mm^2, compression parallel to grain 37–57 N/mm^2, shear 7–11 N/mm^2, cleavage 50–64 N/mm radial and 53–69 N/mm tangential, Janka side hardness 3870–4320 N and Janka end hardness 4910–6350 N. Wood tested in the Philippines at 12% moisture content had a modulus of rupture of 166 N/mm^2, modulus of elasticity of 13 900 N/mm^2, compression parallel to grain of 60 N/mm^2, and Janka side hardness of 6440 N. Wood tested in Papua New Guinea at 12% moisture content had a modulus of rupture of 105–110 N/mm^2, modulus of elasticity of 12 800–14 900 N/mm^2, compression parallel to grain of 56–60 N/mm^2 and Janka side hardness of 4700–6500 N. Figures from tests in Thailand are comparable, although the modulus of rupture is slightly less: 93 N/mm^2 at 12% moisture content.

The rates of shrinkage are medium to high: for Malaysian wood 2.8% radial and 3.5% tangential from green to 15% moisture content, and for wood from Papua New Guinea 3.5% radial and 6.6% tangential from green to 12% moisture content. Kasai usually seasons slowly, with considerable degrade unless handled with care. Collapse mostly occurs during seasoning. Twisting, splitting and surface checking can be prevented if kasai is carefully seasoned and close attention is paid to stacking technique; bowing and end checking will be minimal. Slight to moderate collapse may occur during kiln drying from the green condition. Weighting of stacks at the outset of drying and close spacing of stickers is beneficial. When the timber is kiln dried, a reconditioning treatment may be necessary if considerable collapse or twist develops, otherwise a high humidity treatment should be applied at the completion of drying to relieve stresses, although response to reconditioning can be variable. Even when properly dried, the wood is rather unstable under varying relative air humidity conditions such as those found in temperate zones.

As a rule, kasai is easy to machine when green but slightly difficult to resaw and cross cut when air dried, with little blunting effect on saws (the wood contains no silica), producing fair to excellent surfaces. It planes well with a slight tendency to chip at interlocked grain junctions and it sands to a fine finish. It polishes well to a high finish and takes paint quite satisfactorily. Kasai turns easily with little or no burning. The timber can be nailed without difficulty although occasional splitting does occur, and it has good nail-holding capacity; it glues well, is readily bored and screws well. The steam bending properties are generally good. Fine dust may cause irritation to mucous membranes when working with dried material; an effective dust-extractor is strongly advised. Kasai is moderately easy to rather difficult to cut into smooth, tight veneer of uniform thickness at a cutting temperature of about 70°C; it dries flat and split-free with medium shrinkage. For plywood production the wood can be glued very satisfactorily with modern types of glue and it shows a good bonding strength. However, gluing of veneer is reported as rather difficult in Indonesia.

Kasai heartwood is rated as moderately durable to non-durable. Stake tests show a service life in contact with the ground of up to 5 years under tropical conditions; tests in Indonesia showed a service life of 2–3.5 years. Based on laboratory tests carried out in the Netherlands, the heartwood of material from Irian Jaya was found to be moderately durable to nondurable in contact with the ground under temperate conditions. The heartwood is rated as rarely susceptible to powder-post beetles, as liable to brown stain and as susceptible to attack by dry-wood termites. Timber is only moderately resistant to termite attack and is not resistant to marine borer attack. The air-dried heartwood is classified as very resistant to impregnation of preservatives, the sapwood is moderately resistant. Impregnation with CCA preservative may vary considerably and is classified as moderately difficult to extremely difficult. Using the open tank method, the wood absorbs 5.6 kg/m^3 of a 10% BFCA solution after 7 hours.

The wood contains saponin, as does the fruit, and may produce slight foam in water. Kasai wood (from Indonesia) contains 57% cellulose, 20% lignin, 20% pentosan, 0.8% ash and no silica. The solubility is 2.5% in alcohol-benzene, 0.4% in cold water, 3.4% in hot water and 12.6% in a 1% NaOH solution. The energy value is 19 760 kJ/kg.

Description Medium-sized to fairly large evergreen or shortly deciduous, monoecious trees up to 40(–50) m tall with a straight (New Guinea) or curved or sinuous bole, usually branchless for 13–22 m and up to 100(–140) cm in diameter, often prominently buttressed; buttresses sharp, up to 5.5 m tall and spreading up to 3.5 m from the bole; bark brownish-grey to reddish-brown, shedding small, pockmarked, thick flakes, with occasionally abundant red gum; branchlets grooved or smooth, glabrous, innovations red or purple, densely brown-fulvous hairy. Leaves paripinnate, with (3–)4–13 pairs of leaflets, the lowest pair often stipule-like, the rachis up to 1 m or even longer; leaflets leathery or firmly herbaceous, often asymmetrical, on average 12–30 cm × 4–10 cm, margin smooth or dentate, secondary veins nearly parallel, surfaces smooth. Inflorescence a terminal or rarely axillary panicle of about 15–60 cm long. Flowers functionally unisexual, actinomorphic, 5-merous, small; petals cream-white, disk annular. Fruit a schizocarp, mostly simple by abortion, smooth, ellipsoid, up to 3.5 cm × 3 cm, coloured in variations of yellow, red, purple or brown, pericarp 2–7 mm thick. Seed half to three-quarters of the size of the fruit, covered by an arillode of up to 4 mm thick, shiny brown or red-brown. Seedling with epigeal germination; cotyledons slightly sagittate; first pair of leaves subopposite, imparipinnate with 5 serrate leaflets, transition to paripinnate taking place in the third and fourth leaf.

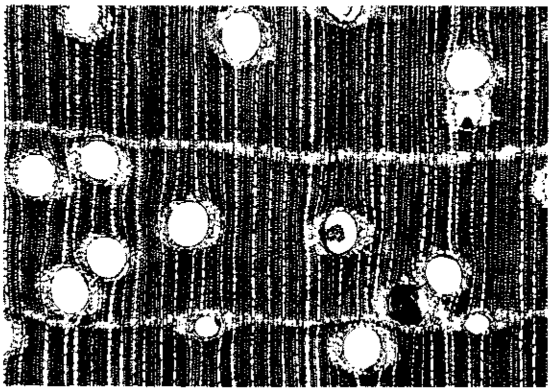
Wood anatomy

– Macroscopic characters:

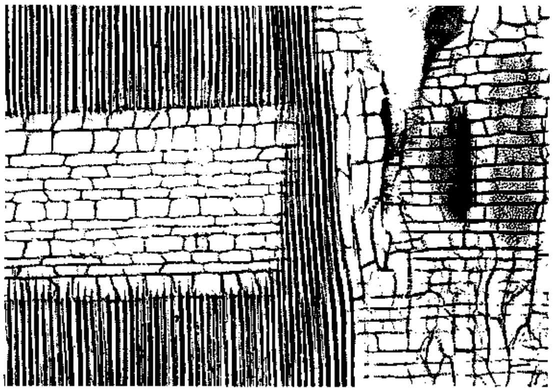
Heartwood light to dark red, medium dark red-brown, sometimes purplish, sometimes with dark coloured ribbons on radial and tangential sections, not always well demarcated from the pink or buff-coloured sapwood. Grain straight or slightly interlocked. Texture rather coarse but even; wood surface glossy. Growth rings vague to distinct by relatively narrow bands of denser and darker tissue or as concentric lines of terminal parenchyma; vessels visible without lens, rays not visible without lens on cross-section, and inconspicuous on the radial plane. Ripple marks absent.

– Microscopic characters:

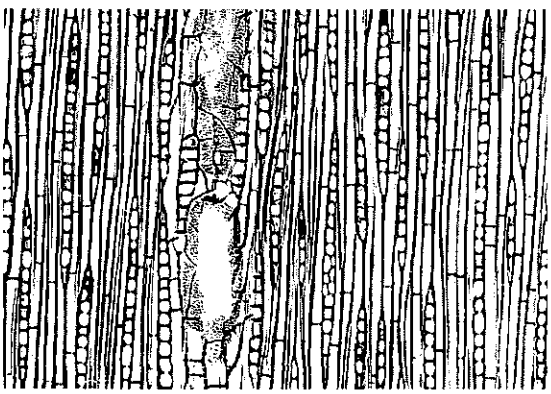
Growth rings marked by concentric bands of marginal parenchyma. Vessels evenly distributed, few, 0–7/mm^2, solitary and in radial groups of 2–10 or in clusters, more or less oval, moderately large with tangential diameter of 70–310(–360) μm; perforations simple; intervessel pits alternate, 3–4 μm in diameter; vessel-ray and vessel-parenchyma pits similar to intervessel pits; helical thickenings present but not pronounced; white or light brown to dark red resin or gum present in



transverse section (×25)



radial section (×75)



tangential section (×75)

Pometia pinnata

wood; tyloses sparse or absent. Fibres 750–1450 μm long, usually septate, walls 3–4 μm thick, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma in marginal, concentric bands and vasicentric to weakly aliform, in 3–8-celled strands. Rays 4–12/mm, uniseriate heterogeneous; biseriate rays scarce; upright cells alternating with procumbent cells, 1–28 cells in height (maximum 520 μm); lumina with red gum and usually with crystals, 1–3 per cell.
Species studied: *P. pinnata*.

Growth and development Seedlings that are partly damaged can regenerate well. Height growth in the first years is rapid (3–5 m/year) when fully released but may be much less (11.6 cm in the first year). In naturally established stands the boles are usually well-formed, straight and long. Flowering periods seem to be fixed per region, with the fruiting season 2–5 months later, but is apparently not correlated with climatic seasons. Bisexual and male flowers are reported to occur on a single tree of *P. pinnata*, but the structurally hermaphrodite flowers are functionally female with no anther dehiscence. Both cross-fertilization and self-fertilization occur. Usually there are 3–4 times as many male as female flowers. Dispersal of the fruits is probably mostly by bats and birds.
Kasai can often be recognized from a great distance by its witches' brooms. These dense masses of leaves, twigs or sometimes inflorescences are typically abundantly hairy. They are up to 1 m in diameter, are shed as a whole and can sometimes be found in large quantities underneath the tree.

Other botanical information The genus *Pometia* belongs to the tribe *Nephelieae*, within which it takes a rather isolated position. *P. pinnata* is an extremely variable species. No less than 8 forms have been recognized and given taxonomic status, but because still other and intermediate forms are encountered, this distinction is probably only useful in e.g. breeding. For reasons of completeness the 8 forms distinguished are given here: f. *pinnata* (synonym: *P. coriacea* Radlk., 1913); f. *acuminata* (Hook.f.) Jacobs (synonyms: *P. acuminata* (Hook.f.) Radlk., 1877, *P. annamica* Gagn., 1947); f. *alnifolia* (Blume) Jacobs (synonym: *P. alnifolia* (Blume) Radlk., 1877); f. *cuspidata* (Blume) Jacobs; f. *glabra* (Blume) Jacobs (synonym: *P. pinnata* var. *javanica* Koord. & Valeton, 1903); f. *macrocarpa* (Kurz) Jacobs (synonym: *P. macrocarpa* Kurz, 1875); f. *repandra* Jacobs; f. *tomentosa* (Blume) Jacobs (synonym: *P. tomentosa* (Blume) Teijsm. & Binnend., 1866).

Kasai is easy to identify; the bark often resembles that of *Intsia* but is distinguished by the red gum.

Ecology Kasai occurs typically in rain forest at altitudes below 500 m. Sometimes, however, it is found to 1000 m above sea-level, and occasionally even to 1700 m in some parts of northern Sumatra (Aceh). It occurs on a variety of soils, on limestone, clayey, sandy or loamy soils, mostly in dryland forest, occasionally in freshwater swamps. In western Malesia it is confined to valleys. In Papua New Guinea and the Solomon Islands it occupies a wider range of habitats and is commonly dominant in forest influenced by shifting cultivation and then prefers well-drained limestone soils. Kasai cannot tolerate a severe dry season.

Propagation and planting Propagation is by seed. Natural regeneration from seeds has often been observed as quite abundant in disturbed or clear-cut forest areas, e.g. at Keravat (Papua New Guinea) and Jayapura and Manokwari (Irian Jaya). Regeneration counts have recorded more than 1000 young trees/ha, which might be sufficient to establish pure stands. No such pure stands are encountered, however, and commonly a mixture with other commercial species such as *Dracontomelon dao* (Blanco) Merr. & Rolfe is present. Artificial regeneration by means of cuttings and seeds is possible. The survival rate of six-month-old seedlings planted in the field at Manokwari (Irian Jaya) was 86%.

The seeds have no dormancy, and start to germinate 1–5 weeks after sowing or after they have fallen to the ground. On cleared land in New Guinea, kasai seedlings often soon establish, probably from seeds dropped by birds or bats. Removal of pericarp and arillode promotes seed germination, and when these are removed, germination takes place within 3 days when sown in pots in the greenhouse, with a germination rate of 85–95%.

Diseases and pests Kasai trees often show malformations known as witches' broom, caused by a fungus or virus. Locally in Papua New Guinea a large number of kasai trees have been reported to be affected by an unidentified fungus causing white rot; the wood of affected logs is only suitable for pulping. In Peninsular Malaysia there are reports of fruits damaged by the moth *Conopomorpha cramerella* (*Gracillaridae*).

Yield A 24 500 ha tract of forest in North Oransbari, New Guinea, had a potential yield of 30.9 m^3/ha.

Genetic resources and breeding Conservation does not seem to be a priority for the moment, but the extreme variability of *P. pinnata* might be diminished by local eradication through large-scale clearing of the forest.

Local varieties of *P. pinnata* used for fruit production have been selected and bred to obtain larger and better-tasting fruit. A race with very large arillodes has been bred in Santa Cruz (the Solomon Islands).

Prospects There is a growing awareness of the potential of kasai, and special interest in supply from New Guinea and the Solomon Islands. The potential for reforestation is good, but neither the timber quality nor bole form merit the tree being given priority in reforestation activities. Local kasai fruit production may easily be superseded by better fruit-producing tree species.

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Selection of species

Pometia pinnata J.R. Forster & J.G. Forster

Charact. Gen. Pl.: 55, t. 55 (1775).

Vernacular names Supplementary to vernacular names for the genus: Indonesia: kayu sapi (Java). Malaysia: kasai daun kecil, kasai daun besar (Peninsular). Papua New Guinea: obahu. Philippines: malugai-liitan (Tagalog), tugaui (Bikol, Tagalog). Thailand: saen ta lom. Vietnam: c[aa]y tr[uw][owf]ng, tr[uw][owf]ng m[aaj]t, s[aa]ng.

Distribution From Sri Lanka and the Andaman Islands throughout South-East Asia towards Taiwan, Fiji and Samoa.

Uses The timber is used as kasai; the wood is also used for charcoal production. The tree is sometimes cultivated for its fruits which can have a thick and sweet-tasting arillode. The seeds are also edible. The leaves and bark are used medicinally.

Observations A medium-sized to fairly large tree up to 40(–47) m tall, with bole up to 100(–140) cm in diameter; leaves with 3–13 pairs of leaflets having dentate margins, and alternate secondary veins ending in a tooth; inflorescence and calyx often hairy. *P. pinnata* occurs in primary and secondary forests up to 500(–1700) m altitude. For more information see genus treatment and the table on wood properties.

Selected sources 11, 35, 88, 89, 97, 102, 145, 153, 159, 175, 190, 199, 238, 242, 243, 257, 262, 281, 297, 303, 316, 336, 341, 362, 364, 371, 387, 408, 417, 418, 420, 441, 447, 458, 459, 484, 516, 528, 545, 554, 579, 610, 701, 711, 793, 801, 802.

Pometia pinnata J.R. Forster & J.G. Forster – 1, tree habit; 2, flowering twig; 3, fruiting twig.

Pometia ridleyi King

Journ. As. Soc. Beng. 65: 443 (1896).

Vernacular names Malaysia: kasai daun licin (Peninsular). Thailand: sai.

Distribution Thailand, Peninsular Malaysia, eastern Sumatra, Simeuluë.

Uses The wood is used as kasai.

Observations A fairly large to large tree up to 50 m tall, with bole up to 100 cm in diameter; leaves with 4–8 pairs of leaflets having entire margins, all secondary veins curving upwards not ending at the margins; inflorescence and calyx glabrous. *P. ridleyi* occurs in primary forest on hill slopes and along streams up to 750 m altitude. It is fairly common in Peninsular Malaysia, more rare elsewhere. The density of the wood is about 835 kg/m^3 at 20% moisture content. See also the table on wood properties.

Selected sources 153, 342, 417, 779.

N.R. de Graaf (general part, selection of species),
J.W. Hildebrand (general part, selection of species),
P.B. Laming (properties),
J.M. Fundter (wood anatomy)

Pouteria Aublet

Hist. pl. Guiane 1: 85 (1775).
SAPOTACEAE
x = unknown; *P. obovata*: $2n = 26$

Trade groups

- Nyatoh: lightweight to medium-heavy hardwood, e.g. *Pouteria duclitan* (Blanco) Baehni, *P. firma* (Miq.) Baehni, *P. linggensis* (Burck) Baehni, *P. malaccensis* (C.B. Clarke) Baehni, *P. obovata* (R.Br.) Baehni (partly).
- Bitis: heavy hardwood, e.g. *P. obovata* (partly).

Vernacular names

- Nyatoh: padang (En). Indonesia: nyatuh. Papua

New Guinea: pencil cedar, planchonella, silk wood. Philippines: white nato. Burma: thitcho. – Bitis: Malaysia: nyatoh batu (Sabah, Sarawak).

Origin and geographic distribution The very large genus *Pouteria* consists of about 320 species and occurs in tropical Asia, the Pacific and South America. Two main centres of diversity may be distinguished, the first being New Guinea, Australia and New Caledonia (the former genus *Planchonella*), the second South America (*Pouteria* s.s.). About 50 species occur in Malesia. New Guinea and New Caledonia are very rich in species, each accommodating about 40 species, most of which are endemic. Among the most widespread species are *P. duclitan*, *P. firma*, *P. linggensis* and *P. obovata*, covering whole Malesia or even more.

Uses The timber is usually marketed together with the timber of other *Sapotaceae* genera as 'nyatoh'. Nyatoh is a general-purpose timber, which is however only moderately durable and therefore particularly suitable for indoor use. It is in demand for fine furniture, decorative doors and panelling. It is also used for interior finishing, joinery and flooring. Locally, nyatoh timber is used for house-building, e.g. in Indonesia. The wood of some species is used for inlaying and carving, and for musical instruments, cabinet work, picture frames and fan ribs, e.g. in the Philippines. Nyatoh can also be used in the production of plywood as it makes good-quality veneer.

Bitis, being heavier and more durable, is used for heavy constructional work, heavy-duty flooring, posts, window and door frames, paving blocks, implements and turnery.

Some species have edible fruits, e.g. *P. campechiana* (Kunth) Baehni (canistel), *P. sapota* (Jacq.) H.E. Moore & Stearn (sapote), and *P. maclayana*, others are used in traditional medicine, e.g. *P. obovata*. A decoction of the leaves of the latter species is used against stomachache, crushed leaves are used as a poultice in cases of lumbago, and heated bark of *P. obovata* and *P. firma* may be chewed against sprue, sometimes together with betel.

The latex is rarely used; in New Guinea the very sticky latex of some species is said to be used as birdlime.

Production and international trade Usually *Pouteria* timber is available only in limited quantities, and in many areas it is much less important than the timber from *Palaquium*, *Payena* and *Madhuca* species, e.g. in Peninsular Malaysia, Borneo and the Philippines. Most of the 'white planchonella' timber, which is imported in constant but not large quantities in Japan, originates from New Guinea and the Solomon Islands. Much of the timber from *Pouteria* species is mixed with that of other *Sapotaceae* genera and traded collectively as nyatoh or occasionally bitis. The export of nyatoh sawn timber from Peninsular Malaysia decreased from 16 500 m^3 (with a value of US$ 2.1 million) in 1981 to 9500 m^3 (with a value of US$ 1.3 million) in 1986. By 1990 the export had increased to 32 500 m^3 (with a value of US$ 6.1 million), but in 1992 it was only 8000 m^3 with a value of US$ 2.8 million. Large amounts of nyatoh are also exported from Sarawak and Sabah; the export of round logs from Sabah was 65 000 m^3 (worth US$ 6.3 million) in 1987, and in 1992 the export of logs was 14 000 m^3 and of sawn timber 8500 m^3 with a total value of US$ 4.4 million. In Papua New Guinea nyatoh is ranked in MEP (Minimum Export Price) group 1, and fetched a minimum export price of US$ 100/m^3 for saw logs in 1992. Nyatoh timber is often exported to Europe as planks of up to 425 cm × 30 cm × 7 cm.

Properties The properties of *Pouteria* timber may differ considerably, e.g. in density which varies between different species from 360 to 1220 kg/m^3 at 15% moisture content. This is not really surprising for such a large genus. The timber can be classified among the light to heavy nyatoh timbers and occasionally (*P. obovata*) as bitis timber.

A general description of nyatoh and bitis is given here. These timber groups are not well demarcated, and include *Pouteria*, *Palaquium*, *Madhuca*, *Payena* and occasionally some other *Sapotaceae* genera. The arbitrary limit lies at a density of 850 kg/m^3.

Nyatoh is a light to medium-weight, moderately hard to hard red meranti-like wood. The heartwood is pinkish-brown to reddish-brown and only moderately distinct from the lighter sapwood. The density is (420–)550–800(–850) kg/m^3 at 15% moisture content; that of the majority of the commercial supply 600–700 kg/m^3. The grain is shallowly interlocked, texture moderately fine and even.

At 15% moisture content the modulus of rupture is 70–130 N/mm^2, modulus of elasticity 10 000–18 000 N/mm^2, compression parallel to grain 28–54 N/mm^2, compression perpendicular to grain 2.5–7 N/mm^2, shear 8.5–11(–17) N/mm^2, cleavage 39–77 N/mm radial and 49–87 N/mm tangential, Janka side hardness 3700–7000 N and Janka end hardness 3900–7600 N.

The recorded rates of shrinkage of nyatoh are moderate, from green to 15% moisture content 1.3–3% radial and 2.3–4% tangential, from green to oven dry about 4.1% radial and 7.6% tangential. Air drying of 40 mm thick boards takes approximately 4 months, 25 mm thick boards about 2 months. The timber can be satisfactorily dried by using kiln schedule E (Malaysia). Form stability is medium to good when dry. *Pouteria* timber from the Philippines (white nato) seasons fairly well, but rapid drying is needed to avoid sap staining and blueing. White nato wood may shrink considerably. Kiln drying of boards of 2.5 cm thick of *Pouteria* timber from Papua New Guinea takes 4–4.5 days under favourable conditions. These boards may shrink up to 7% in width and 8.5% in thickness when dried to 10% moisture content.

The sawing properties are variable, probably depending on the species, but there may also be great variation within a species. Some nyatoh-producing species contain silica, which makes the timber difficult to work. There may be gum accumulation on cutters. Nyatoh is easy to polish when the grain is properly filled. The wood is easy to turn. Pre-boring for nails and screws is advised because of easy splitting. There are no problems with gluing. The fine grain and colour make it suitable for veneer; it can be peeled at a 91° peeling angle without pretreatment. Sometimes the wood is figured and then the veneer can be very attractive, especially when radially sliced. Peeling is reported as easy to fairly difficult, and a good plywood can be made from the timber.

Nyatoh is rated as only moderately durable. Graveyard tests in Indonesia with wood of *P. duclitan* and *P. obovoidea* showed a service life in contact with the ground of 1.2–1.4 years only. Nyatoh is prone to termite attack and susceptible to fungal attack, but not to powder-post beetles. Treated nyatoh timber can be very durable. However, the heartwood is very resistant to preservative treatment. The sapwood is less difficult to impregnate. Small wood samples from *P. doonsaf* may be impregnated completely using a 4% solution of natrium fluoride; the impregnation with copper aphtenate and a mixture of creosote and diesel is less successful.

Bitis comprises heavier timber, with a density of 850–1150 kg/m³ at 15% moisture content. The heartwood is reddish-brown to dark brown, and clearly differentiated form the lighter sapwood. The grain is fairly straight, texture moderately fine and even. Bitis is very hard and strong, and much more durable than nyatoh.

At 15% moisture content the modulus of rupture is 105–170 N/mm², modulus of elasticity 10 000–23 800 N/mm², compression parallel to grain 65–90 N/mm², compression perpendicular to grain 9–12.5 N/mm², shear 10–17 N/mm², cleavage c. 86 N/mm radial and 67 N/mm tangential, and Janka side hardness 14 400–14 900 N.

Bitis is difficult to dry; shrinkage rates are high (from green to 15% moisture content 3.0% radial and 4.0% tangential), and there is a tendency to surface checking. A mild kiln schedule (B in Malaysia) should be used.

Bitis is difficult to work, rapidly blunting saws and cutters due to the presence of silica, but it produces a smooth surface in planing and takes stain and polish satisfactorily. The timber tends to split in boring and mortising. Bitis is not suitable for veneer and plywood because it is difficult to peel.

Bitis timber is rated as durable and is resistant to termite attack. It is very difficult to impregnate.

Freshly felled wood often has a sour smell and bitter taste. It lathers freely when rubbed with water. The dust from sawn timber may cause irritation to skin and mucous membranes.

Description Shrubs to large trees, with latex, up to 50 m tall, with generally columnar, buttressed bole (but buttresses sometimes absent or bole fluted or twisted), up to 100(–150) cm in diameter; outer bark smooth, shallowly cracked or fissured, usually brown, inner bark soft and fibrous or granular, yellowish, red or reddish-brown; twigs usually slender and terete, at first hairy but glabrescent. Leaves arranged spirally, generally loosely to densely clustered at ends of upturning twigs, simple and entire, obtuse to acuminate, usually glabrous above and glabrous to densely hairy beneath; secondary veins usually diminishing until inconspicuous at the leaf margin, tertiary veins transverse to secondary veins, parallel to secondary veins or reticulate; petiole usually of even thickness throughout its length; stipules absent or minute and early caducous. Inflorescence small, axillary or sometimes on a short leafless shoot, 1–many-flowered. Flowers usually bisexual, sometimes unisexual; sepals (4–)5(–6), united at base and arranged spirally, with imbricate lobes; corolla (4–)5(–8)-lobed, usually glabrous, white, pale yellow or whitish-green, rarely pink or red; stamens (4–)5(–8), inserted at the throat of the corolla tube opposite corolla lobes, alternating with staminodes inserted between corolla lobes; pistil 1, with globose or ovoid (4–)5(–6)-celled ovary and rather short style. Fruit a berry with persistent sepals and style and fleshy pericarp, 1-6-seeded. Seed with a thin to rather thick glossy testa and narrow to broad, linear to broadly oblong hilum; endosperm absent to abundant, cotyledons thick or thin. Seedling with epigeal germination, with strongly developed taproot; first pair of leaves opposite or subopposite, subsequent leaves spiral and soon similar to leaves of adult trees.

Wood anatomy

– Macroscopic characters:

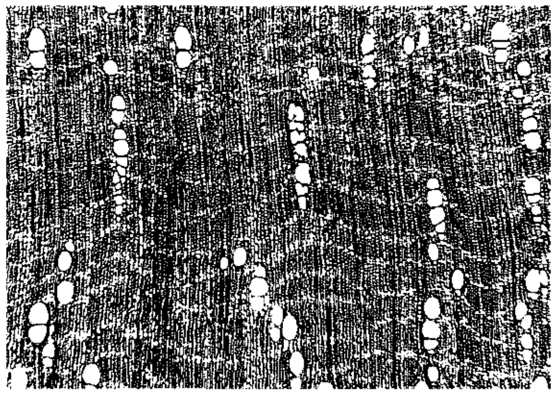
Heartwood light red-brown to yellow-brown, indistinctly demarcated from the sapwood. Grain straight. Texture fine to moderately fine. Growth rings indistinct to barely visible to the naked eye; vessels in a typically radial arrangement which gives the end surface a radially perforated appearance, visible to the naked eye; parenchyma and rays not distinct without a lens.

– Microscopic characters:

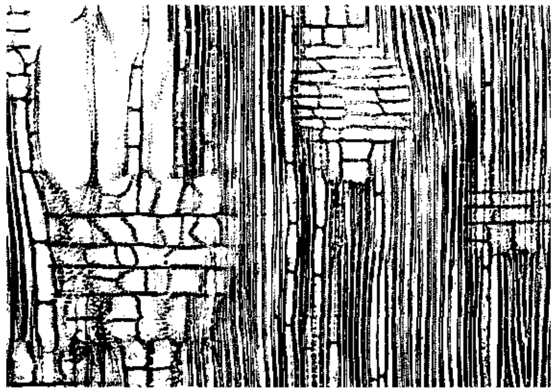
Growth rings faint or absent, if present marked by difference in spacing of tangential parenchyma bands, and in fibre wall thickness on either side of the ring boundary. Vessels diffuse, 12–18/mm^2, mainly in radial multiples of 2–5(–9), in more or less continuous radial to somewhat oblique rows, round to oval, average tangential diameter 50–110 μm; perforations simple; intervessel pits alternate, round to polygonal, (5–)6–8 μm; vessel-ray pits mainly confined to the upright and square cells, mostly large and simple, horizontally to vertically elongate or round, partly half-bordered, scarce in procumbent cells; helical thickenings absent; gum-like deposits absent. Fibres generally 1000–2000 μm long, some fibres septate, mostly medium thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, diffuse, diffuse-in-aggregates or in fine discontinuous to continuous 1–2-seriate, irregular wavy band sometimes forming a reticulate pattern, 5–8 lines per radial mm, in 3–8-celled strands. Rays 11–17/mm, 1–3(–4)-seriate, multiseriates usually with uniseriate tails, up to 800 μm high, heterocellular with 1–4 rows of upright and square marginal cells and procumbent body cells. Crystals and silica bodies sometimes present (although not in the species studied).

Species studied: *P. firma, P. macrantha, P. malaccensis, P. obovata.*

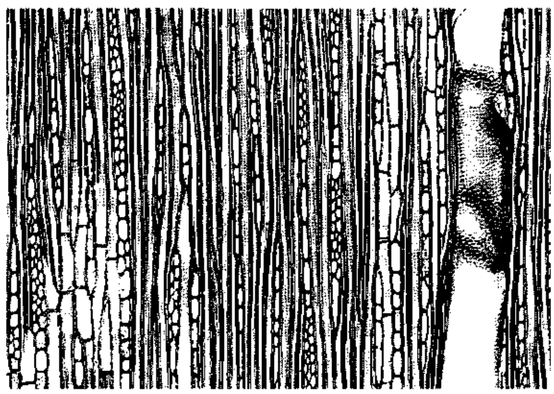
Growth and development The trees flower fairly frequently in comparison with dipterocarps, and there is a tendency for many individuals in a certain area to flower simultaneously. Fruits may ripen in about 7 months after flowering. They are



transverse section (×25)



radial section (×75)



tangential section (×75)

Pouteria firma

eaten by mammals such as monkeys, squirrels and bats, which scatter the seeds. Probably some birds eat the fruits as well.

Other botanical information *Pouteria* as dealt with here, includes *Planchonella.* In most of the literature, *Planchonella* is considered to represent a separate genus, having thin cotyledons and thick endosperm, whereas *Pouteria* has thick cotyledons and thin or lacking endosperm. Moreover, the hilum in *Planchonella* is usually narrow and linear, in *Pouteria* it is usually broad; the fruits in *Pouteria* are often large and fleshy, in *Planchonella* generally smaller. *Planchonella* has an Asiatic main centre of distribution, whereas *Pouteria* in the narrow sense has its main centre of distribution in South America. However, the above-mentioned characters show overlap between the two genera, as do the areas of distribution, which seems to be ample reason for not keeping *Planchonella* apart from *Pouteria.*

Many species now included in *Pouteria* were formerly placed in *Sideroxylon.* In accordance with modern genus delimitations, *Sideroxylon* is principally a genus from South America and Africa (and the surrounding islands), and differs from *Pouteria* in its small and more or less basal hilum.

In Australia some species supply good timber, e.g. *Pouteria pohlmaniana* (F. v. Mueller) Baehni and *P. sericea* (Aiton) Baehni. The timber of *P. vitiensis* (Gillespie) Degener is used in the Fiji Islands.

Ecology Like many other *Sapotaceae*, *Pouteria* trees occur particularly in primary forest, rarely in secondary forest, most commonly in the lowland, but some species can be found in montane forest. In New Guinea some species may reach 2500 m altitude. They belong to the middle or uppermost storey of the forest but are not emergents. The different species can grow on a variety of soils, ranging from sandy to clayey, and sometimes on young volcanic soils (e.g. *P. macrantha* in Sulawesi). Some species are commonly found in swamp forest (e.g. *P. malaccensis*), sometimes even in peat swamps (e.g. *P. maingayi*). Others occur on rocky coasts (e.g. *P. linggensis*) or on limestone (e.g. *P. luzoniensis*). *P. obovata* is ecologically the most versatile species, occurring on rocky and sandy sea coasts, on the landward side of mangroves, on limestone hills and in both primary and secondary forest.

Several species are locally common, but they usually occur scattered in the forest, e.g. *P. duclitan* in Java, *P. maingayi* and *P. malaccensis* in Peninsular Malaysia, *P. macrantha* in the Philippines and *P. luzoniensis* in Papua New Guinea.

Propagation and planting The seeds are fairly large to large (about 1–4 cm long) and may germinate rapidly (4–6 weeks after shedding) or more slowly (10–26 weeks after shedding, e.g. *P. maingayi*).

Silviculture and management Natural regeneration is often scarce in logged-over forest and trees are very slow to colonize secondary forest. Sometimes natural regeneration in logged-over forest is plentiful, e.g. *P. moluccana* in South Sulawesi (Indonesia).

Diseases and pests Living nyatoh trees are reportedly attacked by longhorn beetles in Peninsular Malaysia, the larvae damaging the timber at the base of the trunk by boring long tunnels, and by fungi in Indonesia. Although it is unknown to which genera and species this information refers, *Pouteria* species might also be susceptible to beetle and fungal attack.

Genetic resources Just like other *Sapotaceae* producing timber, *Pouteria* species might be liable to genetic erosion as they occur particularly in undisturbed forest and usually grow scattered in the forest.

Prospects Nyatoh is a silviculturally neglected timber which can be valuable for indoor uses. It is in demand for furniture and plywood. The wood of *P. malaccensis* from Peninsular Malaysia is very suitable for plywood, especially in relation to gluing, which gives good results when using phenol-resorcinol formaldehyde. Promising results were obtained by using mixed-species veneer of *P. malaccensis* and other wood and urea formaldehyde glue. *Pouteria* timber has been tested only rarely, and the identity of the species tested was often doubtful or unknown. Wood property tests on properly identified logs are desirable.

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Selection of species

Pouteria anteridifera (C. White & Francis) Baehni

Candollea 9: 381 (1942).

Synonyms *Planchonella anteridifera* (C. White & Francis) H.J. Lam (1927).

Distribution Papua New Guinea.

Uses The timber is reputed to be used.

Observations A large tree up to 45 m tall; leaves evenly distributed, obovate-elliptical, with distinct transverse tertiary venation, densely puberulous beneath; flowers many together in clusters, borne on 15–25 mm long pedicels, reddish-pink; fruit obovoid or ellipsoid, 4.5–7.5 cm long, glabrous and green. *P. anteridifera* grows in rain forest up to 500 m altitude.

Selected sources 732.

Pouteria chartacea (F. v. Mueller) Baehni

Boissiera 11: 59 (1965).

Synonyms *Planchonella chartacea* (F. v. Mueller) H.J. Lam (1925).

Distribution Morotai, Kai Islands, New Guinea and north-eastern Australia.

Uses The timber is reputed to be used.

Observations A small to fairly large tree up to 40 m tall with a buttressed bole up to 100 cm in diameter; leaves evenly distributed or clustered at tip of twigs, obovate-spatulate, with distinct reticulate tertiary venation, glabrous on both sides; flowers in 3–7-flowered clusters, borne on slender 5–8 mm long pedicels, whitish; fruit ovoid or globose, 1.5–2.2 cm long, glabrous and greenish, but becoming deep red when ripe. *P. chartacea* often resembles *P. linggensis*, but usually differs in the shape of the leaves and in the thicker tertiary venation. It grows in forest, in New Guinea often on frequently inundated localities near rivers, where it sometimes grows in almost pure stands, and it has been found up to 1100 m altitude.

Selected sources 36, 732.

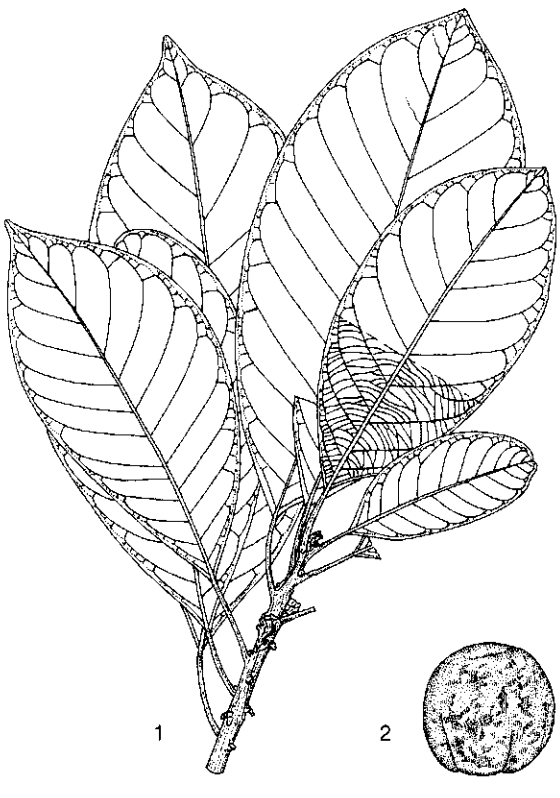
Pouteria doonsaf P. v. Royen

Blumea 8: 486 (1957).

Distribution Irian Jaya (Indonesia).

Uses The timber is reputed to be used as nyatoh.

Observations A fairly large tree up to 35 m tall with cylindrical bole up to 70 cm in diameter; leaves evenly distributed or more or less clustered at tip of twigs, elliptical-ovate, with fairly distinct, transverse tertiary venation, glabrous on both sides; flowers 1 or 2 per leaf-axil, borne on 2–3 mm long pedicels; fruit apple-shaped, 5–10 cm long, glabrous and green. *P. doonsaf* is closely related to



Pouteria doonsaf P. v. Royen – 1, twig with leaves and flower buds; 2, fruit.

P. macrantha. The density of the wood is 490–660 kg/m^3 at 12% moisture content; the wood is pinkish-yellow.

Selected sources 263, 317.

Pouteria duclitan (Blanco) Baehni

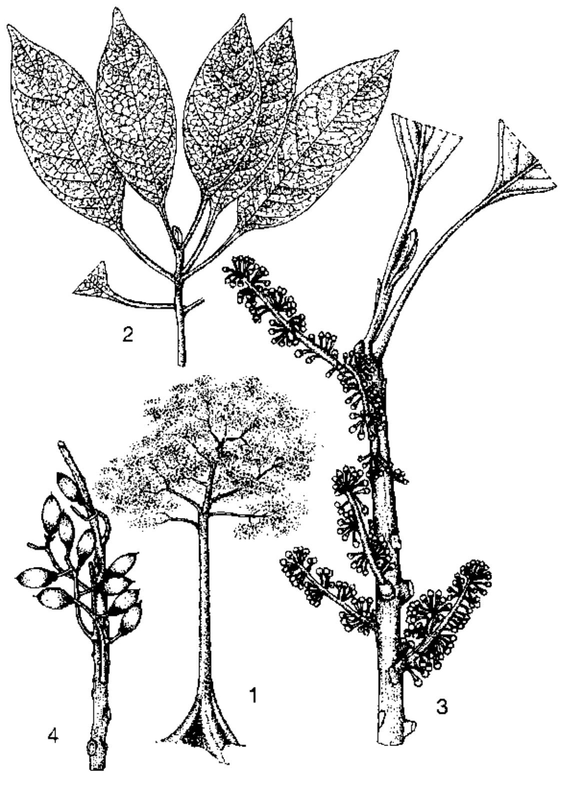
Candollea 9: 283 (1942).

Synonyms *Planchonella nitida* (Blume) Dubard (1912), *Planchonella duclitan* (Blanco) Bakh.f. (1963), *Xantolis nitida* (Blume) Baehni (1965).

Vernacular names Indonesia: karet anjing (Sundanese, Java), nyato (Javanese, Java), sambiring (Sulawesi). Philippines: duklitan, malayhot (Tagalog), bungalong (Iloko).

Distribution Sumatra, Borneo, the Philippines, Java, the Lesser Sunda Islands, Sulawesi, the Moluccas and Irian Jaya.

Uses The timber is used as nyatoh for carving, inlaying, musical instruments, cabinet work, picture frames, household implements, matches and fan ribs, especially in the Philippines ('white nato'). The wood is not durable, and rarely used in house-building.



Pouteria duclitan (Blanco) Baehni – 1, tree habit; 2, sterile twig; 3, flowering twig; 4, fruiting twig.

Observations A medium-sized to large tree up to 50 m tall, with a straight bole up to 150 cm in diameter, sometimes even more, but in the Philippines usually less (up to 100 cm); leaves evenly distributed, elliptical-obovate or elliptical-ovate, with distinct reticulate to slightly transverse tertiary venation, glabrous on both sides; flowers in clusters on leafless or nearly leafless axillary shoots or in axillary clusters, on slender pedicels 2–9 mm long, whitish-green; fruit ovoid, obovoid or globose, 1.2–3.5 cm long, glabrous except at base, orange to blackish green. *P. duclitan* is locally fairly common at low and medium altitudes, e.g. in the Philippines and central and eastern Java (up to 1200 m). In Java it is found in periodically inundated localities and on limestone in teak forest, mixed and secondary forest. The wood is moderately heavy (with a density of about 650 kg/m^3 at 15% moisture content) and moderately hard.

Selected sources 35, 36, 175, 318, 480, 484, 486, 579, 732.

Pouteria firma (Miq.) Baehni

Candollea 9: 284 (1942).

Synonyms *Planchonella firma* (Miq.) Dubard (1912).

Vernacular names Indonesia: madang kayu balam (Sumatra), marchichang (Bangka), nyato lambar (Bangka, Kalimantan). Philippines: bagomaho, manalipsik, topek (Panay Bisaya). Solomon Islands: maliolo.

Distribution Throughout Malesia and on the Solomon Islands.

Uses The timber is used as nyatoh, especially for furniture, light flooring and joinery, but also for plywood and hardboard. The bark is chewed together with betel against sprue.

Observations A medium-sized to fairly large tree up to 35 m tall, with straight bole, rarely exceeding 50 cm in diameter; leaves evenly distributed, elliptical, narrowly elliptical, obovate or narrowly obovate, with closely transverse tertiary venation distinct beneath, initially scurfy but soon becoming glabrous on both sides; flowers usually in clusters in leaf axils, borne on 3–28 mm long pedicels, white, yellow or reddish; fruit ovoid, obovoid, ellipsoid or globose, 0.8–2.5 cm long, glabrous except at base, whitish to almost black. Although *P. firma* is widespread, it is only locally common, e.g. in Bangka. It occurs in lowland as well as in montane forest, in Peninsular Malaysia up to 1500 m altitude, in Papua New Guinea up to 2000 m. The density of the wood is 520–750 kg/m^3

at 15% moisture content. The wood is easy to saw and works well.

Selected sources 36, 100, 102, 318, 359, 480, 486, 581, 732, 779.

Pouteria hochreutineri (H.J. Lam) H.J. Lam

Blumea 5: 337 (1943).

Synonyms *Planchonella hochreutineri* H.J. Lam (1943).

Distribution New Guinea.

Uses The timber is reputed to be used.

Observations A medium-sized to large tree up to 45 m tall; leaves more or less clustered at tip of twigs, elliptical to obovate, with transverse tertiary venation distinct beneath, hairy beneath; flowers in many-flowered clusters below the leaves, borne on 8–10 mm long pedicels, pink or red; fruit unknown. *P. hochreutineri* has been found in forest up to 1600 m altitude.

Selected sources 732.

Pouteria kaernbachiana (Engl.) Baehni

Candollea 9: 338 (1942).

Synonyms *Planchonella kaernbachiana* (Engl.) H.J. Lam (1925).

Vernacular names Papua New Guinea: white planchonella.

Distribution New Guinea.

Uses The timber is used as nyatoh and traded as 'planchonella'. It is used for masts, window and door frames and moulding. The timber is suitable for veneer. The very sticky latex is used as birdlime.

Observations A medium-sized tree up to 30 m tall; leaves evenly distributed, obovate or spatulate with transverse tertiary venation, initially hairy but glabrescent except for veins beneath; flowers in many-flowered axillary clusters, borne on 5–11 mm long pedicels, whitish-green; fruit ellipsoid, 6.5–8 cm long, glabrous, green to blackish. *P. kaernbachiana* resembles *P. vrieseana*. It is found in primary and secondary forest, up to 1600 m altitude. The wood saws easily and works well, it peels and glues well and is easy to nail and screw, but it is resistant to impregnation. The density is 510–570 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 67, 359, 732.

Pouteria linggensis (Burck) Baehni

Boissiera 11: 57 (1965).

Synonyms *Planchonella linggensis* (Burck) Pierre (1890), *Planchonella oxyedra* (Miq.) Dubard (1912) p.p., *Planchonella littoralis* (Ridley) H.J. Lam (1925).

Vernacular names Indonesia: nyato sudu-sudu (Sumatra), towu landuk, jenggot (Java). Malaysia: membatu, geliti, tuak. Philippines: loter (Panay Bisaya), empaparel (Tagbanua), panangkolauan (Bikol).

Distribution Throughout Malesia; also in north-eastern Australia, the Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga, Samoa and Niue.

Uses The timber is used as nyatoh in Sulawesi (Indonesia) and Melanesia for house-building, and also for spears and hatchet-handles.

Observations A shrub, small or medium-sized tree, rarely up to 33 m tall; leaves evenly distributed, elliptical or narrowly elliptical, obovate or lanceolate, with laxly reticulate tertiary venation, initially puberulous but soon glabrous or subglabrous on both sides; flowers in 1–many-flowered clusters in leaf axils, borne on slender pedicels 3–10 mm long, white; fruit ovoid, obovoid or globose, 0.8–2.7 cm long, glabrous except at base, green, pink or red. *P. linggensis* is highly variable in the leaves (shape, size, indumentum, venation). Although this species is widespread, it is uncommon in many places. It usually grows in lowland rain forest (in Peninsular Malaysia on rocky sea coasts) up to 600 m altitude, occasionally up to 1000 m (e.g. Seram).

Selected sources 35, 36, 102, 480, 486, 581, 732, 779.

Pouteria luzoniensis (Merr.) Baehni

Candollea 9: 365 (1942).

Synonyms *Sideroxylon luzoniense* Merr. (1906).

Vernacular names Philippines: banokbok, malapaho (Tagalog), amemangkas (Samar-Leyte Bisaya).

Distribution Bali, Sulawesi, Borneo (Sabah), the Philippines and New Guinea.

Uses The timber is reputed to be used.

Observations A medium-sized tree up to 30 m tall but usually smaller; leaves evenly distributed, ovate, narrowly ovate or obovate, with indistinct, irregularly reticulate or transverse tertiary venation, densely pubescent (sometimes subglabrous) beneath; flowers in 2–6-flowered clusters, subsessile, whitish to pale brown; fruit globose, about 2 cm long, puberulous at base and apex, greenish to purplish. Plants from New Guinea belong to var. *papuana* Erlee, which differs from var. *luzoniensis* in its smaller leaves with shorter petioles and in the hairy corolla. *P. luzoniensis* usually grows on rocks, in Sabah on the sea shore; in the Philippines up to 700 m altitude. In Papua New Guinea it locally dominates the forest up to 1000 m, in association with *Araucaria* spp.

Selected sources 100, 206, 317, 480, 486.

Pouteria maclayana (F. v. Mueller) Baehni

Candollea 9: 307 (1942).

Synonyms *Lucuma maclayana* (F. v. Mueller) H.J. Lam (1925), *Lucuma navicularis* H.J. Lam (1925).

Vernacular names Indonesia: serindieng (Lingga), widorik utan (Moluccas).

Distribution Lingga, the Talaud Islands, the Moluccas, the Kai Islands, New Guinea and the Solomon Islands.

Uses The timber is used locally as nyatoh for house-building. The fruits are sometimes eaten, but they are rather dry and not very palatable.

Observations A medium-sized tree up to 30 m tall; leaves clustered at tip of twigs, narrowly obovate or obovate-lanceolate, with transverse, rarely irregularly reticulate tertiary venation, initially puberulous but glabrescent on both sides; flowers in usually 6-flowered clusters in leaf-axils, borne on rather stout 2–3 mm long pedicels; fruit depressed-globose, very large, up to 13 cm in diameter, glabrous, greenish with yellow pulp. In New Guinea *P. maclayana* is locally fairly common in primary rain forest up to 250 m altitude; possibly it is also locally not uncommon in the Moluccas. The wood is whitish, fairly light and not durable in contact with the soil.

Selected sources 36, 317, 318.

Pouteria macrantha (Merr.) Baehni

Candollea 9: 328 (1942).

Synonyms *Sideroxylon macranthum* Merr. (1905).

Vernacular names Indonesia: sasangkangan (Sulawesi), suing (Moluccas). Philippines: white nato (general), palak-palak (Tagalog), kalamuting (Iloko).

Distribution The Philippines, North Sulawesi and the Moluccas.

Uses The timber is used in the Philippines as nyatoh for carving, inlaying, cabinet work, picture frames and implements. The pulp of the fruit is edible.

Observations A fairly large tree up to 40 m tall, with straight bole up to 80 cm in diameter, but often less (about 25 m tall and 60 cm in diameter); leaves clustered at tip of twigs, narrowly obovate or lanceolate, with distinct irregularly reticulate or more or less transverse tertiary venation, initially often puberulous but glabrescent on both sides; flowers in 5–9-flowered axillary clusters, borne on rather stout 3–6 mm long pedicels; fruit subglobose, 4–6.5 cm in diameter, puberulous and greenish. In the Philippines *P. macrantha* is common in primary forests at low altitudes. The wood is medium-heavy, with density of 530–700 kg/m^3 at 12% moisture content, seasons well (but rapid drying is needed), and works and finishes well; only suitable for indoor uses.

Selected sources 36, 175, 317, 480, 484, 486, 579.

Pouteria macropoda (H.J. Lam) Baehni

Candollea 9: 410 (1942).

Synonyms *Planchonella macropoda* H.J. Lam (1932).

Distribution New Guinea.

Uses The timber is reputed to be used.

Observations A fairly large tree up to 40 m tall; leaves evenly distributed, ovate-elliptical, with distinct transverse tertiary venation, puberulous when young, but glabrescent; flowers in many-flowered clusters, borne on slender pedicels 13–18 mm long, white; fruit ovoid, obovoid to subglobose, 1–4 cm long, glabrous except at base, greyish-green to dark purple. *P. macropoda* is found in the mountains, at 1800–2400 m altitude.

Selected sources 36, 732.

Pouteria maingayi (C.B. Clarke) Baehni

Candollea 9: 343 (1942).

Synonyms *Sideroxylon maingayi* C.B. Clarke (1882), *Lucuma maingayi* (C.B. Clarke) Dubard (1912), *Planchonella maingayi* (C.B. Clarke) P. v. Royen (1957).

Vernacular names Indonesia: nyatuh bungo tanjong, mayang rata (Sumatra). Malaysia: nyatoh nangka merah, nangka-nangka (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo.

Uses The timber is used as nyatoh.

Observations A medium-sized to large tree up to 43 m tall, with columnar bole up to 80 cm in diameter, buttressed; leaves evenly distributed, obovate, with distinct transverse tertiary venation, glabrous when mature; flowers in up to 15-flowered clusters in leaf axils, borne on 2–4 mm long pedicels, whitish; fruit ovoid-ellipsoid or subglobose, 2–5 cm long, glabrous, green. *P. maingayi* occurs throughout Peninsular Malaysia; it usually grows scattered in lowland primary forest, but is locally very common in peat swamps. As it is one of the most widely distributed big-tree *Sapotaceae* in Peninsular Malaysia, it is probably an important nyatoh timber-producing species there. The wood is creamy white or light yellow and is fairly heavy with a density of 680–880 kg/m^3 at 15% moisture content.

Selected sources 36, 102, 190, 581, 732, 779.

Pouteria malaccensis (C.B. Clarke) Baehni

Candollea 9: 203 (1942).

Synonyms *Sideroxylon malaccense* C.B. Clarke (1882), *Lucuma malaccensis* (C.B. Clarke) Dubard (1912), *Xantolis malaccensis* (C.B. Clarke) Baehni (1965).

Vernacular names Malaysia: nyatoh nangka kuning, nangka-nangka (Peninsular).

Distribution Peninsular Malaysia, Sumatra, the Riau Archipelago, Lingga, Sulawesi and Irian Jaya.

Uses The timber is used as nyatoh.

Observations A medium-sized to fairly large tree up to 40 m tall, with bole up to 90 cm in diameter, buttressed; leaves evenly distributed or loosely clustered, usually broadly obovate, with distinct transverse tertiary venation, initially densely hairy beneath, but glabrescent; flowers in 6–22-flowered clusters in axils of leaves, borne on stout 2–4 mm long pedicels, white to pale yellow or whitish-green; fruit subglobose, 2–4 cm long, rusty scurfy but becoming glabrous, yellowish-green or brownish. *P. malaccensis* is a fairly common species, but occurs scattered in lowland primary forest, rarely up to 1300 m altitude. It is found in seasonal swamps as well as on ridges. In Peninsular Malaysia it is probably one of the major nyatoh-producing trees. The wood is creamy white or pale yellow and heavy for nyatoh, with a density of 790–870 kg/m^3 at 15% moisture content. It has been found very suitable for plywood.

Selected sources 36, 102, 190, 317, 318, 491, 581, 779.

Pouteria moluccana (Burck) Baehni

Candollea 9: 327 (1942).

Synonyms *Sideroxylon moluccanum* Burck (1886), *Planchonella moluccana* (Burck) H.J. Lam (1925).

Vernacular names Indonesia: kalaka, karosisi (Sulawesi).

Distribution Flores, Sulawesi, the Moluccas and Irian Jaya.

Uses The timber is reputed to be used.

Observations A small to fairly large tree up to 35 m tall; leaves evenly distributed or more or less clustered at tip of twigs, ovate, obovate or elliptical, with distinct dense transverse tertiary venation, initially pubescent beneath but soon becoming glabrous; flowers in many-flowered clusters in leaf axils, subsessile (pedicels up to 2 mm long); fruit obovoid, 1.5–2.5 cm long, densely ferruginously woolly, green. *P. moluccana* is closely related to *P. firma*, but differs in the sepals being glabrous inside and its subsessile flowers. In Sulawesi *P. moluccana* can be locally one of the dominant tree species in the forest. It is found up to 1800 m altitude.

Selected sources 36, 669, 732.

Pouteria monticola (K. Krause) H.J. Lam

Blumea 5: 337 (1943).

Synonyms *Planchonella monticola* (K. Krause) H.J. Lam (1932).

Distribution New Guinea.

Uses The timber is reputed to be used.

Observations A medium-sized tree up to 30 m tall; leaves usually clustered at tip of twigs, sometimes evenly distributed, ovate-elliptical or narrowly obovate, with indistinct transverse tertiary venation, densely hairy beneath; flowers solitary or in clusters, borne on 10–22 mm long pedicels, whitish; fruit unknown. This species grows in montane forest, 1000–2200 m altitude.

Selected sources 732.

Pouteria obovata (R.Br.) Baehni

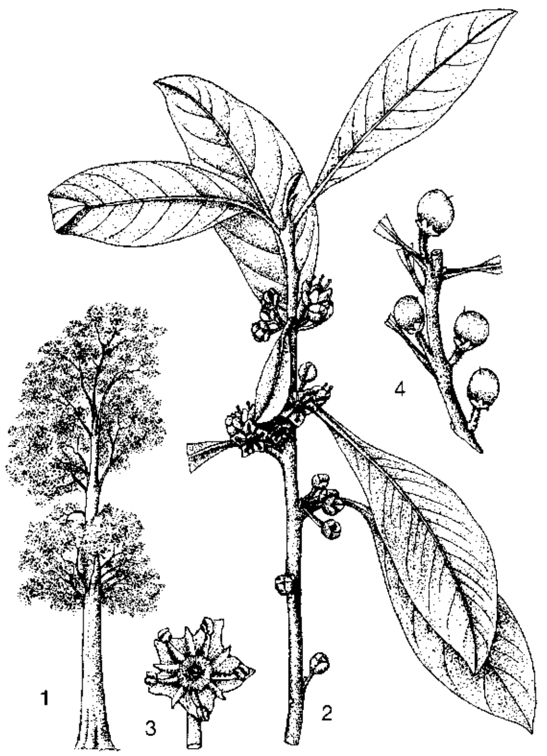
Candollea 9: 324 (1942).

Synonyms *Sideroxylon ferrugineum* Hook. & Arnott (1841), *Planchonella obovata* (R.Br.) Pierre (1890).

Vernacular names Indonesia: nyatu karikit (Sumatra), jengkok (Java), nyatoh gambir (Kalimantan). Malaysia: nyatoh laut (general), menasi, misi (Peninsular), umas umas (Sabah). Philippines: mangkas (Sulu), banasi (Tagalog), bungalong (Iloko). Cambodia: rom denh. Thailand: chan thit so (general), phang ka bok (peninsular), nga sai (Songkhla, Surat Thani). Vietnam: m[ooj]c, c[aa]y tr[uws]ng g[af].

Distribution Throughout southern Asia, from India, Pakistan and the Seychelles, through Indo-China, southern China and Malesia to the Solomon Islands and north-eastern Australia.

Uses The timber is used as nyatoh or bitis. It is suitable for carving and cabinet making, and also



Pouteria obovata (R.Br.) Baehni – 1, tree habit; 2, flowering twig; 3, flower; 4, fruiting twig.

for turned articles; sometimes it is used for house-posts, and for salt-water piling. The bark is chewed against sprue and a decoction of the leaves relieves stomachache; leaves are used as a poultice against lumbago.

Observations A tree of various dimension, from small (10 m) to medium-sized (30 m) or sometimes even up to 40 m tall; bole varying from crooked and gnarled to straight and branchless for over 10 m (and then usually with plank buttresses); leaves evenly distributed, usually obovate but sometimes elliptical-lanceolate, with distinct reticulate tertiary venation, usually velvety beneath, but often glabrescent; flowers in 1–20-flowered clusters in axils of leaves, borne on 2–10 mm long pedicels, white to greenish; fruit obovoid or subglobose, 1–1.5 cm long, glabrous, whitish-yellow, red or blue. *P. obovata* is highly variable and grows on rocky and sandy sea coasts and on the landward side of mangroves, but also on limestone hills and in mixed forest, up to 400 m altitude. The variability is also present in the wood: the recorded density ranges from 560 to 1220 kg/m^3 at 15% moisture content; the wood is reported as durable (the Philippines) and not durable (Indonesia) and it is pale yellow.

Selected sources 35, 36, 89, 100, 102, 235, 318, 480, 486, 579, 581, 732, 779.

Pouteria obovoidea (H.J. Lam) Baehni

Candollea 9: 412 (1942).

Synonyms *Planchonella obovoidea* H.J. Lam (1925).

Vernacular names Indonesia: baineob, waineo (Timor), laro (Morotai).

Distribution Eastern Malesia, from Sulawesi and Timor to Papua New Guinea; also in the Riau Archipelago, the Solomon Islands, north-eastern Australia and Fiji.

Uses The timber is used as nyatoh.

Observations A medium-sized to fairly large tree up to 35 m tall; leaves evenly distributed, ovate, obovate to elliptical, with distinct, laxly reticulate tertiary venation, hairy beneath; flowers in few-flowered clusters, borne on 2–6 mm long pedicels, white or yellowish; fruit obovoid, 1.8–3 cm long, glabrous and red to almost black. *P. obovoidea* is closely related to *P. obovata*, but differs particularly in the circularly broadened stigma in fruit. It is usually found in the lowland, in primary and secondary forest, but in New Guinea up to 2000 m altitude.

Selected sources 36, 732.

Pouteria paucinervia Erlee

Blumea 8: 490, 503 (1957).

Distribution Peninsular Malaysia and Sumatra.

Uses The timber is reputed to be used.

Observations A medium-sized tree up to 30 m tall, with bole up to 60 cm in diameter, usually buttressed and sometimes with stilt roots; leaves obovate to spatulate, with distinct transverse tertiary venation, initially reddish-brown hairy, but glabrescent; flowers in 1–4-flowered clusters in leaf axils, borne on up to 5 mm long pedicels; fruit depressed-globose, 1.5–2 cm in diameter, glabrescent, greenish-brown. *P. paucinervia* is locally common in seasonal swamps in the lowland of Peninsular Malaysia.

Selected sources 317, 779.

Pouteria sussu (Engl.) Baehni

Candollea 9: 315 (1942).

Synonyms *Planchonella sussu* (Engl.) H.J. Lam (1932).

Distribution New Guinea.

Uses The timber is reputed to be used.

Observations A medium-sized tree up to 30 m tall; leaves evenly distributed, elliptical, narrowly elliptical to lanceolate, with distinct transverse tertiary venation, glabrous on both sides; flowers in few to many-flowered clusters in leaf axils (sometimes along a leafless axillary shoot), borne on 5–20 mm long pedicels; fruit obovoid, 3–3.5 cm long, densely hairy but partly glabrescent. *P. sussu* is closely related to *P. firma*. It grows in forest up to 1100 m altitude.

Selected sources 36, 732.

Pouteria torricellensis (K. Schumann) Baehni

Candollea 9: 379 (1942).

Synonyms *Planchonella samoensis* Reinecke ex H.J. Lam (1925), *Planchonella torricellensis* (K. Schumann) H.J. Lam (1932).

Vernacular names Papua New Guinea: red planchonella.

Distribution The Moluccas (Seram), New Guinea and Samoa; perhaps also on Bali.

Uses The timber is used as nyatoh and traded as 'planchonella' in Papua New Guinea. It is used for masts, window and door frames and moulding; it is suitable for veneer.

Observations A large tree up to 45 m tall; leaves evenly distributed, ovate or elliptical, with rather indistinct transverse tertiary venation, initially sparsely hairy but soon glabrescent on both sides; flowers in many-flowered clusters in leaf axils (rarely on a short axillary leafless shoot), borne on filiform pedicels, 5–12 mm long, greenish; fruit obliquely ellipsoid, 1.5–2.5 cm long, glabrous (sometimes except at base), reddish, purplish or maroon when mature. *P. torricellensis* is found in lowland forest up to 700 m altitude. In New Guinea it is locally rather common. The wood saws easily and works well, it peels and glues well and is easy to nail and screw. The density is 510–600 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 67, 359, 732.

Pouteria velutina (Elmer) Baehni

Candollea 9: 380 (1942).

Synonyms *Sideroxylon velutinum* Elmer (1913), *Planchonella velutina* (Elmer) H.J. Lam (1925), *Xantolis velutina* (Elmer) Baehni (1965).

Vernacular names Philippines: boaya-boaya (Sulu), uakatan (Samar-Leyte Bisaya), rirau (Bikol).

Distribution The Philippines (Luzon, Palawan, Samar, Negros, Leyte).

Uses The timber is reputed to be used.

Observations A tree of unknown dimensions, but growing at least 20 m tall with bole diameter of 30 cm; leaves evenly distributed or more or less clustered at tip of twigs, obovate or elliptical, with distinct transverse tertiary venation (or subparallel to secondary veins), whitish or ferruginously hairy beneath; flowers in rather many-flowered clusters, borne on 8–12 mm long pedicels; fruit globose or obliquely obovoid, 1–1.5 cm long, glabrous or sparsely hairy. Var. *sarcocarpa* (Merr.) Baehni (synonym: *Sideroxylon sarcocarpum* Merr.) is distinguished in Luzon. It differs from var. *velutina* in its broader sepals and globose fruit. *P. velutina* is found in forest at low altitudes.

Selected sources 36, 480, 486, 732.

Pouteria villamilii (Merr.) Baehni

Candollea 9: 318 (1942).

Synonyms *Sideroxylon villamilii* Merr. (1915).

Vernacular names Philippines: Villamil nato (general), dolitan (Tagalog).

Distribution The Philippines (Luzon, Siargao).

Uses The timber is used as nyatoh for carving, inlaying, cabinet work, picture frames and implements. It is traded as 'white nato' together with other Philippine *Pouteria* species.

Observations A medium-sized tree up to 30 m tall; leaves evenly distributed, oblong to lanceolate (sometimes ovate), with distinct, laxly reticulate tertiary venation, glabrous on both sides; flowers in up to 7-flowered, axillary clusters, borne on up to 5 mm long pedicels; fruit depressed-globose, up to 5 cm in diameter, glabrous. *P. villamilii* occurs in primary forests at low altitudes. The wood is coarser in texture than the wood of *P. duclitan* and *P. macrantha*, and is obtainable in limited quantities. It is fairly light, with a density of about 530 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 317, 480, 484, 486.

Pouteria vrieseana (Pierre ex Burck) Baehni

Candollea 9: 336 (1942).

Synonyms *Sideroxylon vrieseanum* Pierre ex Burck (1886), *Planchonella vrieseana* (Pierre ex Burck) Dubard (1912), *Xantolis vrieseana* (Pierre ex Burck) Baehni (1965).

Vernacular names Indonesia: mopin, litoko, singanatan (Moluccas).

Distribution The Moluccas.

Uses The timber is used as nyatoh for planks and beams.

Observations A fairly large tree up to 36 m tall, with columnar, straight bole up to 55 cm in diameter, buttressed; leaves evenly distributed, obovate, with distinct transverse tertiary venation, initially ferruginously woolly, but glabrescent, first above, later also beneath; flowers in many-flowered clusters, borne on slender pedicles 20–45 mm long, reddish; fruit ellipsoid, 5.5–6.5 cm long, ferruginously puberulous, reddish-brown. *P. vrieseana* is closely related to *P. kaernbachiana* and *P. anteridifera* from New Guinea. It is found in lowland rain forest. The wood is yellowish-white, rather soft, and not durable when exposed to the weather or soil.

Selected sources 36, 318, 732.

R.H.M.J. Lemmens (general part, properties, selection of species),
B. Louman (general part),
R. Klaassen (wood anatomy)

Pterocarpus Jacq.

Sel. stirp. amer. hist.: 283 (1763).
LEGUMINOSAE
x = probably 11; *P. indicus* f. *indicus*: n = 10, 22; *P. indicus* f. *echinatus*: n = 22

Trade groups Narra: medium-heavy hardwood, e.g. *Pterocarpus indicus* Willd.

Vernacular names Narra: rosewood (a general name for reddish woods used for furniture and cabinet work), amboyna, padauk, red sandalwood (En). Amboine, santal rouge (Fr). Brunei: angsana. Indonesia: sonokembang (general), angsana (Java). Malaysia: angsana (general), sena (Peninsular). Papua New Guinea: New Guinea rosewood. Philippines: apalit (general), vitali (Zamboanga). Burma: sena, padouk, ansanah. Laos: chan dêng. Thailand: pradu (general), pradu-ban (central), sano (Malay, peninsular). Vietnam: gi[as]ng h[uw][ow]ng.

Origin and geographic distribution This pantropical genus consists of 20 species, 5 of which occur in the Indo-Pacific region. Within the Malesian area only one species occurs naturally and is found throughout this area. Most species are found in western tropical Africa (11). If one considers the centre of origin of a genus to be located at the place with the highest species diversity, western tropical Africa can be considered as such.

Uses Narra is used as a structural timber for light to heavy construction, joists, rafters, beams and interior finish. The wood being generally reddish and figured is ranked among the finest for furniture, panelling, musical instruments, high-grade cabinet work, high-class interior joinery, billiard tables, decorative flooring for both light and heavy traffic, agricultural implements, high-class vehicle bodies, cart and gun carriages, oil presses, tool handles, carvings and novelties. A high-grade figured veneer can be sliced from the wood for the outer layers of plywood and cabinet work. Due to its low shrinkage and movement narra is suitable for precision instruments. Its inherent strength to withstand weathering, wearing and insect attacks makes it useful for purposes such as bridges, piles, posts, railway sleepers, shafts and mine timber, although treatment with a preservative is recommended. Because of its comparatively good resistance to marine borer attack it is considered to be suitable for marine construction works as a substitute for teak. In some areas narra is considered the best material for canoes. Physiologically diseased trees, which are found most commonly on Seram, yield a famous strongly figured material known as 'Ambonese gnarl wood' or 'amboyna'.

The bark exudes a gummy or resinous substance which is called 'kino' or 'sangre de drago' (dragon's blood). It is a powerful astringent and the boiled, shredded bark is used against diarrhoea and dysentery. It is sometimes used as a diuretic but its diuretic properties have not yet been clearly demonstrated. The bark also has tanning properties and it dyes a reddish or yellowish colour (e.g. *P. indicus, P. macrocarpus* Kurz and *P. santalinoides* L'Hérit. ex DC.). The wood yields a dye giving a brown or brick-red colour. The colour of the dye is, however, less intense than that of the well-known Indian *P. santalinus* L.f. *P. indicus* is extensively cultivated as an ornamental or shade tree, especially in Peninsular Malaysia, Singapore, Indonesia and the Philippines. It is recommended for planting in denuded areas and brushland to stabilize the soil; it may improve the soil by nitrogen fixation. The flowers and very young leaves are sometimes eaten.

Production and international trade Narra is particularly important in the Philippines, Papua New Guinea and Thailand. In the Philippines the total export of narra wood in 1985 was 3 million kg (40% processed) with a value of US$ 1.1 million. The export declined to 2.3 million kg in 1986 (57% processed) with a value of US$ 935 000, and to 430 000 kg (all processed) with a value of US$ 220 000 in 1987. From then on, the export was negligible and at present there is a total ban on cutting narra trees.

In Papua New Guinea it is an important timber which fetches very high prices; the export of logs is banned, and only processed wood is exported.

Thailand exported 5.8 million kg of sawn *Pterocarpus* (*P. indicus* and *P. macrocarpus*) timber in 1990, worth US$ 10.3 million. However, Thailand also imports this timber, in 1990 to an amount of 11 000 m^3 (non-processed) with a value of US$ 1.9 million, mainly from Burma but also in small amounts from Laos, Cambodia and Vietnam.

Properties Narra is a medium-weight, moderately hard to hard, tough and resilient wood. The heartwood is light yellowish-brown to reddish-brown with darker irregular streaks; it is distinctly demarcated from the generally pale straw-coloured to light grey sapwood. The density is (390–)550–900(–940) kg/m^3 at 15% moisture content. The grain of the wood is interlocked or wavy, texture moderately fine to moderately coarse.

At 12% moisture content the modulus of rupture is 86–96 N/mm^2, modulus of elasticity 11 100–12 300 N/mm^2, compression parallel to grain 55–62 N/mm^2, compression perpendicular to grain 8–9 N/mm^2, shear 10–13 N/mm^2, cleavage c. 56 N/mm radial and 45 N/mm tangential, Janka side hardness 3870–7200 N and Janka end hardness 4540–6900 N.

The rates of shrinkage are low to moderate, from green to 15% moisture content 0.5–1.0% radial and 1.0–1.3% tangential, and from green to oven dry 2.8–3.3% radial and 4.0–5.9% tangential. Narra is generally easy to season with little or no degrade. Once dry, the wood is very stable in service.

Generally the wood is easy to work and does not blunt sawteeth and edges for a considerable time, because it contains very little or no silica. The presence of interlocked grain may result in picking up of grain on radial surfaces during planing. Narra wood turns and chisels very well, and gluing, sanding and polishing give no problems. It nails and screws well and pre-boring is not required; only very thin boards tend to split slightly when nailed. Narra receives paints and varnishes well, but for some material, fillers are needed. It can be peeled very satisfactorily without prior treatments, to produce very decorative veneer.

The figures on durability of narra wood differ considerably, probably because of the wide variation of density of tested wood. Narra is generally rated as durable; this was shown, for instance, in tests of wood from Indonesia, the Philippines and Papua New Guinea, where a service life in contact with the ground of up to 20 years is reported. A test in Malaysia, however, resulted in a classification of the wood as non-durable, with a maximum service life of 2 years. The heartwood is usually resistant to termites, but the sapwood is susceptible to attack by powder-post beetles. Narra is extremely durable when used for interior work in the tropics and subtropics. The heartwood is resistant to preservative impregnation, but the sapwood is permeable. Fresh and dry sawdust may produce an aromatic odour, and may irritate nose and throat.

Wood of *P. indicus* contains 49% cellulose, 24% lignin, 11% pentosan, 0.9% ash and up to 0.3% silica. The solubility is 2.2% in alcohol-benzene, 0.4% in cold water, 4.1% in hot water and 16.2% in a 1% NaOH solution. The energy value is 20 150 kJ/kg. Narra wood contains santalin, a red crystalline compound which constitutes the main colouring matter. The polyphenolic substance isolated from the bark of *P. indicus* inhibits the esterolytic activity of plasmin, and shows carcinostatic activity in mice.

Description Small to large, generally deciduous trees up to 40 m tall; bole often of poor form, strongly fluted and gnarled and up to 350 cm in diameter, with numerous, plank-like buttresses; bark surface finely scaly fissured, finely streaked cream and brown, inner bark thin, producing red sap when cut; crown dense, domed; branchlets often lenticelled; indumentum of simple, usually short and adpressed hairs. Leaves alternate, imparipinnate; stipules generally small, linear or narrowly triangular, usually early caducous; leaflets alternate or sometimes subopposite, entire. Inflorescence axillary or terminal, racemose or paniculate; bracts and bracteoles small, linear to narrowly triangular. Flowers bisexual, irregular; calyx turbinate to campanulate, 5-lobed, the upper two lobes usually larger, sometimes united; petals 5, free, clawed, generally yellow, glabrous or sparsely hairy outside, standard obovate to spatulate, keels shorter than the wings and connate at base; stamens 10, upper stamen free or joined to the staminal sheath, anthers dorsifixed, versatile, dehiscing lengthwise; ovary usually stipitate, with 2–8 ovules and 1 style with a terminal, minute stigma. Fruit a compressed, indehiscent pod, disk-like or sometimes falcate, broadly winged or rarely slightly keeled, with a thickened central, usually woody or corky seed-bearing portion, with 1–3(–4) seeds. Seed kidney-shaped to oblong, usually narrowed and curved near the minute hilum, smooth to undulate, testa brown to blackish, aril minute. Seedling with epigeal germination; the cotyledons borne at or above the soil level; first 2 or 3 leaves simple, arranged spirally, subsequent ones compound and alternate.

Wood anatomy

– Macroscopic characters:

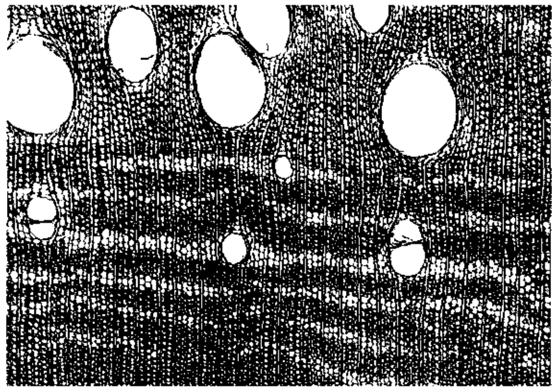
Heartwood light yellowish-brown to reddish-brown and distinctly demarcated from the straw-coloured to light grey sapwood. Grain wavy or interlocked. Texture moderately fine to moderately coarse; ribbon figure present on quarter-sawn faces, zigzag figure present in material with wavy grain; wood not very glossy. Growth rings distinct, formed by concentric alignment of large pore rings and by a layer of darker coloured wood at the end of the ring (ring-porous); vessels visible to the naked eye, particularly distinct at the base of the large pore rings, solitary and in radial multiples of 2–4, tyloses present; axial parenchyma distinct to the naked eye, aliform, in concentric confluent layers and terminal, confluent parenchyma irregularly and closely spaced and wavy; rays barely visible to the naked eye on cross-section but visible to the naked eye on the tangential face because of the storied arrangement (ripple marks).

– Microscopic characters:

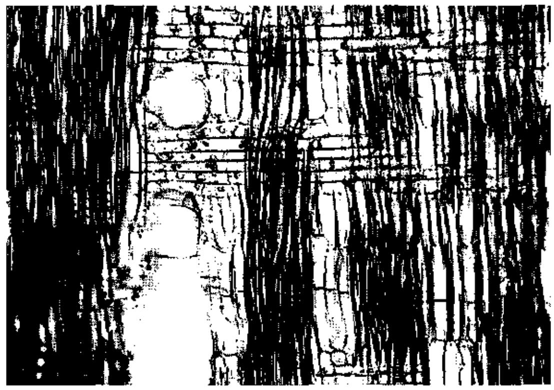
Growth rings distinct, marked by concentric alignment of large pore rings. Vessels very few to few, 1–3(–6)/mm², about 68% solitary, 28% in radial multiples of 2–4, and 4% in clusters, very small in the latewood to very large in the earlywood, 45–375 μm in tangential diameter, mostly medium-sized to moderately large (135–230 μm), vessel elements very short to medium-sized (predominantly 225–360 μm); perforation plates simple; intervessel pits alternate, small, vestured; vessel-ray pits similar to intervessel pits; tyloses occasionally present. Fibres predominantly medium-sized to moderately long (average length 1.3 mm), non-septate, thin-walled, with numerous simple pits with slit-like apertures in the radial walls. Axial parenchyma abundant, aliform-confluent or in irregular confluent bands, and terminal, strands usually 2-celled or parenchyma cells fusiform. Rays 6–10/mm, 1(–2)-seriate, 2–12 cells high, mostly 5–9 cells wide, extremely fine to moderately fine (11–33 μm wide), homocellular and composed of procumbent cells. Rhomboidal crystals present in chambered axial parenchyma cells, 2–8 (or more) in a strand. Axial parenchyma strands and rays distinctly storied.

Species studied: *P. indicus*.

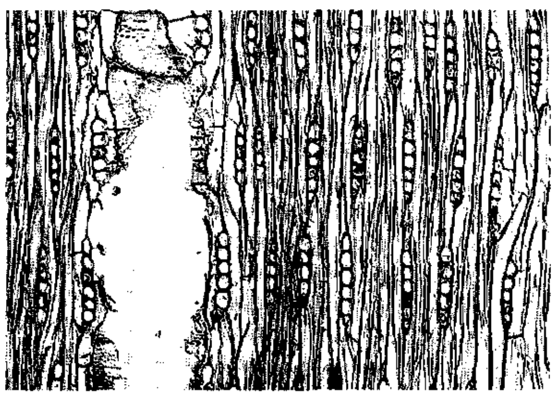
Growth and development After germination, the cotyledons are exposed above the soil on a long



transverse section (×25)



radial section (×75)



tangential section (×75)

Pterocarpus indicus

hypocotyl and the seed-coat is left in or on the soil, usually in the indehiscent pod. Root growth of narra is very extensive and characterized by anastomosing laterals. *P. indicus* is a fairly fast grower; trees are reported to reach a maximum diameter of 58 cm in 40 years. *P. dalbergioides* trees may attain 8 m in height and a diameter of 5.5 cm in 4 years, 14 m in height and 11.5 cm in diameter in 8 years, and 25 m in height in 12 years.

Narra is a deciduous tree, often 'semi-deciduous' (i.e. some trees do not completely lose their leaves). The leaves fall off during the dry season, usually 2–3 months after the end of the rainy season. New leaves develop simultaneously with the flowers, but sometimes young leaves develop fully before flowering begins. Not all flowers in a panicle or raceme open simultaneously. The flowers in the lower portion of the inflorescence open first and later wither, losing their petals which often carpet the ground beneath the tree. After a short period, when the subsequent flowers in the upper portion of the inflorescence open and blossom, there is a second fall of petals, although not as profuse as before. In areas with no distinct wet and dry seasons (e.g. in Singapore), gregarious flowering does not occur frequently, and instead, flowering is asynchronous.

Fruits are mature 3–4 months after flowering. They are dispersed over short distances by wind, and over long distances by water and sometimes by sea currents.

Other botanical information The genus *Pterocarpus* belongs to the tribe *Dalbergieae*. Its closest relatives are believed to be the South American genera *Tipuana* and *Fissicalyx*. The different species of *Pterocarpus* are generally recognized by characters of the fruit (size, width of the wing, and position of the style remnant) and sometimes that of the flower (presence of bracts and bracteoles, hairiness of pedicel, calyx and ovary, number of ovules). Vegetative characters can only be used with any reliability on a local scale.

In addition to *P. indicus* and *P. dalbergioides*, the wood of several other *Pterocarpus* species from outside Malesia is highly appreciated, e.g. *P. macrocarpus* in Burma, Thailand and Indo-China, *P. santalinus* and *P. marsupium* Roxb. in India, and *P. soyauxii* Taub. in Africa.

Ecology Narra prefers a slightly seasonal climate but is found in both evergreen and semi-deciduous forest. Its natural habitat is riparian along banks of rivers and coastal tidal creeks and rocky shores but it is highly adaptable to other environmental conditions. When planted, narra is able to grow in a wide range of habitats and soil conditions, for example in flat sandy areas, in hilly areas with a heavy clay soil but also in waterlogged areas. *P. indicus* thrives best on moist sandy loam or clay-loam soil. Narra is a nitrogen-fixing tree and demands light. In natural conditions narra is often an element of the upper storey of the forest canopy and is sometimes found as a dominant tree together with molave (*Vitex parviflora* Juss.) in the Philippines. In Papua New Guinea *P. indicus* is particularly common as a canopy tree in valleys below 100 m altitude, together with *Kingiodendron alternifolium* (Elm.) Merr. & Rolfe.

Propagation and planting Narra is easily propagated by seed. The weight of 1000 seeds is about 770 g. Germination rate is improved if seeds are extracted from the indehiscent pods before sowing. Seeds are sown in nursery beds, and the seedlings are potted in plastic bags when one month old; at an age of 4–6 months (average height 20–25 cm) they are ready for planting into the field. Since the percentage of viable seeds is often low (sometimes as low as 10–20%) and the survival ability of young seedlings is vulnerable to weed competition, vegetative propagation has become a more important technique nowadays.

Stump cuttings, taken from seedlings or wildlings, can be used as planting material. The recommended stem length is 10–20 cm, root length 20–40 cm and stem diameter 1.5–2 cm. Shoot cuttings of 10 cm in diameter and 2 m in length are used in the Philippines. Treatment with growth hormones enhances root formation. Cuttings were established successfully in 80% of the cases studied in Indonesia.

Narra can also be propagated successfully by tissue culture. Tissue taken from 0.5–3-year-old shoots placed on a growing medium produces callus within 7–12 days. After 21–48 days, root differentation occurs. Irradiation induces dormant buds to develop in tissue culture.

In plantations of *P. indicus* normal spacing is 2.5 m × 2.5 m or 3 m × 3 m. The recommended spacing for *P. dalbergioides* is 1.5 m × 1.5 m or 2 m × 2 m.

Silviculture and management No information is available about the proper management of narra in natural stands. The trees often occur scattered in dipterocarp forest where the cutting is governed by diameter limits (usually 60 cm). However, as narra wood is in great demand for top-class furniture, trees of less than 60 cm diameter are sometimes cut illegally, particularly in the Philippines.

Plantations of narra (and particularly of *P. dalbergioides*) have a reputation to be labour-intensive, requiring much tending such as close initial spacing and regular thinning. This is because of the tendency of the trees to fork and form very short boles.

Diseases and pests In nurseries in the Philippines, an anthracnose seedling disease caused by *Colletotrichum* sp. has been reported, which leads to brownish spots on leaves and stems and subsequent wilting. Fungi such as *Fomes lamaoensis* and *Ganoderma lucidum* may cause root and stem rot. *Phomopsis* sp. (also a fungus) may infest seeds. A plantation of *P. indicus* in southern Sumatra has been severely attacked by a caterpillar *(Melipotis diversipennis)*. In Peninsular Malaysia many trees were attacked and killed late last century by an unknown disease with symptoms resembling those of the Dutch Elm disease in Europe. Narra is susceptible to infestation by parasites such as *Loranthus* sp. and strangling figs (e.g. *Ficus retusa* L.).

Harvesting Large narra trees are often hollow.

Yield Narra trees in a 60-year-old plantation in Malaysia yielded slightly more than 1 m^3/tree, having an average bole diameter of 49 cm and branchless bole length of 7.1 m. The fact that the trees are usually short-boled with big branches limits the yield.

For maximum timber production of *P. dalbergioides* in the Andaman Islands, the rotation is 25–30 years, while the annual production is 6.5 m^3/ha. The total timber volume in a stand of 500 trees/ha after 32 years is reported as 200 m^3/ha. In a natural forest in Seram (the Moluccas) the average standing stock of *P. indicus* was assessed at 6–10 trees/ha.

Genetic resources The native stands of narra are disappearing quickly. The demand for luxury woods such as narra often far exceeds the supply; this easily leads to illegal cutting. *P. indicus* is now probably extinct in Peninsular Malaysia because of overexploiting of its few known stands. Shifting cultivation is another cause of genetic erosion. Narra often grows along rivers, and these sites are often the first to be settled by shifting cultivators. Narra is slightly secured against extinction, because it has a large area of distribution and is often planted, for instance, as a roadside tree.

Prospects The establishment of plantations of narra can help to prevent genetic erosion and will also supply high-quality timber in the future. Plantations can already be harvested at 60 years or even less in favourable sites. Moreover, narra is easy to propagate and plant.

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Selection of species

Pterocarpus dalbergioides Roxb. ex DC.

Prodr. 2: 418 (1825).

Synonyms *Pterocarpus advenus* Baillon (1884).

Vernacular names Andaman padauk, Andaman redwood (En).

Distribution Native to the Andaman Islands. Planted from India to Indonesia and in Madagascar.

Uses The timber is used as narra.

Observations A semi-deciduous, small to medium-sized tree up to 25 m tall, bole straight, cylindrical, up to 90 cm in diameter, buttresses large, branches more or less ascending; leaves 7–18 cm long, the rachis hairy, leaflets 5–9, elliptical to ovate, (4–)6.5–9 cm × (2.5–)3–4.5(–5) cm, reflexed at the top, sparsely hairy below; pod long stipitate, orbicular or suborbicular, 4.5–5.5(–7) cm in diameter, smooth. *P. dalbergioides* occurs in the Andaman Islands in mixed deciduous or semi-evergreen forest on well-drained sites up to 100 m altitude. The density of the wood is about 775 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 145, 396, 585, 622, 712.

Pterocarpus indicus Willd.

Sp. pl. ed. 4, 3: 904 (1802).

Synonyms *Pterocarpus wallichii* Wight & Arn. (1834), *Pterocarpus zollingeri* Miq. (1855), *Pterocarpus papuanus* F. v. Mueller (1886).

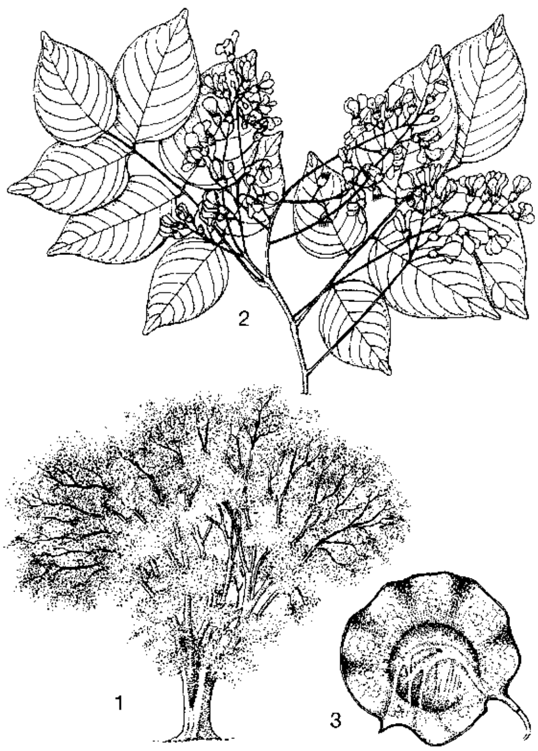
Vernacular names As for the genus.

Distribution From southern Burma through South-East Asia towards the Santa Cruz and Pacific Islands. Cultivated in Africa, India, Sri Lanka, Taiwan, Okinawa, Hawaii and Central America.

Uses The timber is used as narra. See genus treatment for other uses.

Observations A medium-sized to fairly large tree of up to 40 m tall, bole often massive at age and up to 350 cm in diameter, often with double-leader big branches rather close to the base, buttresses usually present, branches drooping; leaves 12–30 cm long, glabrous, leaflets 5–13, generally ovate, (2–)4–5(–9) cm × (4–)6–10(–15) cm; pod shortly stipitate, almost circular, 4–7 cm in diameter, smooth (f. *indicus*) or with bristle-like prickles (f. *echinatus* (Persoon) Rojo, synonym: *Pterocarpus echinatus* Persoon). The latter forma is sometimes regarded as a distinct species. *P. indicus* occurs mainly along tidal creeks and rocky shores, mostly in evergreen forest but also in seasonal forest up to 600 m altitude but it may grow at higher altitudes when planted. The density of the wood is (390–)550–900(–950) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 4, 5, 21, 35, 45, 67, 89, 99, 100, 102, 109, 110, 145, 153, 175, 190, 195, 226, 252, 272, 296, 309, 359, 363, 368, 372, 384, 396, 407, 408, 428, 433, 454, 461, 484, 486, 579, 585, 586, 588, 597, 621, 678, 683, 712, 750, 771, 779.



Pterocarpus indicus Willd. – 1, tree habit; 2, flowering twig; 3, pod.

J.P. Rojo (general part, wood anatomy, selection of species),
D.S. Alonzo (properties)

Scaphium Schott & Endl.

Melet. Bot: 33 (1832).
STERCULIACEAE
x = unknown

Trade groups Kembang semangkok: lightweight to medium-heavy hardwood, e.g. *Scaphium macropodum* (Miq.) Beumée ex K. Heyne.

Vernacular names Kembang semangkok. Indonesia: kapas-kapasan (general), merpayang (Sumatra). Burma: shaw taung-thinbow. Thailand: phungthalai (central), samrong (south-eastern).

Origin and geographic distribution The genus *Scaphium*, consisting of 8 species, is distributed in Burma, Cambodia, Thailand, Peninsular Malaysia, Singapore, Sumatra, Bangka, and Borneo. *S. macropodum* is the most widespread species, covering almost the entire distribution area of the genus. Several species from Sumatra and Borneo are rare or have been collected only once; they are not treated here.

Uses The timber is used particularly for veneer and plywood, but also for interior finishing (e.g. panelling, stairs) and furniture. In the furniture industry in Europe it is sometimes used as a substitute for oak (from *Quercus* spp.), and in India as a substitute for timber from *Salmalia* spp. It is also suitable for match splints, boxes and crates.

The fruits are used medicinally. When the seed is soaked in water, a sour mucilaginous substance is produced which is eaten as a jelly and used as a remedy against lung diseases, colds, diarrhoea, and kidney complaints. It may also be used to prepare a beverage or sorbet by adding sugar, syrup or fruit juice. The bitter basal part should then be removed. The fibrous bark is sometimes applied as walling for local houses.

Production and international trade Large, pure consignments of the timber are difficult to obtain since the trees occur scattered. Sawn kembang semangkok timber is probably traded together with other timbers as mixed light or medium-heavy hardwood. In 1983 the total export of sawlogs of kembang semangkok from Peninsular Malaysia was 2500 m^3 with a value of US$ 110 000. The destinations were particularly East Asian countries, e.g. South Korea, Hong Kong and Taiwan. Japan imports kembang semangkok timber especially from Sabah and Sarawak. The export of round logs from Sabah in 1987 was 59 000 m^3 with a value of US$ 4.2 million (US$ 71.5/m^3); in 1992 the export was 20 000 m^3 of logs and 3000 m^3 of sawn timber with a total value of US$ 2.1 million.

Dried seeds are exported for medicine to India and China under the name 'pungtalai', and to Java under the name of 'buah tampayang'.

Properties Kembang semangkok is a light to medium-weight and soft to moderately hard wood. It is buff-coloured, yellowish-brown to greyish-brown. The density is 515–760(–800) kg/m^3 at 15% moisture content. The grain is straight or shallowly interlocked, texture moderately coarse to coarse and uneven.

At 17% moisture content the modulus of rupture is 92–105 N/mm^2, modulus of elasticity 14 000–17 000 N/mm^2, compression parallel to grain 47–60 N/mm^2, shear 9–12 N/mm^2, cleavage 34 N/mm radial and 52 N/mm tangential, and Janka side hardness 4940–5210 N.

The rates of shrinkage of kembang semangkok are small, from green to 12% moisture content 1.2% radial and 3.0% tangential, from green to oven dry 2.5% radial and 4.2% tangential. Drying is easy and rapid. The timber is liable to small end checks. It takes about 9 weeks to air dry 15 mm thick boards, and about 17 weeks for 50 mm thick boards. The recommended kiln schedule in Malaysia is H.

The timber is not easy to saw because of its high silica content (2.1–2.6%), which causes rapid blunting of saw-teeth. Hard-metal saws are necessary, and stellite-tipped teeth are recommended. Kembang semangkok finishes and turns to a smooth surface, and nailing and screwing are easy. Gluing and staining present no problems. Kembang semangkok gives a decorative veneer. It can be peeled easily to various thicknesses of veneer without any form of pretreatment. Veneers are smooth and tight, and can be glued easily to obtain good plywood.

The timber is not durable. It is perishable in contact with the ground or when exposed to the weather. Graveyard tests in Indonesia showed an average service life in contact with the ground of only 0.9 years, and laboratory tests showed a poor resistance to wood-rotting fungi. The sapwood is susceptible to blue stain fungus and to attack by powder-post beetles and drywood termites. Kembang semangkok is easy to treat with preservatives; using the open tank method and an equal mixture of creosote and diesel, an absorption of 190–320 kg/m^3 is achieved.

The pericarp of fruits of *S. scaphigerum* contains about 15% galactose and 25% pentoses (mainly arabinose). Air-dried fruits of *S. macropodum* contain 4.5% protein, 24% pentosans and 40% carbohydrates. The seeds can be stored for many years without losing their medicinal properties and without changing their taste.

Description Medium-sized to large, deciduous, monoecious trees up to 45 m tall with bole up to 80 cm in diameter, usually having large and thick buttresses; outer bark fissured in patches or flaky in small, rectangular pieces, greyish-brown to brown, inner bark fibrous, pale yellowish-brown, with thin but conspicuous red outer layer; crown usually irregularly hemispherical and somewhat diffuse; twigs stout, with prominent leaf scars. Leaves arranged spirally, in mature trees simple and entire, long-stalked with petiole thickened near top, leathery, those of saplings simple, lobed or palmately pinnate; stipules present but caducous. Inflorescences axillary, paniculate, near tips of branches, scurfy pubescent and many-flowered. Flowers unisexual, with male and female flowers borne on separate inflorescences, small and pale green, globose and sessile in bud; calyx 4–6-lobed, corolla absent; male flowers with staminal column bearing 8 anthers in a globose woolly head; female flowers with slender androgynophore bearing a conical ovary with 2–5 erect or recurved styles terminated by conspicuous disk-like stigmas, and 8–10 sterile anthers around base of ovary. Fruit a large follicle, dehiscing early after fertilization, boat-shaped and membraneous, reticulately veined, with a single basal seed. Seed hairy or glabrous, outer seed-coat swelling on moistening to produce a mass of clear mucilage. Seedling with epigeal germination, phanerocotylar, with strongly enlarging hypocotyl and foliaceous cotyledons; all seedling leaves arranged spirally.

Wood anatomy

– Macroscopic characters:

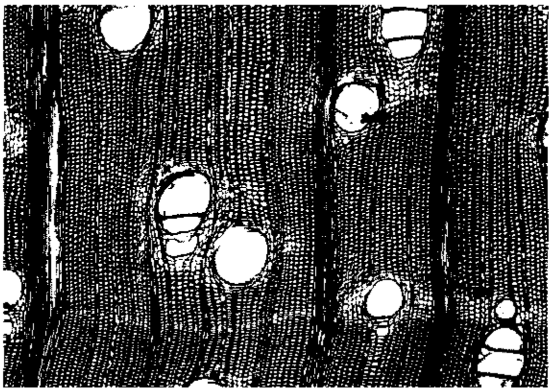
Demarcation between heartwood and sapwood not distinct; sapwood yellowish-white to light yellowish-grey, heartwood somewhat darker. Grain straight to shallowly interlocked. Texture rather coarse. Growth rings indistinct or distinct; rays distinct to the naked eye, showing silvery grain on radial surface. Ripple marks occasionally visible to the naked eye.

– Microscopic characters:

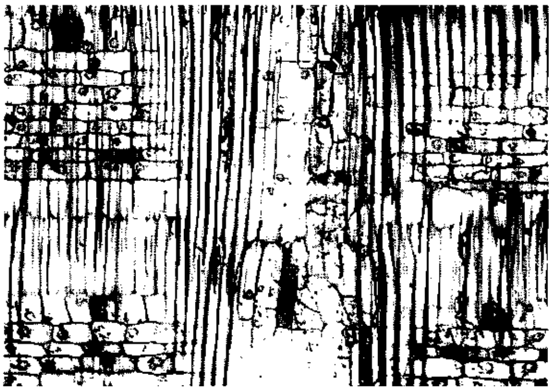
Growth rings, if distinct, marked by parenchyma bands at the ring boundary. Vessels diffuse, 2–3.5/mm^2, solitary and in radial multiples of 2–4, in almost similar proportion, usually 190–270 µm in maximum tangential diameter; perforations simple; intervessel pits alternate, 6–7 µm, often with coalescent apertures; vessel-ray and vessel parenchyma pits almost similar to intervessel pits but half-bordered. Fibres 0.8–1.4 mm long, very thin- to thin-walled (walls c. 2 µm thick); pits with minute borders, numerous, confined to the radial walls. Parenchyma winged-aliform, sometimes confluent, apotracheally diffuse-in-aggregates or in interrupted fine lines, often marginal; usually in 4-celled strands. Rays 5–7/mm, of two distinct sizes, low, 1–2-seriates and high, 6–17-seriates, heterocellular, with one row of square marginal cells (Kribs type heterogeneous III), upright or square cells sheathing the periphery of multiseriate part of the rays, but they are not typical sheath cells; maximum height 3800–4800 µm. Silica bodies present in axial and ray parenchyma cells, the amount depending on the sample. All elements, except the broad rays, storied.

Species studied: *S. macropodum*.

Growth and development The taproot and hypocotyl emerge from the free pole of the fruit, after which a resting stage occurs. Then the hypocotyl becomes erect, the primary seedling leaves ('paracotyledons') spread, and a second resting stage follows. The leaves of seedlings are entire or 3-lobed; those of saplings palmately pinnate (*S. longipetiolatum*), 5–7-lobed (*S. lineari-carpum*, *S. macropodum*) or simple (*S. longiflorum*, *S. scaphigerum*), and always distinctly larger than the entire leaves of mature trees, and with



transverse section (×25)



radial section (×75)

tangential section (×75)

Scaphium longipetiolatum

long petioles. Trees flower when they are leafless and before the new leaves develop. The flowers are insect-pollinated; they attract bees, flies, butterflies and beetles.

Ecology Usually kembang semangkok occurs scattered in primary lowland forest, most commonly in mixed dipterocarp forest in humid tropical conditions and generally in areas with a short dry season. *S. macropodum* and *S. longipetiolatum* are often found on ridges and well-drained undulating land up to 1200 m altitude. *S. longiflorum* grows scattered in swampy forest, whereas *S. scaphigerum* occurs in places with a pronounced dry season.

Propagation and planting Regeneration under natural conditions is usually abundant; seedlings are often numerous in the forest. However, the few tests with seeds in nurseries showed a low percentage of germination. The mortality of planted preconditioned seedlings is low (about 10%), and the seedlings are fairly drought-resistant. Growth is, however, generally rather slow, and seedlings are rarely planted.

Silviculture and management Kembang semangkok has proven to be suitable for enrichment planting in hill dipterocarp forest in Peninsular Malaysia.

Genetic resources *Scaphium* trees occur scattered in primary forest, and several species are rare. This makes the species liable to genetic erosion in areas with large-scale logging operations.

Prospects Kembang semangkok was seldom used until the 1970s because the timber is not durable, it has a high silica content and is abrasive, and because large and pure consignments were difficult to obtain. It is now much more in demand as a general-utility timber resembling light red meranti, but it is particularly popular for veneer. There is a lack of information on almost all silvicultural aspects, and of experience with propagation techniques and planting.

Literature |**1**| Ashton, P.S., 1988. Manual of the non-dipterocarp trees of Sarawak. Vol. 2. Sarawak Branch for Forest Department, Sarawak. pp. 404–408. |**2**| Browne, F.G., 1955. Forest trees of Sarawak and Brunei and their products. Government Printing Office, Kuching. pp. 329–330. |**3**| Burgess, P.F., 1966. Timbers of Sabah. Sabah Forest Records No 6. Forest Department, Sabah, Sandakan. p. 467. |**4**| Cockburn, P.F., 1976. Trees of Sabah. Vol. 1. Forest Department, Sabah, Kuching. pp. 239–243. |**5**| Desch, H.E., 1954. Manual of Malayan timbers. Vol. 2. Malayan Forest Records No 15. Malaya Publishing House Ltd., Singapore. pp. 580–581. |**6**| de Vogel, E.F., 1980. Seedlings of dicotyledons. PUDOC, Wageningen. pp. 439–441. |**7**| Kochummen, K.M., 1972. Sterculiaceae. In: Whitmore, T.C. (Editor): Tree flora of Malaya. Vol. 2. Malayan Forest Records No 26. Longman Malaysia SDN Berhad, Kuala Lumpur. pp. 353–376. |**8**| Kostermans, A.J.G.H., 1953. The genera Scaphium Schott & Endl. and Hildegardia Schott & Endl. (Sterculiaceae). Journal of Scientific Research Indonesia 2(1): 13–21. |**9**| Lim, S.C., 1987. Malaysian timbers – kembang semangkok. Timber Trade Leaflet No 105. Malaysian Timber Industry Board, Forest Research Institute Malaysia. 7 pp. |**10**| Malaysian Timber Industry Board, 1986. 100 Malaysian timbers. Kuala Lumpur. pp. 142–143.

Selection of species

Scaphium borneensis (Merr.) Kosterm.

Reinwardtia 7: 441 (1969).

Synonyms *Firmiana borneensis* Merr. (1929).

Distribution Borneo (Sarawak, Sabah, Brunei, East Kalimantan); possibly also Sumatra.

Uses The timber is rarely used.

Observations A medium-sized tree rarely exceeding 30 m tall, bole up to 50 cm in diameter, with small and thin buttresses; leaves lanceolate, 9–18 cm × 3.5–5.5 cm, obtuse to broadly cuneate at base, acuminate at apex, with very slender secondary veins, glabrous, petiole up to 8 cm long; fruit up to 10 cm long. *S. borneensis* is a rather rare species, although it is locally common in mixed dipterocarp forest on sandy soils at low altitudes. The trees are not common enough and usually too small to be of economic importance.

Selected sources 33.

Scaphium linearicarpum (Masters) Pierre

Fl. forest. Cochinch. fasc. 12, text accomp. pl. 193–195 (1888).

Vernacular names Malaysia: kembang semangkok bulat (Peninsular).

Distribution Peninsular Malaysia, Singapore and Sumatra; rare in Borneo (East Kalimantan).

Uses The timber is used as kembang semangkok.

Observations A fairly large tree up to 35 m tall with fissured bole up to 75 cm in diameter; leaves broadly ovate to suborbicular, 15–35 cm × 12.5–35 cm, deeply heart-shaped at base, rounded at apex with 6–7 pairs of secondary veins, the basal pair prominently branched, glabrous or sparsely hairy beneath, petiole up to 23 cm long; fruit up to 25 cm long; seed up to 25 mm long, hairy. *S. linearicarpum* grows in lowland forest, occasionally up to 700 m altitude, and is locally common in Peninsular Malaysia, but less common than *S. macropodum*.

Selected sources 102, 190, 376, 431, 779.

Scaphium longiflorum Ridley

Journ. Roy. As. Soc. Straits Br. 73: 143 (1916).

Synonyms *Scaphium velutinum* Kosterm. (1953).

Distribution Peninsular Malaysia; perhaps also East Kalimantan.

Uses The timber is used as kembang semangkok.

Observations A fairly large tree up to 36 m tall with shallowly fissured bole up to 70 cm in diameter and fairly large, thin buttresses; leaves oblong to obovate, 10–23 cm × 6–12 cm, rounded to broadly cuneate at base, blunt to rounded, sometimes shortly acuminate at apex, with 7–10 pairs of secondary veins, velvety yellowish pubescent to glabrous beneath, petiole up to 8.5 cm long; fruit up to 15 cm long; seed c. 18 mm long, hairy. Unlike other *Scaphium* species, *S. longiflorum* occurs scattered in lowland swamp forest. The density of the timber is about 515 kg/m^3 at 15% moisture content.

Selected sources 190, 376, 431, 779.

Scaphium longipetiolatum (Kosterm.) Kosterm.

Bull. Bot. Survey Ind. 7: 128 (1965; 'longepetiolatum').

Synonyms *Microcos longipetiolata* Kosterm. (1962).

Vernacular names Malaysia: kembang semangkok jantan (Sabah).

Distribution Borneo (Sarawak, Brunei, Sabah, northern East Kalimantan).

Uses The timber is occasionally traded as kembang semangkok.

Observations A fairly large tree up to 40 m tall with bole up to 75 cm in diameter, having large plank buttresses; leaves elliptical or narrowly elliptical, ovate or obovate, 7–28 cm × 4.5–14 cm, cuneate at base, acute or shortly acuminate at apex, with 3–5 pairs of secondary veins, glabrous, petiole up to 12 cm long; fruit up to 20 cm long; seed up to 25 mm long, glabrous. *S. longipetiolatum* occurs locally frequent on well-drained and clayey soils, particularly in primary forest on ridges and on hills, up to 800 m altitude.

Selected sources 33, 146.

Scaphium macropodum (Miq.) Beumée ex K. Heyne

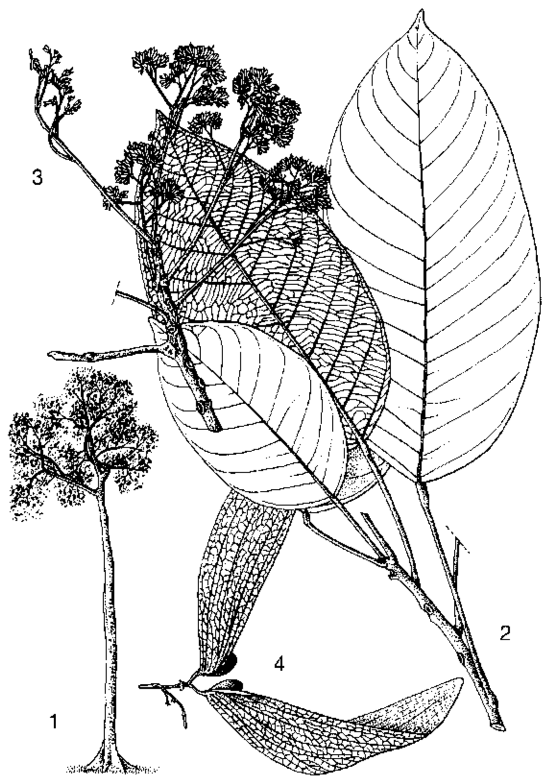
Nutt. pl. Ned. Ind., ed. 2: 1068 (1927).

Synonyms *Scaphium affinis* (Masters) Pierre (1888; 'affine'), *Scaphium beccarianum* Pierre (1888), *Scaphium lychnophorum* (Hance) Pierre (1888; 'lichnophorum').

Vernacular names Indonesia: kepayang, merpayang (Sumatra), tempayang (Java). Malaysia: kembang semangkok jantong (Peninsular), kembang semangkok batu (Sabah). Thailand: phungthalai (central), samrong (south-eastern).

Distribution Cambodia, south-eastern and peninsular Thailand, Peninsular Malaysia, Singapore, Sumatra, Bangka and Borneo.

Uses *S. macropodum* is the principal source of kembang semangkok timber. The seeds are used medicinally to treat diarrhoea, dysentery and asthmatic complaints. The sour jelly obtained



Scaphium macropodum (Miq.) Beumée ex K. Heyne – 1, tree habit; 2, sterile twig; 3, flowering twig; 4, fruits.

from the outer seed-coat is used to prepare a beverage, together with sugar or fruit juice. The fibrous inner bark is sometimes used as walling for houses.

Observations A large tree up to 45 m tall with bole up to 80 cm in diameter, having large and often spreading buttresses; leaves variable in shape and size, broadly ovate, ovate, elliptical, oblong or lanceolate, (8–)15–25(–40) cm × (1–)7–12(–30) cm, shallowly cordate, truncate, rounded to broadly cuneate at base, acute or acuminate at apex, with 6–11 pairs of secondary veins, glabrous, petiole up to 15 cm long; fruit up to 22 cm long; seed up to 25 mm long, glabrous, red. *S. macropodum* is by far the most common *Scaphium* species and is locally abundant on well-drained undulating land and ridges up to 1200 m. For more information see genus treatment and the table on wood properties.

Selected sources 10, 33, 100, 102, 146, 155, 183, 190, 318, 376, 431, 578, 779.

Scaphium scaphigerum (Wallich ex G. Don) Guibourt & Planchon

Hist. nat. drogues simples, ed. 7, 3: 632 (1876).

Synonyms *Scaphium wallichii* Schott & Endl. (1832).

Vernacular names Burma: shaw taun-thinbow, thibyu. Thailand: thai phao (Nakhon Si Thammarat), thai phao khao, thai phao daeng (Trang).

Distribution Burma, Cambodia, Thailand and northern Peninsular Malaysia.

Uses The timber is used as kembang semangkok. The seeds are used medicinally and in beverages just like those of *S. macropodum*. The inner bark yields a fibre.

Observations A fairly large tree up to 36 m tall with deeply fluted bole up to 75 cm in diameter, having very large buttresses; leaves ovate, 12–20 cm × 6–11 cm, subcordate at base, acute or acuminate at apex, with 3–7 pairs of secondary veins, glabrous, petiole up to 14 cm long; fruit c. 20 cm long; seed c. 25 mm long, hairy. *S. scaphigerum* occurs in regions with a pronounced dry season. The density of the timber is 450–520 kg/m^3 at 15% moisture content.

Selected sources 102, 155, 376, 431, 779.

A.J.G.H. Kostermans (general part),
J.E. Polman (properties),
S. Sudo (wood anatomy),
R.H.M.J. Lemmens (selection of species)

Shorea Roxb. ex Gaertner f. (red meranti)

Fruct. 3: 47 (1805).

DIPTEROCARPACEAE

$x = 7$; $2n = 14$ for the majority of species, *S. ovalis*: $2n = 28$

Trade groups

- Light red meranti: lightweight hardwood, e.g. *Shorea leprosula* Miq., *S. ovalis* (Korth.) Blume, *S. parvifolia* Dyer, *S. smithiana* Sym.
- Dark red meranti: lightweight to medium-heavy hardwood, e.g. *S. curtisii* Dyer ex King, *S. macrantha* Brandis, *S. ovata* Dyer ex Brandis, *S. pauciflora* King, *S. platyclados* v. Slooten ex Foxw.

Wood of intermediate colour which cannot be grouped satisfactorily within one of the classes mentioned above is usually given the general name red meranti. Apart from the division into light and dark red meranti, the wood of several species is sometimes traded under a distinct name. The most important ones are: 'alan batu' and 'alan bunga' for heavy and lightweight timber, respectively, of *S. albida*, 'belangeran' for timber of *S. balangeran*, 'kawang jantong' for timber of *S. macrophylla*, 'melantai' for timber of *S. macroptera* and 'meranti bakau' for timber of *S. uliginosa*. Heavier grades of some species may be traded as red balau (e.g. *S. albida*, *S. balangeran* and *S. inaequilateralis*); hence, the distinction between the trade groups red meranti and red balau is not sharp.

Vernacular names

- Light red meranti: Brunei: meraka bunga. Indonesia: meranti merah muda, seraya merah, meranti bunga. Malaysia: (light) red seraya (Sabah), lup (Iban, Sarawak). Philippines: (light) red lauan, almon, mayapis. Thailand: saya, saya-khao.
- Dark red meranti: Brunei: meraka. Indonesia: meranti merah tua, meranti ketuko. Malaysia: (dark) red seraya (Sabah), perawan (Iban, Sarawak), obar suluk (Sabah). Philippines: (dark) red lauan, tangile, tiaong. Thailand: saya, saya-daeng.

Origin and geographic distribution *Shorea* consists of about 194 species, 163 of which occur in Malesia. The genus is distributed from Sri Lanka and India through Indo-China towards Malesia. Within Malesia the species occur eastward to the Moluccas. The genus is absent from the Lesser Sunda Islands but fossil wood has been recorded for Timor.

The 70 species belonging to the red meranti group of *Shorea* occur from southern Thailand towards Borneo, the Philippines and the Moluccas. The greatest diversity occurs in Borneo (62 species), followed by Sumatra (23 species), Peninsular Malaysia (19 species), the Philippines (5 species) and the Moluccas (1 species). Red meranti is absent from Sulawesi.

Uses *Shorea* is economically the most important timber genus in the humid Asian tropics.

Red meranti is the most common general utility timber of western Malesia. Due to its non-siliceous nature it is generally easy to work. However, because the wood is not durable (both fungi and insects attack it rapidly), it should not be used in contact with the ground or in exposed conditions, unless properly treated. The general use of the timber is for light constructional work and especially for plywood and veneer. Because of its relatively short fibre length, no high-quality pulp can be produced from the wood.

Light red meranti, being somewhat less heavy than dark red meranti, is used for light-duty flooring, fittings, panelling, ceiling, shelving, interior partitions, joinery, low-grade decking and boat planking, concrete shuttering, musical instruments (organ pipes), coffins, boxes, toys, turnery and matches. Both hardboard and particle board of satisfactory quality can be obtained. Light red meranti is widely used for plywood, both as face and core veneer.

Dark red meranti is used largely for the same purposes as light red meranti but the heavier grades are suitable for medium or even heavy constructional work. Apart from the purposes mentioned above, dark red meranti is used for door and window frames, beams, joists, rafters, utility flooring, vehicle bodies, weatherboarding and boat building. Selective species can be quite decorative and are used for carving, turnery, cabinets, panelling and flooring.

Several species of red meranti yield an opaque, yellow dammar which is of low grade but often available in large quantities and sold as 'damar daging' or 'damar batu'. It is mainly used locally for torches, sometimes also in plasters, varnishes and lacquers, and as a solution in chloroform or xylene for preserving animal and vegetable specimens for microscopy.

Several *Shorea* species are important sources of illipe nuts; a name which leads to confusion with the illipe nuts produced by *Madhuca* spp. (*Sapotaceae*). The nuts yield a fat similar to cocoa butter which is used in Europe for the manufacture of chocolates and cosmetics and was formerly used in soaps, candles and tallow. Locally the boiled fruits of many species are eaten.

The bark of several species may be peeled off in large slabs to be used for panelling walls of native houses and for the manufacture of baskets and bins. The bark of some species is also used for tanning leather.

Production and international trade For Indonesia, only export figures for sawn meranti as a whole are available. However, red meranti forms by far the major part of this trade group, the export of which amounted in 1989 to 1.4 million m^3, worth US$ 301 million. The production and export of plywood (estimated export value in 1990 3000 million US$), in which red meranti wood contributes the major part, is much more important in Indonesia.

In Peninsular Malaysia the average annual volume of exported sawn red meranti was 802 000 m^3 in the period 1981–1991. The export values in 1989 and 1990 were US$ 301 million and US$ 271 million respectively, and in 1992 US$ 210 million. Dark red meranti represented about 75% of these values, light red meranti about 7.5%, the rest being traded under the general trade name 'red meranti'. In 1992 the price of exported sawn dark red meranti timber was US$ 516/m^3, US$ 441/m^3 for light red meranti, and US$ 216 for 'red meranti'.

The export of round logs of red meranti from Sabah was 2.6 million m^3 in 1987, with a value of US$ 282 million; in 1992 the export of logs was 815 000 m^3 and of sawn timber 795 000 m^3, with a total value of US$ 324 million. Light red meranti represented about 75% of this value.

In the period 1980–1989 the value of exported red meranti, for the major part 'red lauan' (*S. negrosensis*) and 'white lauan' (*S. contorta*), in the Philippines fluctuated from US$ 261 million to US$ 117 million. In 1990 it fell to US$ 11 million because of changes in timber policy. In the course of the 1980s the condition of the export product changed from non-processed to processed wood.

Properties Red meranti is a light to medium-heavy hardwood. The heartwood varies from pale pinkish or light red-brown to pinkish-red or dark red, or even weathering to dark red-brown; it is distinct from the lighter coloured sapwood. Quarter-sawn surfaces often display an attractive stripe figure. The density varies from 300–860 kg/m^3 at 15% moisture content. The grain of the wood is interlocked or wavy, sometimes straight, texture usually coarse but even. The darker and heavier wood (often over 600 kg/m^3 at 15% moisture content) is often traded as 'dark red meranti', the lighter coloured and lightweight wood (often less than 600 kg/m^3) as 'light red meranti'. However, there is considerable overlap between these groups.

The mechanical and physical properties of this large group of species are widely divergent. At 15% moisture content, the modulus of rupture is 32–92 N/mm^2, the modulus of elasticity 6550–17 150 N/mm^2, compression parallel to grain 21–46 N/mm^2, compression perpendicular to grain 2.5–5 N/mm^2, shear 2.5–9(–11) N/mm^2, cleavage 23–61 N/mm radial and 19–75 N/mm tangential, Janka side hardness 510–3960 N and Janka end hardness 1050–4480 N.

The rates of shrinkage are variable, depending on the species, from green to 15% moisture content 1.1–2.6% radial and 3.3–5.4% tangential and from green to oven dry 1.5–4.0% radial and 3.5–8.5% tangential. Red meranti dries usually fairly rapid without drying defects or degrade. Air seasoning of 15 mm and 40 mm thick boards takes 2–2.5 months and 4.5–5 months, respectively. Weighting is recommended to prevent warping. In Malaysia kiln schedule F is used; 25 mm thick boards can be kiln dried from 50% to 10% moisture content in 6–7 days, 50 mm thick boards in about 20 days. At the end of drying, the moisture content of boards may vary considerably, due to different drying properties of wood from different species. This may necessitate modified kiln schedules.

Red meranti timber is easy to resaw, to cross cut, to plane, to bore and to turn. The planed and turned surface is smooth, the bored surface may, however, be rough in some species (e.g. *S. hemsleyana* and *S. parvifolia*). The presence of interlocked grain may give rise to 'picking up' of grain in quarter-sawn material. Occasionally, resin deposits may cause difficulties during sawing. The nailing properties are usually rated as good, but some species have poor resistance to splitting (e.g. *S. hemsleyana*). The wood sands to a smooth surface and receives stains and polishes well.

Red meranti is highly preferred and widely used for plywood production. It is easy to peel, although defects such as brittle heart, hollow core, worm holes and end splits may reduce the yield. Veneers dry without defects, and the gluability is good. The wood can be made into hardboard of good quality, both by wet and dry processes. When defibred at 170°C, the wood can be made into hardboard of good quality without chemical treatment and into superhardboard by oil tempering. Experimental particle boards made with 8% resin and 1% wax and of density above 630 kg/m^3 showed properties exceeding those stipulated in the British standard.

Light red meranti is classified as non-durable. Graveyard tests conducted in Malaysia indicated that the average service life in contact with the ground is less than 2 years. Dark red meranti can be moderately durable with an average service life ranging from 2.0 years (e.g. *S. singkawang*) to 4.2 years (e.g. *S. platyclados* and *S. uliginosa*). The sapwood is susceptible to dry-wood termite attack; the termites may subsequently affect the heartwood. The wood is usually resistant to fungal and powder-post beetle attack, and it is susceptible to attack by marine borers (particularly light red meranti), but sometimes fairly resistant (e.g. *S. curtisii*). The wood is generally resistant to preservative impregnation. Using the open tank treatment and an equal mixture of creosote and diesel fuel, an absorption of 24–60 kg/m^3 can be obtained and 57–192 kg/m^3 when using the full-cell pressure treatment. However, some species absorb preservatives more easily (e.g. *S. parvifolia* with an average absorption of 312 kg/m^3 using the full-cell pressure treatment).

Red meranti wood consists of 50–56% cellulose, 31–37% lignin, 8–24% pentosan, up to 0.9% ash (*S. smithiana*), and up to 0.3% silica (*S. leprosula*). The solubility is 0.6–5.4% in alcohol-benzene and 2.3% in hot water.

The dammar consists of volatile oil, resins and bitter substances. It is yellowish-white, semi-transparent, and has varying degrees of hardness. It is insoluble in water, but soluble in alcohol, chloroform and ether.

Description Medium-sized to very large trees up to 60(–70) m tall; bole straight, cylindrical, free of branches for 10–30(–42) m and with a diameter of 70–180(–255) cm; buttresses usually prominent, up to 3(–5) m tall; bark surface smooth, prominently V-section fissured or becoming flaky, sometimes scaly, grey or brown; outer bark rather thick, brown, inner bark rather thick, reddish, pink or orange, exuding an olive brown to reddish resin which becomes opaque yellow after exposure; mature crown hemispherical or dome-shaped, sympodial. Leaves alternate, simple, entire, glabrous, pinnately veined with scalariform tertiary venation, often glaucous on the lower surface; stipules and bracts usually large, persistent or fugaceous. Inflorescences terminal or axillary, paniculate. Flowers secund or distichous, usually rather crowded, bisexual, 5-merous, actinomorphic, scented; calyx lobes free, hirsute; petals connate at base, lanceolate, cream suffused with pink, the outer surface hirsute; stamens usually 15, sometimes up to 50(–70), the anthers with 4 pollen sacs, linear-oblong to subglobose, with short to long but glabrous appendages; ovary with or without a stylopodium, style usually longer than the ovary. Fruit usually shortly stalked, with the outer 3 calyx lobes usually much elongated, these thickened and saccate at base; nut 1-seeded, free from the calyx, subglobose to ovate, sharply pointed. Seedling with epigeal germination; pericarp splitting irregularly; cotyledons usually green; first two leaves opposite, subsequent leaves arranged spirally, often larger than those of mature trees.

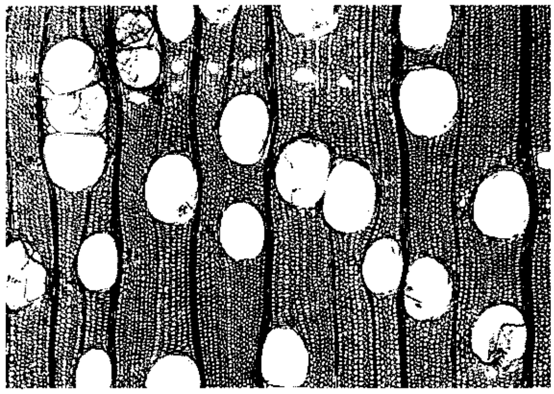
Wood anatomy

– Macroscopic characters:

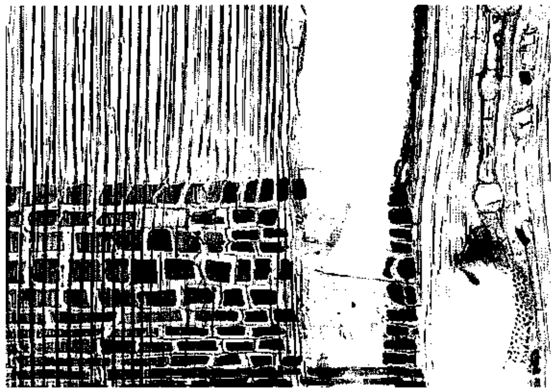
Heartwood light red (varying to almost white), light pinkish-brown (light red meranti), dark pinkish-brown or dark red and weathering to dark red-brown (dark red meranti), usually distinctly demarcated from the lighter sapwood (often with a grey tinge). Grain usually interlocked and wavy. Texture rather coarse but even; planed radial surface often with a prominent stripe figure (especially dark red meranti), quarter-sawn surface sometimes with attractive speckles (light red meranti), planed surface fairly lustrous. Growth rings usually indistinct or absent (sometimes moderately distinct in light red meranti); vessels mostly solitary, less often in oblique or radial pairs or multiples (up to 4 vessels in a series), tyloses generally present but not abundant, vessels visible to the naked eye; parenchyma sparse to moderately abundant, distinct or indistinct with a lens; rays usually distinct to the naked eye on cross-section, conspicuous (light red meranti) or fairly conspicuous (dark red meranti) on the radial surface. Ripple marks usually absent or indefinite, but occasionally distinct. Resin canals generally smaller than vessels, barely distinct to the naked eye, in long concentric lines, filled with white or yellowish-white resin.

– Microscopic characters:

Growth rings usually absent or indistinct. Vessels diffuse, 3–10/mm^2, mostly solitary but also in oblique or radial multiples of 2–4 (15–20%), sometimes with a tendency to form diagonal lines, round to oval, with a tangential diameter of 160–330 μm; perforations simple; intervessel pits alternate, vestured, with an average diameter of 8 μm; vessel-ray pits simple, large and round to gash-like; helical thickenings absent. Fibres 900–1600 μm long, 16–25 μm in diameter, usually non-septate but occasionally septate (e.g. *S. acuminata*, *S.*



transverse section (×25)



radial section (×75)

tangential section (×75)

Shorea leprosula (red meranti)

beccariana, S. ovata, S. rugosa, S. singkawang), walls 3–6 μm thick (but c. 8 μm in *S. balangeran* and *S. inaequilateralis*), pits indistinctly or minutely bordered, lumen sometimes filled with colourless, solid substances (e.g. in *S. pinanga, S. selanica*). Parenchyma variable in amount (scarce to abundant, depending on the species), of two types, paratracheal and apotracheal; paratracheal parenchyma restricted to narrow, often incomplete sheaths to the vessels (narrowly vasicentric), sometimes distinctly aliform or locally confluent; apotracheal parenchyma diffuse and diffuse-in-aggregates or appearing as discontinuous, narrow, irregular tangential bands enclosing resin canals, sometimes as discontinuous lines of 1 to a few cells wide; parenchyma strands irregularly storied in some specimens. Rays 4–5(–12)/mm, usually multiseriate, mostly 3–4 cells wide (average width 60 μm), up to 40 cells high, composed of procumbent central cells and 2–4 rows of upright and square marginal cells (Kribs type heterogeneous II) or with a single row of square marginal cells (Kribs type heterogeneous III). Prismatic crystals scarce to moderately frequent in normal parenchymatic cells and/or in enlarged idioblasts, sometimes crystals absent (e.g. *S. argentifolia, S. curtisii, S. dasyphylla, S. palosapis, S. negrosensis*). Resin canals in tangential rows and in elongated groups embedded in parenchyma, their number varying greatly between the species, average diameter 40–80 μm, but sometimes up to 200 μm (e.g. *S. ovata, S. teysmanniana*), filled with white resin; radial canals occasionally present in *S. leprosula*.

Species studied: *S. acuminata, S. argentifolia, S. balangeran, S. beccariana, S. curtisii, S. dasyphylla, S. ferruginea, S. hemsleyana, S. inaequilateralis, S. johorensis, S. lepidota, S. leprosula, S. macrantha, S. macroptera, S. negrosensis, S. ovalis, S. ovata, S. pachyphylla, S. palembanica, S. palosapis, S. parvifolia, S. pauciflora, S. pinanga, S. platycarpa, S. platyclados, S. rugosa, S. scaberrima, S. scabrida, S. selanica, S. singkawang, S. teysmanniana.*

Red meranti differs from red balau by its lower density and usually less numerous rays. This distinction is, however, not sharp. White and yellow meranti differ from red meranti by their colour (whitish-brown and yellowish-brown), generally more numerous vessels, and more contrasting, yellowish parenchyma and rays.

Growth and development Red meranti seedlings often grow faster on sunny than on shaded sites, but many seedlings suffer severe damage from prolonged exposure to full sunlight. Full sunlight usually causes the soil temperature near the seedlings to rise, and this inactivates their mycorrhizae. Seedlings usually survive best in intermittent sunlight. Survival and growth in heavy shade varies between species; *S. curtisii* is reported to be shade-tolerant, but *S. macroptera* less so.

Mycorrhizae are essential for optimal growth. For instance, nursery-grown seedlings of *S. stenoptera* showed a considerable increase in growth after inoculation with mycorrhiza of *Scleroderma* sp. and the best results for *S. pinanga* were obtained by inoculation with *Russula* sp. Mycorrhizal infection of seedlings in a selectively logged-over forest in Peninsular Malaysia was high: 78% for *S. leprosula* and 86% for *S. curtisii*.

Growth rates differ between species. In 40 years red meranti trees may reach a diameter of 48 cm (*S. curtisii*), but sometimes up to 80 cm (*S. scaberrima, S. leprosula*) or exceptionally even up to 105 cm (*S. parvifolia*). Fast-growing species are selected for multiplication in nurseries and for planting, but fast-growing trees may develop brittle heart. In plantations in West Java mean annual height increment of *S. leprosula* is 1–1.3 m, and mean annual diameter increment 1.9–2.0 cm. *S. johorensis* grows more slowly; at 3 years seedlings reach an average height of 5 m when grown under *Calliandra*; plantation trees of *S. johorensis* increase about 1 m/year in length and about 1 cm/year in diameter. In some species initial seedling growth is slow (e.g. seedlings of *S. curtisii* reach an average height of only 15 cm after 1 year.)

Flowering generally starts when the tree crown reaches the canopy storey, which may be as soon as 10–15 years after germination for solitary specimens of fast-growing species. Trees of *S. pinanga* planted in Malaysia flowered and fruited after only 6 years when growth was stimulated by the use of fertilizers. Most dipterocarp species flower gregariously at intervals of 2–5 years. Closely related species may differ in flowering periodicity. In Peninsular Malaysia *S. leprosula* flowers on average every 2 years, *S. parvifolia* once in 3 years in plantations but every 5 years in nature. For the hill species *S. curtisii* and *S. platyclados* the flowering interval is also about 5 years. For several red meranti-producing species it was found that up to 50% of the stands flowered in years of gregarious flowering. The pollinators include thrips, psyllid bugs and honey bees (*Apis* spp.). Research during gregarious flowering of red meranti showed that there is only a slight overlap in the peak blooming period of different species, but that fruits ripen simultaneously. Fruit production in the forest may be abundant in so-called 'mast years'. *S. contorta* trees in the Philippines produce up to 185 000 fruits per fruiting season. Almost 90% of the fruits fall within 20 m of the mother tree. Under normal wind conditions and in a closed forest the dispersal of viable fruits is within 30 m. This may explain the clustering of trees in the forest. Clustered trees of *S. leprosula* in Malaysia were found to produce more fruits than isolated trees.

Cross-fertilization may occur between certain species, but is generally rare. Natural hybridization is reported to occur between *S. splendida* and *S. stenoptera*. Most dipterocarps have been found to be predominantly outbreeders, with high within-population variability. *S. ovalis*, however, is pseudogamous and self-compatible. Apomixis is found in several species, e.g. in *S. ovalis*, *S. macroptera* and *S. parvifolia*, where multiple seedlings occur.

Other botanical information At infrageneric level the species may be classified by anatomical features of the wood and bark. The division of the genus *Shorea* into 4 major timber groups (red meranti, white meranti, yellow meranti and balau) coincides in broad outline with the division of the genus into botanical sections. Timber trees of the red meranti group belong to the sections *Brachypterae* Heim, *Mutica* Brandis, *Ovalis* P. Ashton, *Pachycarpae* Heim and *Rubella* P. Ashton. The distinction between red meranti and red balau is not sharp. Several species may yield both types of timber depending on the denisty (e.g. *S. albida*, *S. balangeran*, *S. inaequilateralis*, *S. kunstleri*). Their classification in either one of the groups, as presented here, is debatable. All these species are treated as red meranti, except for *S. kunstleri*.

S. contorta belongs to the section *Pentacme* (A.DC.) P. Ashton but is classified either as a light red meranti or as a white meranti, or even as a white lauan, the latter being the timber name for species of the genus *Parashorea*. The red meranti group is the most heterogeneous timber group within the genus. Species yielding light or dark red meranti are somewhat evenly distributed amongst the sections mentioned above.

Ecology *Shorea* species are confined to tropical climates with a mean annual rainfall exceeding 1600 mm and with a dry season of less than 6 months. Most species occur below 1000 m altitude. Species and individuals are most numerous on deep, well-drained yellow or red soils in the lowland. Most species are restricted to a single vegetation type or substratum. Some are common to gregarious in a certain habitat. A few species are confined to certain edaphic habitats such as heath forest (e.g. *S. coriacea*, *S. venulosa*), on sandy soils (e.g. *S. curtisii*, *S. flemmichii*, *S. rugosa*, *S. scaberrima*), and in peat swamps (e.g. *S. albida*, *S. balangeran*, *S. inaequilateralis*, *S. macrantha*, *S. pachyphylla*, *S. platycarpa*, *S. teysmanniana*, *S. uliginosa*).

Propagation and planting Until recently *Shorea* species were never planted. The only method for propagation was by seed, but without infection by suitable ectomycorrhizal fungi, attempts to grow seedlings failed. The wildling collection method for dipterocarp seedlings has been improved and naturally infected seedlings have been collected and planted under a vegetation producing light shade.

Red meranti is still propagated by seed. It is recommended to start seed collecting as soon as the fruit-wings begin to turn brown. The best time to harvest *S. pinanga* seeds is 5 months after anthesis. The seeds soon lose viability and can be stored for comparatively short periods only. Seeds of *S. almon* stored at 40% moisture content in ventilated containers at 16°C declined in viability to 20% within 14 days; storage at 21°C gave a similar result. The maximum storage period for seeds of *S. parvifolia* is also 2 weeks. However, seeds of *S. platyclados* can be stored for 50–60 days. In general, the optimum temperature for storage of seeds is 22–28°C. Viability can be prolonged by storing in sealed wooden boxes or by coating the seeds with wax. Seeds of *S. pinanga* stored in this way showed a viability of 46–63% after 4 weeks, whereas seeds in open containers lost their viability completely. The germination medium recommended for red lauan (*S. negrosensis*) in the Philippines is sand or an equal mixture of sand and ordinary garden soil.

Application of fertilizers may improve growth of seedlings. In the Philippines, seedlings of *S. palosapis* responded best in growth after 2 consecutive applications of 1 g and 2 g NPK fertilizer per seedling; for *S. contorta* seedlings fertilizing with 2 g NPK per plant is recommended.

Nowadays, methods of vegetative propagation are fairly commonly practised. Stem cuttings can be used, but with varying rates of success. Single-node cuttings from seedlings of *S. macrophylla* 8–15- month-old root easily under continuous mist, with or without application of auxins, but only up to 6% of stem cuttings of *S. acuminata*, treated with growth regulators, rooted in experiments in Malaysia. For *S. leprosula* the results of propagation by cuttings diverge widely. Good results were obtained by using stem cuttings comprising 1 node and 10 cm of internode below the bud and taken from 1-year-old seedlings; 65% of the stem cuttings rooted without the use of growth regulators. In other experiments only 6% of stem cuttings of *S. leprosula* rooted, and growth regulators did not improve the result. However, treating the roots of red meranti seedlings with growth regulators may increase survival and height growth.

In the Philippines, *S. contorta* has been propagated successfully by air layering and grafting, but the success rate was low (20% and 5%, respectively). Experiments with in vitro culture showed that leaf explants of young *S. curtisii* plants formed callus when they contained a part of the midrib and when they were taken from the lower half of a leaf; a full strength Murashige and Skoog medium was used. Terminal and axillary buds grow best on a half-strength medium.

For enrichment planting with 4-month-old red meranti seedlings, strips 1 m wide and with a planting distance of 3 m are recommended. For plantations, the best planting distance is probably 4 m × 4 m.

Silviculture and management Natural regeneration and growth of planted seedlings in logged-over or planted forest is generally satisfactory, but canopy manipulation is often needed for optimal growth of seedlings and saplings. It is advisable to remove overhead shade within 3–6 months after planting *S. parvifolia* seedlings in a forest. Sometimes, weeding is necessary. Regeneration of *S. curtisii* in Peninsular Malaysia is often hampered by forest undergrowth of bertam (*Eugeissona tristis* Griffith), and may be increased considerably by control of this stemless palm. In plantations, overstorey light should be increased by thinning after the crowns have developed sufficiently (more than 50% closure). For moderately fast growing species like *S. johorensis*, this can begin in plantations about 30-year-old.

Diseases and pests *Fusarium* fungi may kill seedlings (e.g. of *S. leprosula* and *S. pinanga*). Seeds and seedlings (e.g. of *S. pinanga*) are occasionally attacked by another fungus, *Cylindrocarpon destructans*. Weevils like *Alcidodes dipterocarpi* and *Nanophyes shoreae* are major pests of seeds, locally damaging up to 85% of the seeds. Other seed-attacking insects include *Microlepidoptera* (small moths) of the families *Pyralidae* and *Totricidae*, and beetles of the family *Scolytidae*. Terrestrial vertebrates, particularly boars and squirrels feed on fallen seeds and are the major cause of seed mortality. Ants and termites also feed on fallen seed. Some caterpillars eat seedlings, although seedling predation is generally low.

Harvesting Red meranti logs float in water and can be transported by river. This is commonly practised in Borneo.

Yield In forest in Kalimantan the standing volume of trees over 60 cm in diameter is usually 60–90 m^3/ha, and 110 m^3/ha is not exceptional. Three-quarters of these trees belong to meranti (of which red meranti is dominant). The average yield of red meranti wood is 10–12 m^3/tree.

Genetic resources A timber trade group including a large number of species blurs information on individual species threatened with extinction and such species may therefore receive insufficient protection. This is surely the case with red meranti. Some species are widespread and gregarious (e.g. *S. parvifolia*) and are not seriously threatened by logging, but others are much less common or occur only locally (e.g. *S. mecistopteryx*) and may easily become endangered. Locally, stands of species have already been considerably depleted because of logging and destruction of habitats, e.g. the peat-swamp forest species *S. teysmanniana* and *S. uliginosa* in Peninsular Malaysia. Ex situ conservation is important for endangered and rare species. Large collections of *Shorea* trees are present in several botanical gardens, e.g. in Bogor (Indonesia) and Kepong (Forest Research Institute Malaysia). These collections can be important sources of seed, although there is growing evidence that such seed may be inferior because of inbreeding depression.

Breeding No breeding has been done so far. However, improved methods of vegetative propagation have opened new opportunities for the near future. Fast-growing species which propagate comparatively easy may be domesticated for timber production by propagation of superior clones, e.g. *S. macrophylla* which yields illipe nuts in addition to timber.

Prospects Species producing red meranti are very promising for the establishment of large-scale plantations. Several species grow fast and yield a good-quality timber. In the past, the absence of successful propagation methods was a major constraint, but since the 1980s much research has been conducted on the propagation and planting of merantis and the results are useful for establishing plantations. When, in addition, appropriate systems of sustainable management of production forest are established and employed, the future of the market for processed red meranti will be promising. However, a reduction of yield and export, and rising prices seem to be unavoidable. Besides, complete preservation of large tracts of lowland forest in different ecological habitats is needed, to ensure the survival of the many less common species and to conserve the genetic variability of others as this is lost in vegetatively propagated stands.

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Selection of species

Shorea acuminata Dyer

Fl. Brit. India 1: 305 (1874).

Vernacular names Indonesia: bunia, meranti hitam batang (western Sumatra, Riau), meranti sarang burung (eastern Sumatra). Malaysia: meranti hijau, meranti rambai daun (Peninsular).

Distribution Peninsular Malaysia, Sumatra, the Riau and Lingga Archipelago.

Uses The timber is used as light or dark red meranti. The tree yields a low-grade resin.

Observations A large tree up to 54 m tall, bole branchless for 18–31 m and up to 180 cm in diameter, buttresses prominent, up to 1.5 m high; leaves ovate-falcate, 6–12 cm × 2.6–6 cm, with 7–11 pairs of arched secondary veins, shiny beneath, stipules more than 20 mm long; petals dark wine red, stamens 15, with subglobose anthers, ovary without a stylopodium; larger fruit calyx lobes up to 9 cm × 1.2 cm. *S. acuminata* occurs on well-drained undulating land up to 400 m altitude. The density of the wood is 350–700 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 125, 136, 137, 253, 258, 417, 514, 645, 677, 743, 748.

Shorea albida Sym.

Gard. Bull. Str. Settl. 8: 283, pl. 26 (1935).

Vernacular names Brunei: seringawan. Malaysia: alan, alan bunga (Sarawak).

Distribution North-western Borneo.

Uses *S. albida* is an important source of dark red meranti timber. Comparatively heavy timber is sometimes traded as 'alan batu' which is similar to red balau. Lighter material is called 'alan bunga'.

Observations A medium-sized to very large tree up to 70 m tall, with a long bole up to 190 cm in diameter, buttresses prominent, up to 5 m high, twigs compressed; leaves oblong-elliptical, 7.5–15 cm × 4.5–6.5 cm, with 16–20 pairs of secondary veins, midrib obscure above; stamens 20–25, anthers narrowly oblong; larger fruit calyx lobes up to 8 cm × 1.4 cm. *S. albida* occurs typically in peat-swamp forest and locally on podzolic soils in heath forest up to 1200 m altitude. The density of the wood is variable: 590–850 kg/m^3 at 15% moisture content.

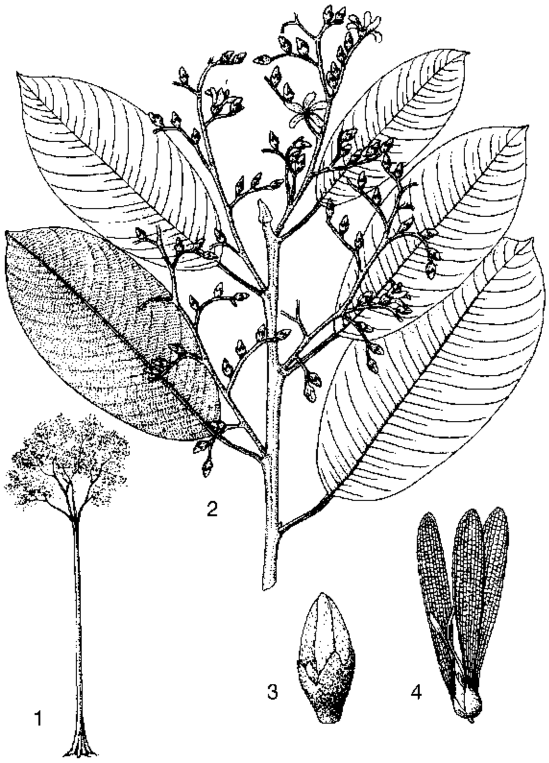
Selected sources 30, 89, 258, 748.

Shorea almon Foxw.

Philipp. Journ. Sc. 67: 313 (1938).

Synonyms *Shorea eximia* Foxw. non (Miq.) R. Scheffer.

Vernacular names Brunei: meranti buaya bukit. Malaysia: seraya buaya bukit, seraya kerukup (Sabah), meranti buaya bukit (Sarawak). Philip-



Shorea albida Sym. – 1, tree habit; 2, flowering twig; 3, flower bud; 4, fruit.

pines: almon (general), danlig-mayapis (Tagalog), malasinoro (Bikol, Samar-Leyte Bisaya).

Distribution North-eastern Borneo and non-seasonal areas of the Philippines.

Uses The timber is used as red meranti and is in great demand for plywood. In the Philippines it is sometimes traded separately as almon timber. It is reported that wood extractives are tumour-inhibiting.

Observations A large or very large tree, up to 70 m tall with bole branchless for 20–30 m and up to 160(–200) cm in diameter, buttresses prominent; leaves concave, 9–16 cm × 3.5–7 cm, with 17–20 pairs of secondary veins, lower surface scabrid tomentose; stamens 15, anthers subglobose with long appendages, ovary without a stylopodium; larger fruit calyx lobes up to 14 cm × 2.5 cm. *S. almon* occurs on clay soil on hills in mixed dipterocarp forest generally at low altitudes. The density of the wood is 400–580 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 100, 175, 258, 476, 579, 674, 748.

Shorea amplexicaulis P. Ashton

Gard. Bull. Sing. 19: 273, pl. 10 (1962).

Vernacular names Brunei: kawang pinang, meranti kawang, pinang lichin. Indonesia: orai lanyung, awang rambut (south-eastern Kalimantan). Malaysia: engkabang pipit, tengkawang megeh telur (Sarawak), kawang bukit (Sabah).

Distribution Borneo.

Uses The timber is used as light red meranti.

Observations A medium-sized to large tree, up to 50 m tall with tall bole up to 125 cm in diameter, buttresses up to 1 m high; leaves elliptical, 11–21 cm × 5–8 cm, with 9–12 pairs of secondary veins, stipules amplexicaul, subpersistent; stamens 15, anthers narrowly oblong with long appendages, ovary without a stylopodium; larger fruit calyx lobes up to 18 cm × 3 cm. *S. amplexicaulis* is fairly common on hillsides, slopes and especially ridges on clay or sandy soils with a high clay content from sea-level up to 700 m altitude. The density of the wood is 495–610 kg/m^3 at 15% moisture content.

Selected sources 30, 100, 258, 748.

Shorea argentifolia Sym.

Gard. Bull. Sing. 17: 489 (1960).

Vernacular names Brunei: merangau, meranti binatoh. Indonesia: senkajang, seraya pasir, seraya pipit (northern Kalimantan). Malaysia: binatoh, sinkajang (Sarawak), seraya daun mas (Sabah).

Distribution North-eastern Borneo.

Uses *S. argentifolia* is an important source of light red meranti timber within its distribution area.

Observations A medium-sized to large tree up to 53 m tall with bole up to 130 cm in diameter, buttresses prominent, up to 4 m high; leaves oblong-lanceolate, thinly leathery, 6–11 cm × 2.5–4.5 cm, with 20–25 pairs of secondary veins, the lower surface pinkish-golden velvety tomentose; stamens 15, anthers subglobose with short appendages, ovary and stylopodium pear-shaped; larger fruit calyx lobes up to 7.5 cm × 1.2 cm. *S. argentifolia* occurs locally abundant and gregarious and is found on clay soils, usually on undulating land and in valleys up to 680 m altitude. The density of the wood is 480–835 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 476, 514, 748.

Shorea balangeran (Korth.) Burck

Ann. Jard. Bot. Buitenzorg 6: 214 (1887).

Synonyms *Hopea balangeran* Korth. (1841), *Parashorea balangeran* (Korth.) Merr. (1921).

Vernacular names Indonesia: balangeran, kahoi (Kalimantan), melangir (Bangka, Belitung).

Distribution Kalimantan, Bangka and Belitung.

Uses *S. balangeran* is a major source of red meranti timber, but heavier grades are sometimes traded as red balau. The bark is used for the walling of houses. A comparatively valuable resin can be obtained from the wood.

Observations A medium-sized tree up to 30 m tall with a straight bole, buttresses up to 1.2 m high; leaves oblong-elliptical to lanceolate, 7–18 cm × 3–8 cm, with 13–18 pairs of slender secondary veins not prominent, lower surface cream lepidote; stamens 15, anthers broadly ovoid with slender appendages, stylopodium absent; larger fruit calyx lobes up to 50 mm × 7 mm. *S. balangeran* is common and occurs often gregarious in peat-swamp forest. The density of the wood is 730–990 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 258, 462, 743, 748.

Shorea beccariana Burck

Ann. Jard. Bot. Buitenzorg 6: 213 (1887).

Synonyms *Shorea franchetiana* Heim (1891).

Vernacular names Brunei: kawang pinang, meranti langgai. Indonesia: tengkawang tengkal, engkabang maha (West Kalimantan). Malaysia: abang (Dusun, northern Borneo), meranti langgai (Sabah, Sarawak).

Distribution Northern Borneo.

Uses The timber is used as light red meranti. The fruits are collected as illipe nuts.

Observations A very large tree up to 60 m tall with bole up to 110 cm in diameter, buttresses up to 1.5 m high, bark laminated; leaves elliptical to ovate, 11–20 cm × 5.5–7 cm, with 11–14 pairs of secondary veins; stamens 15, anthers oblong with long and slender appendages, stylopodium cylindrical; larger fruit calyx lobes up to 19 cm × 2.7 cm. *S. beccariana* is common on deeply leached soils in the lowlands and on shale or sandstone ridges up to 1350 m altitude. The density of the wood is 520–800 kg/m³ at 15% moisture content.

Selected sources 30, 89, 258, 476, 514, 748.

Shorea contorta S. Vidal

Sinopsis: 15, t. 15E (1883).

Synonyms *Pentacme contorta* (S. Vidal) Merr. & Rolfe (1908), *Pentacme mindanensis* Foxw. (1918).

Vernacular names Philippines: mindanao white lauan, white lauan (general), malaanonang (Tagalog, Bikol).

Distribution Throughout the Philippines.

Uses The timber is used as light red meranti, or as white meranti; it is often traded as white lauan in the Philippines where it is an important timber.

Observations A large tree up to 50 m tall with bole of 15–20 m long, up to 100(–180) cm in diameter and with V-section fissured bark; leaves ovate to lanceolate, thinly leathery, 9–29 cm × 5.5–11 cm, with 5–8(–9) pairs of secondary veins, base subequal; stamens 15, anthers linear and apically prolonged; larger fruit calyx lobes up to 12 cm × 3 cm. *S. contorta* is common and occurs often semi-gregarious in seasonal semi-evergreen dipterocarp forest up to 700 m altitude. The density of the wood is 420–560 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 49, 175, 258, 579, 681, 748.

Shorea coriacea Burck

Ann. Jard. Bot. Buitenzorg 6: 214 (1887).

Vernacular names Brunei: meranti tangkai panjang. Indonesia: lampong mengkabang (south-eastern Kalimantan), meranti jurai, samar benua (West Kalimantan). Malaysia: meranti tangkai panjang (Sarawak), seraya tangkai panjang (Sabah).

Distribution Borneo.

Uses The timber is used as dark red meranti.

Observations A large tree up to 50 m tall with bole of up to 145 cm in diameter, buttresses up to 1.5 m high; leaves subpeltate, ovate, 10–15 cm × 5–8 cm, with 16–20 pairs of secondary veins not prominent beneath, petiole 2.5–4 cm long; stamens 15, anthers subglobose with long slender appendages, stylopodium absent; larger fruit calyx lobes up to 9 cm × 1.5 cm. *S. coriacea* occurs in heath forest on podzolic soils or on ultrabasic rocks up to 1000 m altitude. The density of the wood is 625–865 kg/m³ at 15% moisture content.

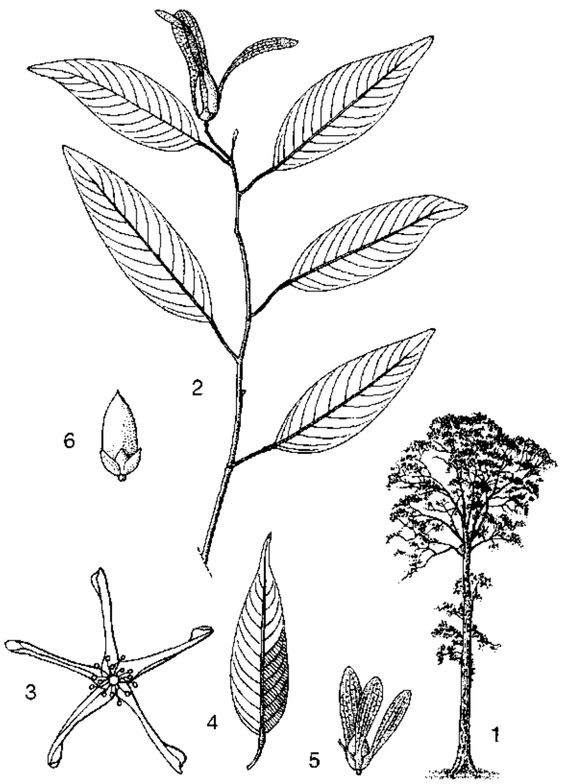
Selected sources 30, 89, 258, 748.

Shorea curtisii Dyer ex King

Journ. As. Soc. Beng. 62(2): 111 (1893).

Vernacular names Brunei: seraya. Indonesia: meranti merah tua. Malaysia: seraya (Malay, Peninsular), jarang (Sakai, Peninsular), meranti seraya (Sarawak). Thailand: saya-daeng, saya-luang (Thai, peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, the Riau and Lingga Archipelago and Borneo.



Shorea curtisii Dyer ex King – 1, tree habit; 2, fruiting twig; 3, corolla; 4, leaf; 5, fruit; 6, nut.

Uses The wood is an important and valued source of dark red meranti. A resin can be obtained from the tree but it is of little value.

Observations A large or very large tree up to 70 m tall with bole branchless for 18–28 m and up to 220 cm in diameter, buttresses prominent, up to 2.5 m high; leaves ovate-lanceolate, 6–9 cm × 2.5–3.5 cm, with 9–11 pairs of secondary veins not prominent beneath, lower surface pale pink to grey scaly; stamens 15, anthers subglobose with short appendages, stylopodium present; larger fruit calyx lobes up to 7 cm × 1 cm. *S. curtisii* is common and occurs often gregarious, typically on ridges in hill dipterocarp forest in Peninsular Malaysia and Sumatra; also on deep and dry soils on coastal hills up to 850 m altitude throughout its range. The density of the wood is 490–815 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 101, 102, 136, 253, 258, 297, 318, 413, 417, 514, 628, 632, 677, 716, 748.

Shorea dasyphylla Foxw.

Mal. For. Rec. 10: 224, pl. 18 (1932).

Vernacular names Indonesia: meranti balur, meranti gombung, meranti sabut (Sumatra). Malaysia: meranti batu (Peninsular, Sarawak), meranti sabut (Peninsular), seraya batu (Sabah).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and north-western Borneo.

Uses The timber is used as light red meranti.

Observations A medium-sized to large tree up to 45 m tall, with bole branchless for 18–28 m and up to 115 cm in diameter, buttresses up to 1.8 m high, bark closely, deeply fissured and dark; leaves ovate to elliptical, 7–14 cm × 3–6 cm, with 11–15 pairs of secondary veins, lower surface tomentose; stamens 15, anthers subglobose with short appendages, stylopodium present; larger fruit calyx lobes up to 9 cm × 1.3 cm. *S. dasyphylla* occurs on well-drained flat country and low hills in mixed dipterocarp forest up to 700(–1000) m altitude. The density of the wood is 335–690 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 89, 100, 102, 125, 253, 258, 515, 628, 677, 748.

Shorea fallax Meijer

Acta Bot. Neerl. 12: 335. pl. 7 (1963).

Synonyms *Shorea oleosa* Meijer (1963).

Vernacular names Brunei: engkabang layar, mentalun, meranti sepit undang. Indonesia: kontoi, tuntong seluing (Kalimantan). Malaysia: engkabang layar, engkabang pinang (Sarawak), seraya daun kasar (Sabah).

Distribution Borneo.

Uses The timber is used as light red meranti.

Observations A medium-sized to very large tree up to 60 m tall with bole up to 125 cm in diameter, buttresses up to 2 m high, bark shallowly fissured and flaked; leaves broadly oblong to ovate, 12–24 cm × 5.5–11 cm, with 15–19 pairs of secondary veins, scabrid rufous-brown tomentose beneath; stamens 15, anthers oblong with long, slender appendages, stylopodium pear-shaped; larger fruit calyx lobes up to 5 cm × 0.8 cm. *S. fallax* is locally frequent on clay soils in mixed dipterocarp forest on well-drained flat or hilly sites up to 600 m altitude. The density of the resinous wood is 560–690 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 476, 748.

Shorea ferruginea Dyer ex Brandis

Journ. Linn. Soc. Bot. 31: 91 (1895).

Vernacular names Brunei: meranti menalit. Indonesia: lampong tahan, tehan betung, tehan paru (south-eastern Kalimantan). Malaysia: meranti menalit, engkabang keli (Sarawak), seraya melantai kecil (Sabah).

Distribution Borneo.

Uses The timber is used as light red meranti.

Observations A very large tree up to 60 m tall with bole up to 160 cm in diameter, buttresses prominent, up to 3.5 m high, bark orange-brown to fawn; leaves lanceolate, 7–12 cm × 2.2–4 cm, with 13–15 pairs of secondary veins not prominent beneath, lower surface dull, with minute hair tufts; larger fruit calyx lobes up to 16 cm × 2.5 cm. *S. ferruginea* is fairly common on narrow ridges and well-drained clay soils up to 1100 m altitude. The density of the wood is 450–465 kg/m^3 at 15% moisture content.

Selected sources 29, 30, 89, 100, 258, 748.

Shorea flemmichii Sym.

Gard. Bull. Str. Settl. 10: 378, pl. 26 (1939).

Vernacular names Brunei: kayu raya, meranti raya. Malaysia: meranti raya (Sarawak).

Distribution Sarawak and Brunei.

Uses Locally the timber is an important source of dark red meranti.

Observations A very large tree up to 70 m tall with bole up to 255 cm in diameter, buttresses stout, up to 1.5 m high, bark dark, deeply fissured, flaky; leaves broadly elliptical or ovate, 5–9 cm × 3–4.5 cm, with 14–17 pairs of secondary veins, lower surface golden-tawny tomentose; stamens 15, anthers subglobose with long, slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 6.5 cm × 1.5 cm. *S. flemmichii* is locally abundant and occurs on deep yellow sandy soils and coastal hills below 400 m altitude. The density of the wood is about 850 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 748.

Shorea hemsleyana (King) King ex Foxw.

Mal. For. Rec. 10: 167 (1932).

Synonyms *Balanocarpus hemsleyanus* King (1893), *Shorea grandiflora* Brandis (1895), *Pachychlamys hemsleyanus* (King) Ridley (1922).

Vernacular names Brunei: chengal pasir daun besar, meranti gading. Indonesia: meranti kunyit, meranti rawang (eastern Sumatra). Malaysia: chengal pasir daun besar, meranti daun besar (Peninsular), meranti gading (Sarawak). Thailand: phayom-khao.

Distribution Peninsular Thailand, north-western Peninsular Malaysia, eastern Sumatra and north-western Borneo.

Uses The timber is used as light or dark red meranti.

Observations A medium-sized tree up to 30 m tall with bole branchless for 9–21 m and up to 85 cm in diameter, buttresses low or medium-sized; leaves oblong, 14–35 cm × 4–15 cm, with 14–17 pairs of secondary veins, the lower surface hairy; stamens 15, anthers subglobose with short appendages, stylopodium absent; larger fruit calyx lobes small, up to 2.5 cm × 1.8 cm. *S. hemsleyana* has two subspecies and is found locally in shallow peat swamps and on leached sandy soils up to 400 m altitude. The density of the wood is 675–835 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 89, 102, 137, 253, 258, 297, 417, 514, 628, 677, 748.

Shorea inaequilateralis Sym.

Gard. Bull. Str. Settl. 8: 281, pl. 25 (1935).

Vernacular names Brunei: semayur. Malaysia: semayur (Sarawak).

Distribution Sarawak and Brunei.

Uses The timber is used as red meranti or red balau for constructional purposes, and is also frequently traded under its own name 'semayur'.

Observations A medium-sized to large tree up to 45 m tall, with often sinuate bole, up to 95 cm in diameter, buttresses up to 2 m high, crown with pendulous branches; leaves ovate, papery, 9–14 cm × 4.5–7.5 cm, with a distinctly unequal, cordate base and 11–13 pairs of secondary veins; stamens 15, anthers oblong with long slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 14 cm × 2 cm. *S. inaequilateralis* is locally abundant in mixed peat-swamp forest. The density of the wood is about 850 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 748.

Shorea johorensis Foxw.

Mal. For. Rec. 10: 236, pl. 21 (1932).

Synonyms *Shorea leptoclados* Sym. (1939).

Vernacular names Brunei: meranti majau, selangan pelandok. Indonesia: meranti merkuyung (Kalimantan, Sumatra), damar kanuar tampukelat (Kalimantan), merkuyang putih (Sumatra). Malaysia: meranti pepijat (Peninsular), meranti majau (Sarawak), seraya majau (Sabah).

Distribution Peninsular Malaysia, eastern Sumatra and Borneo.

Uses The timber is used as light red meranti of a very good quality.

Observations A very large tree up to 60(–70) m tall with bole branchless for more than 30 m and up to 160 cm in diameter, buttresses up to 3 m high, outer bark with thin, papery scales; leaves ovate, papery to thin leathery, 9–14 cm × 4.2–7.5 cm, with 10–12 pairs of slender secondary veins, lower surface with prominent domatia, stipules up to 3.5 cm long; stamens 15, anthers oblong, with long, slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 12 cm × 2.3 cm. *S. johorensis* is locally common and occurs on well-drained flat and undulating land below 600 m altitude. In Indonesia it is one of the merantis receiving priority as a plantation tree. The density of the wood is 320–695 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 253, 258, 476, 630, 677, 748.

Shorea lepidota (Korth.) Blume

Mus. Bot. Lugd.-Bat. 2: 32 (1852).

Synonyms *Shorea nitens* Miq. (1860), *Vatica stipulosa* Miq. (1860), *Shorea megistocarpa* Foxw. (1932).

Vernacular names Indonesia: abang gunung, meranti ketrahan, meranti rumbai (Sumatra). Malaysia: damar siput, meranti langgong, meranti labu (Peninsular).

Distribution Peninsular Malaysia and Sumatra.

Uses The timber is used as light red meranti. The fruits are collected as illipe nuts but are of minor importance.

Observations A large tree up to 50 m tall with bole branchless for 18–27 m and a diameter of up to 135 cm, buttresses prominent, up to 5 m high, bark deeply fissured; leaves narrowly ovate to oblong, 6–14 cm × 3–6 cm, with 14–16 pairs of secondary veins, glabrescent, stipules persistent, 1.5–2.5 cm long; stamens 15, anthers subglobose with short appendages; larger fruit calyx lobes up to 11 cm × 2.5 cm. *S. lepidota* is a common species occurring on undulating land in lowland dipterocarp forest up to 350 m altitude. The density of the wood is 300–750 kg/m³ at 15% moisture content.

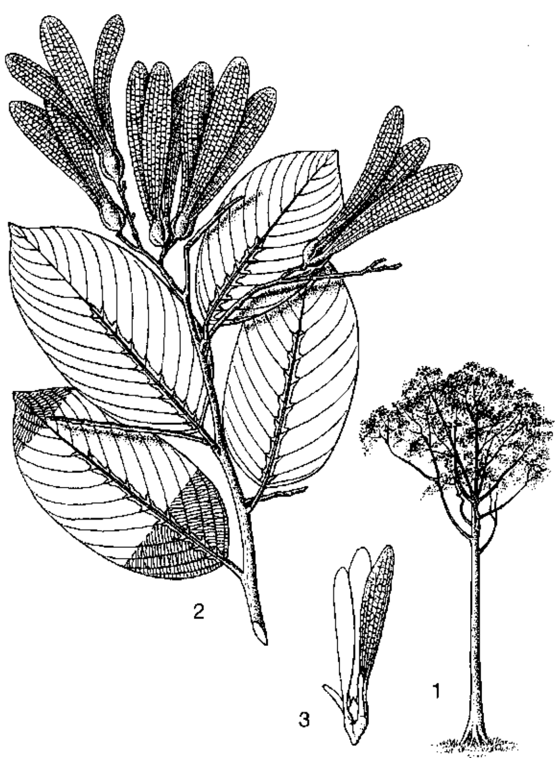
Selected sources 102, 125, 253, 258, 318, 677, 748.

Shorea leprosula Miq.

Fl. Ind. Bat., Suppl.: 191, 487 (1861).

Synonyms *Hopea maranti* Miq. (1861), *Shorea maranti* (Miq.) Burck (1887).

Vernacular names Brunei: meranti tembaga. Indonesia: meranti tembaga (general), kontoi bayor (West Kalimantan), lempong kumbang (East Kalimantan). Malaysia: meranti tembaga (general), meranti pusuh (Sarawak), seraya tembaga (Sabah). Thailand: saya-daeng, ta yom (Thai, peninsular).



Shorea leprosula Miq. – 1, tree habit; 2, fruiting twig; 3, fruit.

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses *S. leprosula* is one of the commonest light red meranti timbers. A resin called 'damar daging' is found between the roots and is used in traditional medicine. The bark is used for tanning.

Observations A large to very large tree up to 60 m tall with bole branchless for up to 35 m and up to 175 cm in diameter, buttresses up to 2 m high; leaves elliptical to ovate, 8–14 cm × 3.5–5.5 cm, with 12–15 pairs of secondary veins, lower surface cream tomentose and lepidote, with domatia; stamens 15, anthers subglobose, with short appendages, stylopodium ovoid; larger fruit calyx lobes up to 10 cm × 2 cm. *S. leprosula* is common on well-drained or swampy sites on clay soils below 700 m altitude. The density of the wood is 300–865 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 123, 125, 137, 253, 258, 297, 318, 413, 417, 461, 514, 628, 644, 645, 677, 743, 748.

Shorea macrantha Brandis

Journ. Linn. Soc. Bot. 31: 97 (1895).

Vernacular names Brunei: engkabang bungkus, ajul. Indonesia: meranti kait-kait, meranti lengkung daun (Sumatra). Malaysia: meranti kepong hantu (Peninsular), engkabang bungkus (Sarawak).

Distribution Peninsular Malaysia, eastern Sumatra and north-western Borneo.

Uses The timber is used as light or dark red meranti. The fruits are collected as illipe nuts.

Observations A small to large tree up to 45 m tall with bole up to 95 cm in diameter, small buttresses and drooping branches; leaves narrowly ovate, 6–17 cm × 2.5–8 cm, with a subequal base and 13–17 pairs of secondary veins, lower surface tomentose; stamens 15, anthers subglobose with slender but short appendages, stylopodium indistinct; fruit wingless, calyx lobes subequal. *S. macrantha* occurs locally in mixed peat-swamp forest. The density of the wood is 570–880 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 258, 677, 748.

Shorea macrophylla (de Vriese) P. Ashton

Gard. Bull. Sing. 20: 278 (1963).

Synonyms *Hopea macrophylla* de Vriese (1861), *Shorea gysbertsiana* Burck (1886), *Pachychlamys gysbertsiana* (Burck) Ridley (1922).

Vernacular names Brunei: kawang jantong. Indonesia: awang katolok, tengkawang buah (East Kalimantan), tengkawang hantelok (Kalimantan). Malaysia: engkabang jantong, engkabang ringgit (Sarawak), kawang jantong (Sabah).

Distribution Borneo.

Uses The timber is used as a light red meranti. Being one of the lightest in this trade group it is sometimes regarded as a white meranti or traded separately as 'kawang jantong'. *S. macrophylla* is one of the most important sources of illipe nuts.

Observations A medium-sized to large tree up to 50 m tall, with bole up to 130 cm in diameter, buttresses up to 2 m high; leaves elliptical-oblong, 17–35 × 10–14 cm, base obtuse to subcordate, with 11–20 pairs of secondary veins, stipules up to 5 cm × 1.3 cm; stamens 15, anthers elliptical-oblong, with long appendages, stylopodium pyriform; larger fruit calyx lobes up to 11 cm × 3 cm. *S. macrophylla* is one of the fastest growing *Shorea* species and is common along water courses and on clay-rich periodically flooded land below 600 m altitude. The density of the wood is 270–600 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 253, 318, 436, 476, 514, 748.

Shorea macroptera Dyer

Fl. Brit. India 1: 308 (1874).

Synonyms *Shorea bailloni* Heim (1891), *Shorea sandakanensis* Sym. (1938).

Vernacular names Brunei: meranti melantai. Indonesia: meranti kuning (eastern Sumatra), lukup (Riau Archipelago), sepit udang (northern Kalimantan), tengerangan sibu (East Kalimantan). Malaysia: meranti melantai (Peninsular, Sarawak), seraya melantai (Sabah). Thailand: chanhoi (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, eastern Sumatra and Borneo.

Uses The timber is a valuable source of light red meranti and is sometimes traded separately as 'melantai'. A resin called 'damar batu' or 'damar daging' has been collected but is of little value. The bark is favoured locally for walls, floors and roofs.

Observations A medium-sized to very large tree up to 60 m tall with bole branchless for 18–27 m and up to 135 cm in diameter, buttresses up to 2.5 m high; leaves narrowly elliptical to oblong, 8–19 cm × 3–7(–9.5) cm, with 10–15 pairs of secondary veins, lower surface shiny; stamens 15, anthers broadly oblong, with short appendages, stylopodium conical; larger fruit calyx lobes up to 12 cm × 2.3 cm, with 2 auricles. *S. macroptera* is a very variable species with 4 subspecies and occurs on well-drained clay soils on undulating land and hillsides up to 900 m altitude. The density of the wood is 370–770 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 125, 253, 258, 318, 357, 476, 514, 628, 677, 716, 748.

Shorea mecistopteryx Ridley

Kew Bull.: 280 (1925).

Synonyms *Shorea chrysophylla* Ridley (1926).

Vernacular names Brunei: kawang tikus, meranti kawang burong. Indonesia: abang alit (East Kalimantan), tengkawang layar (West Kalimantan). Malaysia: enkabang larai (Sarawak), kawang burong (Sabah).

Distribution Borneo.

Uses The timber is used as light red meranti. The wood yields a dark brown dammar of good quality. The fruits are small and only collected locally as illipe nuts.

Observations A very large tree up to 60 m tall with bole up to 160 cm in diameter, buttresses up to 2 m high; leaves oblong, 13–20(–30) cm × 6–10(–12) cm, with a cordate base and 16–20 pairs of secondary veins, lower surface golden tomentose, stipules up to 25 mm long; stamens 15, anthers oblong with long slender appendages, stylopodium spindle-shaped; larger fruit calyx lobes up to 23 cm × 3.3 cm. *S. mecistopteryx* occurs locally on yellow sandy clay soils on low hills up to 400 m altitude. The density of the wood is 400–735 kg/m^3 at 15% moisture content.

Selected sources 30, 258, 476, 514, 748.

Shorea negrosensis Foxw.

Philipp. Journ. Sc. 6: 274, pl. 44 (1911).

Vernacular names Philippines: malatbang (Tagalog), manggachapui (Panay Bisaya), red lauan (general).

Distribution Throughout the Philippines.

Uses The timber is used as red meranti. It is reported that wood extractives are tumour-inhibiting. The bark contains 9–10% tannin, and may be used for tanning sole leather.

Observations A large tree up to 50 m tall, with bole branchless for 20–30 m and a diameter up to 200 cm, buttresses prominent; leaves ovate to elliptical, thinly leathery, 6.5–17 cm × 3–7.5 cm, with (8–)11–15 pairs of secondary veins; stamens about 48, anthers linear-oblong with short appendages, stylopodium indistinct; larger fruit calyx lobes up to 7 cm × 1.3 cm. *S. negrosensis* is common and occurs often gregarious in evergreen and seasonal dipterocarp forest at low altitudes. The density of the wood is 420–805 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 175, 579, 748.

Shorea ovalis (Korth.) Blume

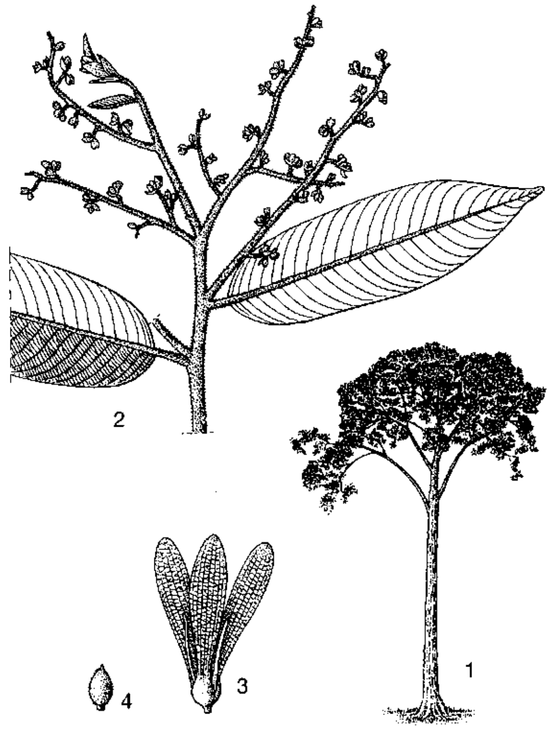
Mus. Bot. Lugd.-Bat. 2: 33 (1852).

Synonyms *Shorea eximia* (Miq.) R. Scheffer (1870), *Shorea sericea* Dyer (1874), *Shorea rigida* Brandis (1895).

Vernacular names Brunei: meranti kepong, meranti luang. Indonesia: meranti kelungkung (general), abang gunung putih (East Kalimantan), meranti sepang (southern Sumatra). Malaysia: kepong labu (Peninsular), meranti kepong (Peninsular, Sarawak), seraya kepong (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as light red meranti. The bark is used in local houses for walls and floors and for temporary shelters.



Shorea ovalis (Korth.) Blume – 1, tree habit; 2, flowering twig; 3, fruit; 4, nut.

Observations A medium-sized to very large tree up to 60 m tall with bole branchless for 18–27 m and up to 125 cm in diameter, buttresses up to 1.5 m high; leaves broadly oblong to narrowly ovate, 10–22 cm × (2–)3–10 cm, with (20–)22–25 pairs of secondary veins, lower surface scabrid; stamens 50–70, anthers broadly elliptical to oblong, with short, rudimentary appendages, stylopodium narrowly conical; larger fruit calyx lobes up to 11 cm × 1.4 cm. *S. ovalis* is a variable species with 3 subspecies and occurs on moist sites in lowland mixed dipterocarp forest up to 500 m altitude. The density of the wood is 320–860 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 124, 253, 258, 318, 357, 461, 476, 514, 525, 579, 628, 645, 748.

Shorea ovata Dyer ex Brandis

Journ. Linn. Soc. Bot. 31: 91 (1895).

Synonyms *Shorea plagata* Foxw. (1918), *Shorea agsaboensis* W. Stern (1965).

Vernacular names Brunei: meranti sarang punai bukit. Indonesia: meranti mandirawan (general), bankirai lintah (South Kalimantan), ketrahan (northern Sumatra). Malaysia: meranti pitis (Sarawak), meranti sarang punai bukit (Peninsular), seraya punai bukit (Sabah). Philippines: tiaong (general).
Distribution Peninsular Malaysia, Sumatra, Borneo and the southern Philippines (Mindanao).
Uses The timber is used as dark red meranti.
Observations A medium-sized or rarely large tree up to 30(–50) m tall with bole up to 130(–175) cm in diameter, buttresses up to 2.5 m high; leaves broadly ovate, 4–8 cm × 2.5–4.5 cm, with 8–10 pairs of secondary veins, lower surface shortly tomentose; stamens 15, anthers subglobose with short appendages, stylopodium narrowly conical; larger fruit calyx lobes up to 5.5 cm × 1 cm. *S. ovata* occurs locally on sandy soils and coastal or inland ridges up to 1300 m altitude. The density of the wood is 520–990 kg/m³ at 15% moisture content.
Selected sources 30, 89, 100, 258, 579, 677, 748.

Shorea pachyphylla Ridley ex Sym.

Journ. Mal. Br. Royal As. Soc. 19: 163, pl. 7 (1941).
Vernacular names Brunei: kukup, meranti kerukup. Indonesia: meranti mesupang, tengkawang hutan padang (Kalimantan). Malaysia: kerukup (Sarawak).
Distribution North-western Borneo.
Uses The timber is a valuable dark red meranti.
Observations A medium-sized to large tree up to 50 m tall with bole up to 145 cm in diameter, buttresses up to 2.5 m high; leaves broadly ovate to suborbicular, thickly leathery, 10–20 cm × 9–16 cm, with 7–9 pairs of secondary veins, glabrous; stamens 15, anthers subglobose, with long, slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 16 cm × 3.5 cm. *S. pachyphylla* occurs locally gregariously in mixed peatswamp forest especially near the coast. The density of the wood is 530–1010 kg/m³ at 15% moisture content.
Selected sources 30, 89, 258, 748.

Shorea palembanica Miq.

Fl. Ind. Bat., Suppl.: 487 (1861).
Synonyms *Shorea aptera* Burck (1887), *Shorea brachyptera* Heim (1891).
Vernacular names Brunei: engkabang asu. Indonesia: tengkawang majau (general), melebekan (Java, southern Sumatra), melebekan rawang bunga (southern Sumatra). Malaysia: engkabang asu (Sarawak), meranti tengkawang ayer, merpak (Peninsular).
Distribution Peninsular Malaysia, Sumatra and Borneo.
Uses The timber is used as light or dark red meranti. The large fruits are an important source of illipe nuts although they are of inferior quality.
Observations A small to very large tree up to 60 m tall with bole often of poor shape, up to 125 cm in diameter, buttresses prominent; leaves ovate to oblong, papery, 8–25 cm × 4–10 cm, with 12–16 pairs of secondary veins; stamens 15, anthers broadly ellipsoid, with long, slender appendages, stylopodium absent; fruit calyx lobes subequal, up to 5 cm × 0.7 cm. *S. palembanica* is locally abundant along river banks, where the trees overhang the river, and in freshwater swamps at low altitude. The density of the wood is 365–755 kg/m³ at 15% moisture content.
Selected sources 89, 258, 514, 677, 748.

Shorea palosapis (Blanco) Merr.

Sp. Blanc.: 271 (1918).
Synonyms *Shorea squamata* (Turcz.) Benth. & Hook.f. ex DC. (1868).
Vernacular names Philippines: mayapis, tabak (Tagalog), pura (Bikol).
Distribution Throughout the Philippines.
Uses The timber is used as light red meranti. It is reported that wood extractives are tumour-inhibiting.
Observations A large tree up to 50 m tall with bole branchless for 20–25 m and up to 150(–180) cm in diameter, buttresses prominent; leaves oblong, 12–24 cm × 8–11 cm, base shallowly cordate, with 14–19 pairs of secondary veins, stipules up to 15 mm × 11 mm; stamens 15, anthers subglobose with long, slender appendages, stylopodium pear-shaped; larger fruit calyx lobes up to 12(–17) cm × 1.5 cm. *S. palosapis* is common on well-drained soils in evergreen mixed dipterocarp forest up to 1000 m altitude. The density of the wood is 365–680 kg/m³ at 15% moisture content. See also the table on wood properties.
Selected sources 95, 175, 258, 579, 748.

Shorea parvifolia Dyer

Fl. Brit. India 1: 305 (1874).
Synonyms *Shorea scutulata* King (1893), *Shorea gentilis* Parijs (1933).
Vernacular names Brunei: meranti sarang punai. Indonesia: meranti sarang punai (general),

abang gunung (East Kalimantan), kontoi burung (West Kalimantan). Malaysia: meranti sarang punai (general), meranti samak (Sarawak), seraya punai (Sabah). Thailand: saya-luang (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is the main source of light red meranti in South-East Asia.

Observations A very large tree up to 65 m tall with bole branchless for 18–30 m and up to 190 cm in diameter, buttresses up to 4 m high; leaves broadly ovate, thinly leathery, 5-9(-11) cm × 2.5-5(-6) cm, with 10–13 pairs of secondary veins not prominent beneath, lower surface sparsely pale brown pubescent; stamens 15, anthers subglobose with short appendages, stylopodium ovoid to conical; larger fruit calyx lobes up to 9 cm × 1.5 cm. *S. parvifolia* is possibly the commonest dipterocarp species in Malesia and occurs on a variety of usually well-drained clay soils up to 800 m altitude. The density of the wood is very variable and ranges between 290 kg/m^3 and 835 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 125, 137, 253, 258, 297, 318, 357, 417, 461, 469, 476, 514, 628, 677, 748.

Shorea pauciflora King

Journ. As. Soc. Beng. 62(2): 116 (1893).

Vernacular names Brunei: nemesu, meranti cheriak, obar suluk. Indonesia: abang gunung (East Kalimantan), meranti ketuko (Kalimantan, Sumatra), ketuko nilau (Sumatra). Malaysia: meranti nemesu (Peninsular), meranti cheriak (Sarawak), obar suluk (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is regarded as a valuable dark red meranti and is especially used for boats, doors and frames.

Observations A very large tree up to 70 m tall with bole branchless for 18–27 m and up to 220 cm in diameter, buttresses prominent, up to 4 m high, bark uniformly flaky; leaves ovate, thinly leathery, 9–15 cm × 4–5.5 cm, with 8–9 pairs of secondary veins, lower surface glabrous; stamens 15, anthers broadly oblong with long and setose appendages, stylopodium ovoid to conical; larger fruit calyx lobes up to 9 cm × 1.5 cm. *S. pauciflora* occurs on well-drained deep soils in lowland and hill forest up to 700 m altitude. The density of the wood is 490–835 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 136, 253, 258, 297, 417, 461, 476, 514, 578, 677, 748.

Shorea pinanga R. Scheffer

Nat. Tijd. Ned. Ind. 31: 350 (1870).

Synonyms *Shorea compressa* Burck (1886).

Vernacular names Brunei: kawang, meranti langgai bukit. Indonesia: awang boi (south-eastern Kalimantan), tengkawang biasa, tengkawang rambai (West Kalimantan). Malaysia: kawang pinang (Sabah), meranti langgai bukit (Sarawak).

Distribution Throughout Borneo.

Uses The timber is used as light red meranti but is of minor economic importance although it has potential to become more important. The fruits are collected as illipe nuts.

Observations A medium-sized to large tree up to 50 m tall, with bole up to 125 cm in diameter, buttresses small, up to 1.5 m high; leaves elliptical to narrowly ovate, thinly leathery, 11–24 cm × 4–9 cm, with 10–20 pairs of secondary veins, stipules up to 6 cm long; stamens 15, anthers subglobose with long, slender appendages, stylopodium long and slender; larger fruit calyx lobes up to 28 cm × 3.5 cm. *S. pinanga* is locally common on clay soils and especially on broad ridges up to 700 m altitude. The density of the wood is 305–630 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 31, 100, 388, 411, 476, 599, 676, 748.

Shorea platycarpa Heim

Bull. Mens. Soc. Linn. Paris 2: 956 (1891).

Synonyms *Shorea palustris* Ridley (1922).

Vernacular names Brunei: meranti paya. Indonesia: lanan tembaga (South Kalimantan), meranti lengkung daun (Sumatra), pengerawan pepa (West Kalimantan). Malaysia: meranti paya (general), perawan tulop (Sarawak), seraya paya (Sabah).

Distribution Peninsular Malaysia, Sumatra, Borneo and intervening islands.

Uses The timber is used as light or dark red meranti.

Observations A medium-sized to large tree up to 50 m tall with bole branchless for 18–26 m and up to 125 cm in diameter, buttresses up to 4 m high; leaves elliptical-oblong to broadly ovate, thinly leathery, 9–17 cm × 5.5–10 cm, with 16–20 pairs of secondary veins, lower surface scabrid tomentose; stamens 15, anthers subglobose with short appendages, stylopodium narrowly ovoid;

larger fruit calyx lobes up to 6.5 cm × 1.2 cm. *S. platycarpa* is locally common or semi-gregarious in mixed peat-swamp forest at 300–1350 m altitude. The density of the wood is 515–865 kg/m^3 at 15% moisture content and the wood is therefore comparatively heavy.

Selected sources 30, 89, 100, 102, 253, 258, 514, 677, 748.

Shorea platyclados v. Slooten ex Foxw.

Mal. For. Rec. 10: 214 (1932).

Vernacular names Brunei: meranti bukit. Indonesia: banio (Sumatra), ketir (South Kalimantan), meranti cingham (eastern Sumatra). Malaysia: meranti bukit (general), jalak (Peninsular), seraya bukit (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as dark red meranti of excellent quality.

Observations A medium-sized to very large tree up to 60 m tall with bole branchless for 18–30 m and up to 160(–235) cm in diameter, buttresses up to 4 m high, twigs compressed; leaves lanceolate, 6–9 cm × 2–3 cm, with 15–18 pairs of secondary veins not prominent beneath; stamens 15, anthers subglobose with long, slender appendages, stylopodium pear-shaped; larger fruit calyx lobes up to 10 cm × 1 cm. *S. platyclados* occurs in hilly to mountainous areas on deep soils with high humus content at (200–)700–1350 m altitude. The density of the wood is 340–880 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 101, 102, 136, 253, 258, 297, 417, 461, 476, 514, 677, 679, 741, 748, 811.

Shorea polysperma (Blanco) Merr.

Publ. Govt. Lab. Philipp. 27: 22 (1905).

Synonyms *Dipterocarpus polyspermus* (Blanco) Blanco (1845), *Shorea warburgii* Gilg (1894), *Shorea teysmanniana* Foxw. non Dyer ex Brandis.

Vernacular names Dark red Philippine mahogany (En). Philippines: tangile (general), balagayan (Mangyan), malagiso (Tagalog).

Distribution Throughout the Philippines.

Uses The wood is the most important red meranti timber of the Philippines and is especially used for furniture.

Observations A large tree up to 50 m tall with bole branchless for 20–30 m and up to 200 cm in diameter, buttresses prominent; leaves elliptical, thinly leathery, 7.5–15 cm × 2.5–6.5 cm, with 9–12 pairs of secondary veins, lower surface glabrous; stamens 15, anthers subglobose with long, slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 9 cm × 1.8 cm. *S. polysperma* commonly occurs in hilly country in evergreen mixed dipterocarp forest up to 1500 m altitude. The density of the wood is 395–815 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 175, 258, 579, 674, 748.

Shorea quadrinervis v. Slooten

Bull. Bot. Gard. Buitenzorg, ser. 3, 17: 220, f. 21 (1942).

Vernacular names Brunei: dangar siak (Murut), meranti sudu. Indonesia: kontoi genut, meranti tempelong, tengkawang tikus (West Kalimantan). Malaysia: meranti sudu, sasak merambai (Sarawak), seraya sudu (Sabah).

Distribution North-western Borneo.

Uses The timber is an important source of light red meranti. The resin is used locally for torches and caulking boats.

Observations A medium-sized to large tree up to 40(–50) m tall with bole up to 145 cm in diameter, buttresses up to 2.5 m high, branches pendent; leaves broadly ovate to elliptical, 10–18 cm × 5–8 cm, with about 4 pairs of secondary veins, stipules up to 2.5 cm long; stamens 15, anthers subglobose with short appendages, stylopodium conical; larger fruit calyx lobes up to 8 cm × 1.3 cm. *S. quadrinervis* is common on well-drained deep sandy clay soils up to 400(–700) m altitude. The density of the wood is 440–760 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 742, 748.

Shorea rugosa Heim

Bull. Mens. Soc. Linn. Paris 2: 973 (1891).

Vernacular names Brunei: meranti buaya hantu. Indonesia: awang belaitok (East Kalimantan) bankirai lutung (South Kalimantan), meranti lanan (Kalimantan). Malaysia: meranti buaya hantu (Sarawak), seraya buaya hantu (Sabah).

Distribution Borneo.

Uses The timber is used as dark red meranti.

Observations A very large tree up to 65 m tall with bole up to 125 cm in diameter, buttresses up to 2.5 m high, bark deeply fissured; leaves oblong-ovate to oblong-obovate, 9–17 cm × 4–9 cm, with 14–19 pairs of secondary veins, lower surface densely tomentose; stamens 15, anthers subglobose with short appendages, stylopodium conical; larger fruit calyx lobes up to 10.5 cm × 2.5 cm. *S.*

rugosa occurs on leached yellow and white sandy soils in mixed dipterocarp or heath forest up to 400 m altitude. The density of the wood is 565–850 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 514, 748.

Shorea scaberrima Burck

Meded. 's-Lands Plantentuin 3: 22 (1886).

Vernacular names Brunei: meranti paya bersisek. Indonesia: kontoi entimus, tengkawang kijang (West Kalimantan), meranti sandakan (northern Kalimantan). Malaysia: engkabang pinang, kawang bukit (Sabah), meranti paya bersisek (Sarawak).

Distribution North-western Borneo.

Uses The timber is used as light red meranti.

Observations A small to fairly large tree up to 40 m tall with bole up to 110 cm in diameter, buttresses up to 1.5 m high, bark appearing smooth; leaves oblong-obovate to oblong-ovate, thinly leathery, 7–20 cm × 4–9 cm, with 14–17 pairs of secondary veins, lower surface tawny tomentose; stamens 15, anthers oblong with long appendages, stylopodium narrow; larger fruit calyx lobes up to 4.5 cm × 1 cm. *S. scaberrima* occurs on well-drained yellow sandy clay soils on flat and undulating land or ridges up to 850 m altitude. The density of the wood is 440–735 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 318, 514, 748.

Shorea scabrida Sym.

Gard. Bull. Str. Settl. 8: 287, pl. 28 (1935).

Vernacular names Brunei: meranti lop, meranti telor. Indonesia: meranti pepak lantai, meranti tembalang, pengerawan surai (West Kalimantan). Malaysia: meranti lop (Sarawak), seraya lop (Sabah).

Distribution Eastern Sumatra and Borneo.

Uses The timber is used as light red meranti.

Observations A medium-sized to large tree up to 45 m tall with bole up to 95 cm in diameter, buttresses up to 1.5 m high; leaves obovate to elliptical, 5–9 cm × 3–5 cm, obtuse or retuse, with 8–11 pairs of secondary veins, lower surface glabrous except for the veins; stamens 15, anthers subglobose with long appendages, stylopodium narrowly conical; larger fruit calyx lobes up to 7 cm × 1.5 cm. *S. scabrida* occurs locally in swamp forest or on shallow peat or even sandy soils in mixed dipterocarp or heath forest. The density of the wood is 410–770 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 476, 748.

Shorea selanica (DC.) Blume

Mus. Bot. Lugd.-Bat. 2: 33 (1852).

Synonyms *Engelhardtia selanica* (DC.) Blume (1828), *Hopea selanica* (DC.) Wight & Arn. (1834).

Vernacular names Indonesia: meranti bapa (general), biahut (Buru), kayu bapa (Moluccas).

Distribution The south-western Moluccas.

Uses *S. selanica* is the most valuable red meranti construction timber of the Moluccas. The trunk copiously exudes a dammar which is used locally for torches and caulking boats.

Observations A large tree up to 50(–58) m tall, with bole branchless for 34–42 m and up to 100 cm in diameter, buttresses prominent; leaves oblong-ovate, thinly leathery, (7–)9–18 cm × 3–7 cm, base unequal, with 19–23 pairs of secondary veins; stamens 15, anthers broadly ellipsoid with long appendages, stylopodium indistinct; larger fruit calyx lobes up to 10 cm × 1.5 cm. *S. selanica* is often the dominant species in the lowland forest on well-drained soils in the south-western Moluccas up to 150 m altitude. The density of the wood is 440–530 kg/m^3 at 15% moisture content.

Selected sources 258, 318, 744, 748.

Shorea singkawang (Miq.) Miq.

Ann. Mus. Bot. Lugd.-Bat. 3: 84 (1867).

Synonyms *Hopea singkawang* Miq. (1860), *Shorea thiseltonii* King (1893), *Pachychlamys thiseltonii* (King) Ridley (1922).

Vernacular names Indonesia: sengkawang pinang, singkawang daun halus (Sumatra). Malaysia: meranti bahru, meranti sengkawang merah, siput melantai (Peninsular). Thailand: maak on (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and eastern Sumatra.

Uses The timber is used as dark red meranti. The fruits are collected as illipe nuts.

Observations A small to medium-sized tree up to 30 m tall with bole branchless for 12–21 m and up to 95 cm in diameter, buttresses up to 3.5 m high; leaves oblong-lanceolate, (8–)12–24 cm × (2.3–)5.5–9 cm, with 7–17 pairs of secondary veins; stamens 15, anthers subglobose with short appendages, stylopodium indistinct; larger fruit calyx lobes up to 8 cm × 0.8 cm, only slightly longer than the nut. *S. singkawang* has two subspecies and occurs on well-drained undulating land or near streams up to 400 m altitude. The density of the wood is 330–805 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 136, 253, 258, 318, 514, 628, 677, 748.

Shorea smithiana Sym.

Gard. Bull. Str. Settl. 9: 345, pl. 26 (1938).

Vernacular names Brunei: berat (Murut), meraka belang, meranti rambai. Indonesia: campega, kakan putih (East Kalimantan), meranti merumbung (Kalimantan). Malaysia: meranti rambai (Sarawak), seraya timbau (Sabah).

Distribution Northern and eastern Borneo.

Uses The timber is one of the chief sources of light red meranti in north-eastern Borneo. The wood yields a light brown dammar of good quality.

Observations A very large tree up to 60 m tall with bole up to 160 cm in diameter, buttresses up to 2 m high; leaves broadly obovate to oblong or ovate, 12–20 cm × 6.5–11.5 cm, base obtuse to subcordate, with 14–17 pairs of secondary veins, lower surface grey lepidote; stamens 22–26, anthers broadly oblong with long appendages, stylopodium narrowly pear-shaped; larger fruit calyx lobes up to 20 cm × 2.8 cm. *S. smithiana* occurs on undulating land on deep yellow sandy clay soils up to 400 m altitude. The density of the wood is 300–720 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 100, 258, 461, 476, 514, 748.

Shorea splendida (de Vriese) P. Ashton

Gard. Bull. Sing. 20: 279 (1963).

Synonyms *Shorea martiniana* R. Scheffer (1873).

Vernacular names Indonesia: tengkawang bani, tengkawang goncang, tengkawang rambai (West Kalimantan). Malaysia: engkabang bintang, melindang (Sarawak).

Distribution Western Borneo.

Uses The timber is used as light red meranti but the trees are often protected by traditional rights. *S. splendida* is one of the main sources of illipe nuts.

Observations A small to medium-sized tree up to 30 m tall, with bole up to 65 cm in diameter, buttresses low; leaves oblong, papery, 8.5–23 cm × 4.2–11 cm, with 9–12 pairs of secondary veins, lustrous, stipules up to 2.5 cm long; stamens 15, anthers broadly ellipsoid, with long, slender appendages, stylopodium spindle-shaped; larger fruit calyx lobes up to 7.5 cm × 2.3 cm. *S. splendida* is a fairly common riparian species of periodically flooded clayey alluvium.

Selected sources 31, 89, 124, 258, 748.

Shorea stenoptera Burck

Meded. 's-Lands Plantentuin 3: 11 (1886).

Vernacular names Indonesia: tengkawang tayau, tengkawang tungkul (West Kalimantan). Malaysia: engkabang kerangas (Iban), engkabang rusa (Sarawak).

Distribution Western Borneo.

Uses The timber is used as red meranti. The illipe nuts are the largest known and *S. stenoptera* has been planted deliberately for the fruits.

Observations A small to medium-sized tree up to 25 m tall, with bole up to 60 cm in diameter, buttresses small or absent; leaves oblong, thickly leathery, 18–40 cm × 8–22 cm, with 10–14 pairs of secondary veins; stamens 15, anthers ellipsoid, with long, slender appendages, stylopodium spindle-shaped; larger fruit calyx lobes up to 7.5 cm × 2 cm. *S. stenoptera* is locally common in heath forest on poorly drained sandy soils and podzols at low altitudes. The density of the wood is 430–720 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 89, 124, 258, 318, 461, 599, 748.

Shorea teysmanniana Dyer ex Brandis

Journ. Linn. Soc. Bot. 31: 100 (1895).

Synonyms *Shorea paludosa* Foxw. (1932).

Vernacular names Brunei: meranti lilin. Indonesia: meranti bunga tanyung (eastern Sumatra), meranti daun halus (Sumatra), lintang (South Kalimantan). Malaysia: meranti bunga (Peninsular), meranti lilin (Sarawak), seraya bunga (Sabah).

Distribution Peninsular Malaysia, eastern Sumatra and Borneo.

Uses The timber is used as light red meranti.

Observations A medium-sized to large tree up to 45 m tall with bole up to 125 cm in diameter, buttresses up to 3 m high; leaves ovate, 7.5–11 cm × 3.5–7 cm, lustrous, glabrous, with 8–11 pairs of secondary veins slightly prominent beneath; stamens 15, anthers subglobose with short appendages, stylopodium narrowly conical; larger fruit calyx lobes up to 8 cm × 1 cm. *S. teysmanniana* occurs frequently in mixed peat-swamp forest up to 300(–900) m altitude. The density of the wood is 400–815 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 137, 253, 258, 318, 417, 461, 476, 677, 748.

Shorea uliginosa Foxw.

Mal. For. Rec. 10: 210, 277 (1932).

Synonyms *Shorea rugosa* Heim var. *uliginosa* Sym. (1939).

Vernacular names Brunei: meranti buaya. Indonesia: meranti daun lebar, meranti kelungkung daun (Sumatra), pengarawan buaya (West Kalimantan). Malaysia: meranti bakau (Peninsular), meranti buaya, perawan durian (Sarawak).

Distribution Peninsular Malaysia, eastern Sumatra, Bangka and western Borneo.

Uses *S. uliginosa* is an important source of dark red meranti timber, and is sometimes traded separately as 'meranti bakau'.

Observations A large tree up to 50 m tall with bole branchless for 18–30 m and up to 145 cm in diameter, buttresses up to 4 m high; leaves elliptical-oblong, papery, 12–22 cm × 6–12 cm, boat-shaped, with 16–21 pairs of secondary veins, lower surface densely tomentose; stamens 15, anthers subglobose with short appendages, stylopodium conical; larger fruit calyx lobes up to 6 cm × 1.2 cm. *S. uliginosa* is locally abundant in mixed peat-swamp forest at low altitude. The density of the wood is 420–810 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 253, 258, 461, 677, 748.

Shorea venulosa Wood ex Meijer

Acta Bot. Neerl. 12: 342, pl. 10 (1963).

Vernacular names Brunei: meranti tangkai panjang padi. Malaysia: meranti tangkai panjang padi (Sarawak), seraya kerangas (Sabah).

Distribution Northern Borneo.

Uses The timber is used as dark red meranti.

Observations A large tree up to 55 m tall with bole up to 125 cm in diameter, buttresses up to 3 m high; leaves ovate, 6–10 cm × 3–5 cm, glabrous, with 15–18 pairs of secondary veins not prominent beneath; stamens 15, anthers oblong with long, slender appendages, stylopodium indistinct; larger fruit calyx lobes up to 6 cm × 1.3 cm. *S. venulosa* is locally common and occurs on podzolic and ultrabasic soils up to 1600 m altitude. The density of the wood is 705–910 kg/m^3 at 15% moisture content.

Selected sources 30, 258, 748.

K.M. Kochummen (general part),
W.C. Wong (properties),
J.M. Fundter (wood anatomy),
M.S.M. Sosef (selection of species)

Shorea Roxb. ex Gaertner f. (white meranti)

Fruct. 3: 47 (1805).

DIPTEROCARPACEAE

$x = 7$; $2n = 14$ for the majority of species, *S. resinosa*: $3n = 21$

Trade groups White meranti: lightweight hardwood, e.g. *Shorea assamica* Dyer, *S. bracteolata* Dyer, *S. henryana* Pierre, *S. javanica* Koord. & Valeton, *S. roxburghii* G. Don.

Vernacular names White meranti. Indonesia: meranti putih (general), damar putih (Sumatra), damar tenang putih (Moluccas). Malaysia: meranti pa'ang, temak (Peninsular), raruk, melapi (Sarawak), melapi (Sabah). Philippines: yellow lauan, manggasinoro (both names also used for yellow meranti). Cambodia: lum'-baô. Thailand: phayom (central), saya-khao (Narathiwat), kiam-khanong (Nakhon Ratchasima, Prachin Buri). Vietnam: s[ees]n, v[ee]n v[ee]n.

Origin and geographic distribution *Shorea* consists of about 194 species, 163 of which occur in Malesia. The genus is distributed from Sri Lanka and India through Indo-China towards Malesia. Within Malesia the species occur eastward to the Moluccas. The genus is absent from the Lesser Sunda Islands but fossil wood has been recorded for Timor.

The species belonging to the white meranti group occur throughout the range of the genus. Within Malesia 22 species are found distributed as follows: Peninsular Malaysia (11 species), Sumatra (9 species), Borneo (13 species), the Philippines (3 species), Java (1 species), Sulawesi (1 species, possibly 2), and the Moluccas (2 species).

Uses *Shorea* is economically the most important timber genus in the Asian humid tropics. White meranti is used as a light construction timber. The wood is not very durable and should, therefore, not be used in contact with the ground unless treated. Because of the high silica content, white meranti is not very popular as a sawn timber but it has been used for a wide variety of purposes such as door and window frames, posts, beams, joists, rafters, planking, light flooring, ceiling, furniture, interior and shop fitting, vehicle bodies, sporting goods, vats, wine casks, food containers, stair stringers, and for ship and boat building.

The most important use of white meranti is as a plywood and veneer timber, for which it has excellent properties and is highly preferred. The wood is satisfactorily used for pulp in the manufacture of paper too.

The bark of several species has been stripped and locally used for house walls and for the manufacture of baskets and bins. The trunk yields a usually clear, pale yellow dammar which might be suitable for varnish, but is generally of inferior quality and used locally for torches.

Production and international trade For Indonesia, only export figures for meranti as a whole are available. The export of sawn meranti timber from Indonesia increased slightly from 1.3 million m^3 (with a value of US$ 249 million) in 1987, to 1.4 million m^3 (with a value of US$ 301 million) in 1989. Much more important in Indonesia is the production and export of plywood (estimated export value in 1990: US$ 3000 million), in which white meranti wood contributes an important part, together with red meranti (which contributes the major part), and keruing (*Dipterocarpus* spp.).

Export of white meranti from Peninsular Malaysia is not significant, but in Sarawak and Sabah 'melapi' is a fairly important export timber. In 1987 export of round logs from Sabah was 260 000 m^3 with a value of US$ 27 million. White meranti is at present traded from Sabah together with white seraya (*Parashorea* spp.) in one trade group; in 1992 635 000 m^3 of logs and 233 000 m^3 of sawn timber was exported in this combined trade group with a total value of US$ 162 million. No export statistics are available from other countries.

Properties White meranti is a lightweight hardwood. The heartwood is yellowish-white and indistinct from the sapwood when freshly cut, but gradually becomes yellowish-brown or light brown and slightly more distinct from the sapwood on exposure. The density is (380–)495–870(–945) kg/m^3 at 15% moisture content. The grain of the wood is usually interlocked, texture moderately coarse but even. The planed surface is lustrous, often with subtle ribbon figures.

At 15% moisture content, the modulus of rupture is 57–132 N/mm^2, modulus of elasticity 9500–19 400 N/mm^2, compression parallel to grain 29–67 N/mm^2, compression perpendicular to grain 4–11 N/mm^2, shear 5–14 N/mm^2, cleavage 41–58 N/mm radial and 43–60 N/mm tangential, and Janka side hardness 2765–9210 N.

The rates of shrinkage are low to moderate, from green to 15% moisture content 0.6–1.8% radial and 1.4–3.0% tangential, and from green to oven dry 2.5–3.5% radial and 5.7–7.5% tangential. White meranti dries fast to moderately slowly and without defects, except for occasional slight cupping, bowing and end and surface checks. It takes about 3 months and 5 months respectively to air dry boards of 15 mm and 40 mm thick. In Malaysia kiln-drying schedule J is recommended. The kiln-drying period of 25 mm thick boards is approximately 5 days.

The silica present in white meranti easily blunts cutter-tool edges. For sawing the logs, band saws need to have specially inserted teeth such as the tungsten-carbide type. Resawing is slightly difficult and the sawn surface tends to be woolly; cross cutting is also slightly difficult and sometimes difficult (*S. henryana*). Planing of air-dry timber is moderately difficult and the planed surface is rough for *S. bracteolata* and *S. henryana* but moderately smooth for *S. hypochra* and *S. roxburghii*. Boring is generally easy, with the exception of *S. henryana*, and the bored surface is rough. Turning is moderately easy to moderately difficult and gives a rough surface. The resistance to splitting when nailed is generally poor.

The creamy white and uniform colour, even texture and good gluing properties make white meranti a highly preferred timber for plywood production. The veneer is generally tight, smooth and of reasonably good quality; it shows few drying defects. However, the high silica content of the wood makes it difficult to saw. Experimental particle boards of 610 kg/m^3 made with 8% resin and 1% wax have properties exceeding those stipulated in the British standards.

White meranti is moderately durable. Graveyard tests with stakes in Malaysia indicated that the average service life in contact with the ground ranged from 2.6 years for *S. bracteolata* to 4.5 years for *S. roxburghii*. Under temperate conditions the service life in contact with the ground is 5–10 years. The sapwood appears to be readily attacked by pinhole borers after felling. Discoloration by blue stain fungi is common. The timber is not resistant to marine borer attack, even though it has a high silica content. Drastic schedules must be used to impregnate white meranti timber with preservatives, and even then the absorption of chemicals is low.

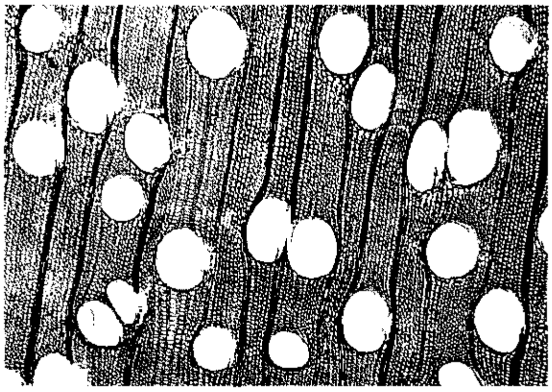
Wood of *S. bracteolata* contains 54% cellulose, 24% lignin, 16.5% pentosan and 1.4% ash. The silica content is c. 1.1% for *S. bracteolata* and up to nearly 2% for *S. resinosa*. The solubility of *S. bracteolata* wood is 6.0% in alcohol-benzene, 0.9% in cold water, 4.5% in hot water and 11.4% in a 1% NaOH solution. The energy value is 20 120 kJ/kg.

Description Medium-sized to very large trees up to 60 m tall; bole straight, cylindrical, branchless for up to 30(–37) m and with a diameter of up to 180(–225) cm; buttresses prominent, up to 3.5(–4.8) m high; bark surface with irregular section fissures, rarely scaly, grey or light brown, outer bark usually thick, chocolate brown, inner bark laminated with bands of orange-yellow (rarely pink) and whitish tissue, exuding a clear, yellow resin; mature crown hemispherical or dome-shaped, sympodial. Leaves alternate, simple, entire, glabrous or with stellate hairs, pinnately veined with scalariform tertiary venation and an obscure midrib, often glaucous on the lower surface; stipules and bracts often large and more or less persistent. Inflorescence terminal or axillary, paniculate. Flowers secund or distichous, bisexual, 5-merous, actinomorphic, scented; calyx lobes free, hirsute; petals broadly elliptical to ovate-lanceolate, loosely connate at base, white often tinged with pink, the outer surface hirsute; stamens 15–30, the anthers with 4 pollen sacs, narrowly oblong to linear, with prominent, scabrous or glabrous appendages; ovary without a distinct stylopodium, tomentose or glabrous; style longer than the ovary. Fruit usually shortly stalked; the outer 3 calyx lobes much elongated, more or less thickened and saccate at base; nut 1-seeded, free from the calyx, subglobose to ovate, sharply pointed. Seedling with epigeal germination; pericarp splitting irregularly; cotyledons usually pale yellow to reddish; first two leaves opposite, subsequent leaves arranged spirally, often larger than those on mature trees.

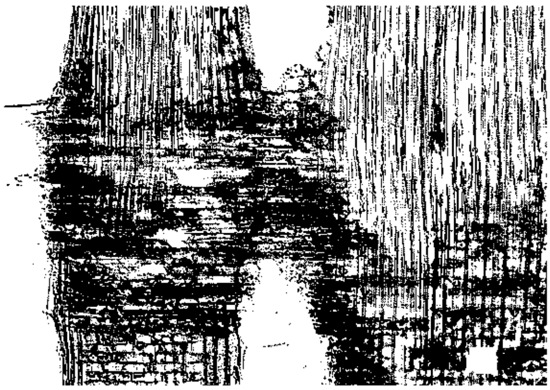
Wood anatomy

– Macroscopic characters:

Heartwood almost white when freshly cut but becoming yellowish or even brownish with age, lacking a pink tinge; sapwood pale yellow when freshly cut but gradually turning light yellow-brown on exposure, 5–7 cm wide, fairly distinctly demarcated from the heartwood in dry timber. Grain usually interlocked to deeply interlocked, sometimes wavy, rarely straight. Texture moderately coarse and even, finer than most red meranti; vague ribbon figure present on radial surfaces. Freshly cut wood with a characteristic fresh, sappy smell, dried wood without odour and taste. Growth rings indistinct or absent; vessels markedly reticulate in arrangement, visible to the naked eye, tyloses usually sparse and vessels conspicuously open; parenchyma sparse to moderately abundant, often bright yellow, fairly conspicuous, especially on wetted cross-section; rays just visible to individually distinct to the naked eye on end surfaces, individually distinct to the naked eye as short lines



transverse section (×25)



radial section (×75)

tangential section (×75)

Shorea javanica (white meranti)

darker in colour than the ground tissue of fibres on tangential surfaces, distinct but not conspicuous on radial surfaces. Ripple marks usually absent or indistinct to the naked eye. Intercellular canals in more or less continuous tangential lines, usually smaller than the vessels, barely visible to the naked eye on all surfaces, filled with white contents.

– Microscopic characters:

Growth rings indistinct or absent. Vessels diffuse, 2–8/mm^2, mostly 4–6/mm^2 (in *S. hypochra* 5–20/mm^2), mostly solitary but occasionally in radial multiples of 2–3, sometimes arranged in oblique or almost tangential lines, round to slightly oval, 100–300(–400) μm in tangential diameter, average length of vessel elements 350–800 μm; perforation plates simple; intervessel pits alternate, vestured, 2.5–6 μm; vessel-ray pits and vessel-parenchyma pits large (over 10 μm in diameter), round and gash-like. Fibres 900–1600 μm long, non-septate, moderately thick-walled, occasionally thin-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma predominantly paratracheal, apotracheal parenchyma sparse; paratracheal parenchyma incompletely vasicentric, often aliform and locally confluent; apotracheal parenchyma diffuse and diffuse-in-aggregates and in tangential lines surrounding vertical resin canals, sometimes in short, fine, irregularly spaced lines. Rays 4–8(–12)/mm, commonly multiseriate (4–10-seriate), 30–100 μm wide, low to extremely low (130–1700 μm, average 400 μm), generally distinctly lower than in other dipterocarps, with 1–2(–4) rows of marginal cells (Kribs type heterogeneous III, rarely II). Crystals absent. Silica bodies characteristically abundant in ray cells. Vertical resin canals in more or less continuous tangential lines, round and bead-like, filled with white resin. Parenchyma storied.

Species studied: *S. assamica, S. bracteolata, S. gratissima, S. hypochra, S. javanica, S. ochracea.*

White meranti differs from white seraya (*Parashorea* spp.) by the absence of crystals, the presence of silica and the often distinctly yellow parenchyma and rays. It can be distinguished from yellow meranti by the wood colour and lustre, and by the absence of radial intercellular canals.

Growth and development Seedlings need shade until they reach a height of about 1.5 m. Then the shade trees can be gradually removed to provide sunlight. The young trees show a tendency to form multiple leaders when exposed to full sunlight. Mycorrhizal infection promotes growth considerably. Five species of common ectomycorrhizal fungi associated with the roots of *S. javanica* have been identified: *Amanita hemibapha, Cantharellus cibarius, Lactarius* sp., *Russula* sp. and *Scleroderma* sp. In a 60-year-old forest plantation, 84% of the trees of *S. bracteolata* were found to be infected by mycorrhizae.

In general, the growth of white meranti trees is moderately fast. Trees of *S. javanica* may reach a height of 40–50 m in 50 years. Measurements of planted trees in Malaysia showed that the maximum diameter after 40 years can be as much as 86 cm for *S. assamica*, 65 cm for *S. resinosa* and *S. roxburghii*, 55 cm for *S. agamii*, and 53 cm for *S. bracteolata*.

The formation of pro-embryos and the occurrence of multiple seedlings was demonstrated in *S. agamii* and *S. resinosa*, suggesting apomixis.

S. roxburghii is fire-tolerant and shows fire-resistant adaptations in India and Burma, just like *S. robusta* Gaertner f. It has a thick bark and is deciduous during the dry period. It forms co-dominant or almost pure stands, and trees flower in most years, shortly before, during or after leaf fall. In seedlings the roots often become deep and extensive before a permanent leader shoot is established, and mature trees sucker readily in response to damage.

Other botanical information Anatomical features of the wood and bark, as well as anther characters, provide useful evidence for the classification of species at infrageneric level. The division of the genus *Shorea* into 4 major timber groups (red meranti, white meranti, yellow meranti and balau) coincides in broad outline with the division of the genus into botanical sections. Timbers belonging to the white meranti group belong to the section *Anthoshorea* Heim, which is related to the section *Doona* (Thwaites) P. Ashton from Sri Lanka, the red meranti section *Brachypterae* Heim, and the genus *Dryobalanops*.

S. contorta S. Vidal, belonging to the section *Pentacme* (A.DC.) P. Ashton, is sometimes considered to be a white meranti. Its wood ('white lauan') often has a pink tinge, and this species is treated here as red meranti.

Ecology *Shorea* species are confined to tropical climates with a mean annual rainfall exceeding 1600 mm and with a dry season of less than 6 months. Most species occur below 1000 m altitude. The largest numbers of species and of individuals are found on deep, well-drained yellow or red soils in the lowland. In general, white meranti is more abundant in seasonal than in aseasonal forests.

Propagation and planting Seeds rapidly lose their viability. Time of seed collection is important for the germination success. Mature seeds germinate well (about 96%) immediately after collection, but storage often causes rapid deterioration. However, seeds collected 4 and 2 weeks before maturity show only 66% and 79% germination immediately after collection, but loss of viability of immature seeds during storage is much less. Storage in sealed bags gives good results. Experiments in Thailand showed that seeds of *S. roxburghii* stored for 56 days at 15°C maintain 90% germination. Storage in ventilated containers or sealed bags at 16–21°C enables seeds to survive for up to 10 months with over 50% viability. Seeds of other species can probably be stored for only comparatively short periods. Germination tests showed that *S. javanica* seeds can best be kept at 20–27°C and 60–67% relative humidity. The weight of 1000 nuts of *S. javanica* (fruit wings removed) is about 1200 g, that of 1000 nuts of *S. assamica* is about 1050 g.

Stem cuttings of *S. bracteolata* treated with growth regulators and planted in coarse river sand may show 100% rooting success. The survival of stump transplants (defoliated seedlings without the top half of the leader shoot) is correlated with their starch content. The starch content of seedlings of *S. hypochra* and *S. roxburghii* is comparatively high, and they are recommended for bare-root planting. For bare-root planting of *S. roxburghii* at least one node must be retained above the cotyledons. Stump transplants can be stored in plastic bags for over 7 months at 25°C and can be vegetatively propagated by cuttings or by planting horizontally to make several shoots.

S. roxburghii has also been successfully propagated in vitro. Development of axillary shoots was induced in embryonic axes on a modified Murashige and Skoog medium containing 5 mg/l of 6-benzylaminopurine. Excised axillary shoots rooted vigorously on filter paper in a liquid medium containing naphthalene-acetic acid and indole-butyric acid.

The best planting material is 50–100 cm tall seedlings raised in the nursery, wildlings, or stump cuttings obtained from about 1.5-year-old nursery stock. Planting distance is usually 3 m × 3 m.

Silviculture and management Natural regeneration of white meranti species in the forest is often gregarious. However, in logged-over forest, enrichment planting may be necessary to maintain an important proportion of white meranti in the forest. When shade trees such as *Paraserianthes falcataria* (L.) Nielsen are used, plantations can be established in deforested areas. White meranti is planted when the shade trees are 3–5 years old.

In southern Sumatra a multistorey agroforestry system has been in use for decades, in which dammar from *S. javanica* is produced, and other crops, such as coffee, are also grown. The trees grow in a rotation of about 50 years and in this period they form a stand 40–50 m high. The dammar-producing trees are often planted mixed with other useful tree species (e.g. fruit-producing trees) or bamboos and rattans. In 1954 about 70 ha were in production for dammar in southern Sumatra.

Diseases and pests Plantations of *S. javanica* easily become infested by galls caused by the bacterium *Phytomonas tumefaciens*. The gall disease occurs first on 1–2-year-old seedlings, and is not necessarily fatal, as new sprouts arise when the diseased part of the plant is removed. Pathogenic fungi of *Fusarium* cause sapling defoliation and death of *S. javanica*. Beetles of the family *Scolytidae* can cause damage to fruits.

Harvesting In mixed dipterocarp forest in Indonesia trees of over 50 cm in diameter are harvested, and at least 25 healthy trees/ha of 20–50 cm in diameter are left for future cut. Since the logs float, they can be transported by river.

Genetic resources Just as in other meranti trade groups, white meranti includes several species, some of which are common and widely distributed (e.g. *S. assamica, S. bracteolata*), whereas other species occur only locally or scattered. When large-scale logging is practised without distinction at species level, certain species can become endangered, such as *S. gratissima* in Peninsular Malaysia, *S. polita* in the Philippines, or *S. retinodes* in Sumatra.

Prospects White meranti seems to have good potential for large-scale enrichment planting and for the establishment of timber plantations, especially for plywood production. Several species (e.g. *S. roxburghii*) are comparatively easy to propagate, and white meranti often grows fast. Propagation techniques and artificial regeneration in the forest are still in a trial stage, and need more research.

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Selection of species

Shorea agamii P. Ashton

Gard. Bull. Sing. 19: 270, pl. 9 (1962).

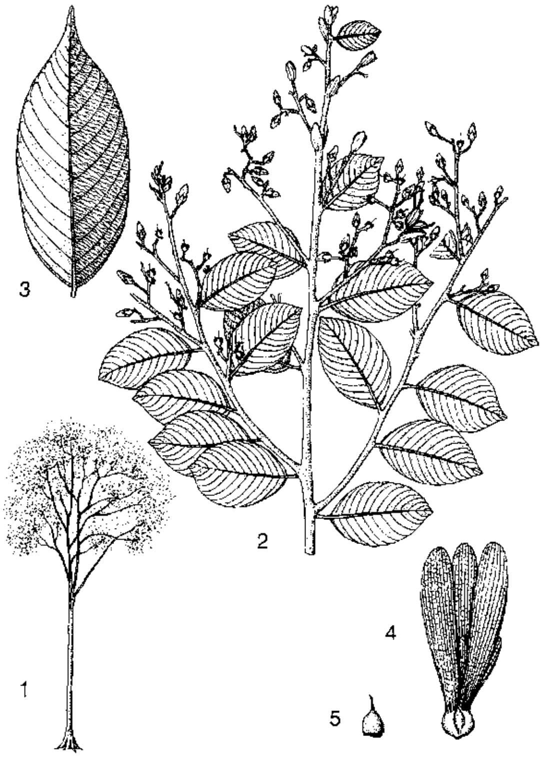
Vernacular names Brunei: meranti puteh timbul. Malaysia: melapi agama (Sabah).

Distribution Northern and western Borneo.

Uses *S. agamii* is an important source of white meranti timber.

Observations A very large tree up to 60 m tall with bole up to 225 cm in diameter and short buttresses; leaves broadly ovate to oblong or narrowly ovate, 4.5–15 cm × 2.5–10 cm with 9–13 pairs of secondary veins, lower surface glabrous, petiole 1–1.5 cm long; stamens 15, anthers with long, slender appendages; fruit base impressed, larger fruit calyx lobes up to 12 cm long. *S. agamii* has two subspecies (subsp. *agamii* and subsp. *diminuta* P. Ashton) and occurs on leached soils on undulating land or low hills below 700 m altitude. The density of the wood is about 665 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 357, 358, 514, 748.



Shorea assamica Dyer – 1, tree habit; 2, flowering twig; 3, leaf showing tertiary venation; 4, fruit; 5, nut.

Shorea assamica Dyer

Hook.f., Fl. Brit. India 1: 307 (1874).

Synonyms *Shorea philippinensis* Brandis (1895), *Shorea koordersii* Brandis ex Koord. (1898), *Shorea globifera* Ridley (1922).

Vernacular names Indonesia: damar mesegar (general), pini boti pien (Moluccas), damar larieh (Sulawesi), sogar baringin nabotar (Sumatra). Malaysia: lemsa kulat, meranti pipit (Peninsular). Philippines: danlig (Tagalog), manggasinoro (general), siyau (Panay Bisau). Thailand: saya-khao.

Distribution India, peninsular Thailand, Peninsular Malaysia, Sumatra, Borneo, the Philippines, Sulawesi and the southern Moluccas.

Uses The timber is the major source of white meranti. The resin, called 'damar tenang', was once collected on a commercial scale in North Sulawesi.

Observations A large tree up to 55 m tall with bole up to 150 cm in diameter and prominent buttresses; leaves ovate, elliptical or rarely obovate, (4–)5–9(–10) cm × 2–4(–6) cm, with 13–18 pairs of secondary veins, lower surface sometimes pilose, petiole 5–7 mm long, stipules auriculate, up to 15 mm long; stamens 15, anthers with short to long appendages; fruit pedicel c. 2 mm long, larger fruit calyx lobes up to 11 cm × 2 cm. *S. assamica* is very variable with 4 subspecies which occur in evergreen or semi-evergreen forest on fertile clay soils on well-drained flat or hilly country up to 1000 m altitude. The density of the wood is 420–680 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 89, 102, 175, 253, 258, 318, 327, 499, 514, 579, 628, 677, 744, 748.

Shorea bentongensis Foxw.

Mal. For. Rec. 10: 169, pl. 12 (1932).

Synonyms *Shorea pahangensis* Foxw. (1932).

Vernacular names Malaysia: bok, meranti mengkai, meranti sega (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as white meranti.

Observations A medium-sized to large tree with bole branchless for a considerable height and exceeding 75 cm in diameter, buttresses inconspicuous, bark more or less smooth, finely longitudinally cracked; leaves broadly ovate, 7–15 cm × 4–8 cm, with 13–16 pairs of secondary veins, lower surface glabrous, petiole 8–13 mm long; stamens 15, stylopodium cylindrical, tapering; larger fruit calyx lobes up to 7.5 cm × 0.8 cm. *S. bentongensis* is locally common and favours low-lying land and deep valleys in hilly country. The density of the wood is 550–755 kg/m³ at 15% moisture content.

Selected sources 253, 258, 677, 748.

Shorea bracteolata Dyer

Hook.f., Fl. Brit. India 1: 305 (1874).

Vernacular names Indonesia: bunyau (East Kalimantan), damar kedontang (general), ngerawan bunga (Sumatra). Malaysia: badau betul (Sarawak), melapi pa'ang (Sabah), meranti pa'ang (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *S. bracteolata* is an important source of white meranti timber, especially in Peninsular Malaysia. The pale dammar is used locally for torches.

Observations A medium-sized to very large tree up to 60 m tall with bole branchless for 23–30 m and up to 165 cm in diameter, buttresses up to 3 m high; leaves oblong-ovate to elliptical, thinly leathery, 9–14 cm × 4–6 cm, with 12–16 pairs of secondary veins, petiole slender, 1–2 cm long; stamens 15, stylopodium absent; larger fruit calyx

Shorea bracteolata Dyer – 1, flowering twig; 2, part of inflorescence; 3, fruit.

lobes up to 10 cm × 1.7 cm. *S. bracteolata* is variable and occurs on well-drained soils on coastal hills and undulating land up to 600 m altitude. The density of the wood is 510–840 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 141, 253, 258, 297, 318, 413, 417, 461, 514, 644, 677, 743, 748.

Shorea dealbata Foxw.

Mal. For. Rec. 10: 192, pl. 14 (1932).

Vernacular names Brunei: meranti bumbong. Malaysia: badau batu (Sarawak), meranti bumbong (Peninsular).

Distribution Peninsular Malaysia (Pahang), Lingga and north-western Borneo.

Uses The timber is used as white meranti.

Observations A medium-sized tree up to 30 m tall with bole up to 80 cm in diameter and inconspicuous buttresses; leaves ovate to elliptical, 8–16 cm × 4–7.5 cm, with (11–)20–24 pairs of secondary veins, lower surface pale pink lepidote, petiole stout, 1.5–2.5 cm long; stamens 17, stylopodium absent; larger fruit calyx lobes up to 9 cm × 1.3 cm. *S. dealbata* is locally common on yellow sandy soils in flat coastal swamps and on low hills up to 150 m altitude. The density of the wood is 560–870 kg/m³ at 15% moisture content.

Selected sources 31, 89, 253, 258, 677, 748.

Shorea gratissima (Wallich ex Kurz) Dyer

Hook.f., Fl. Brit. India 1: 307 (1874).

Vernacular names Malaysia: melapi laut (Sabah), meranti laut (Peninsular). Burma: uban. Thailand: (ta)khian-sai, rieo-nok-thung, yom (Thai, peninsular).

Distribution Burma, peninsular Thailand, Peninsular Malaysia, West Kalimantan and north-eastern Sabah.

Uses The timber is used as white meranti.

Observations A large tree up to 55 m tall with bole up to 115 cm in diameter and short buttresses; leaves ovate to elliptical, 4–10 cm × 1.5–4.5 cm, with 12–14 pairs of secondary veins, midrib acute beneath, petiole 8–15 mm long; stamens 25, stylopodium absent; larger fruit calyx lobes up to 7 cm × 1.3 cm. *S. gratissima* occurs on well-drained soils near the coast. The density of the wood is 495–800 kg/m³ at 15% moisture content.

Selected sources 100, 253, 258, 476, 628, 677, 748.

Shorea henryana Pierre

Lanessan, Pl. util. colon. franç.: 302 (1886).

Synonyms *Shorea sericeiflora* Fischer & Hutch. (1926).

Vernacular names Malaysia: meranti jerit. Burma: kaban ywet-thai, kanban thangyin, thingan byu. Thailand: chueam, khiam-khanong, khian-sai (peninsular). Vietnam: s[ees]n, b[oo] b[oo], s[ees]n ngh[eej].

Distribution Southern Burma, Thailand, Laos, southern Vietnam and Peninsular Malaysia.

Uses The timber is of a hard and heavy type of white meranti and is used for special purposes such as ship building. The clear dammar is of fairly good quality and has been gathered commercially.

Observations A fairly large tree up to 40 m tall with bole up to 115 cm in diameter and stout but short buttresses, twigs rusty-pink; leaves broadly lanceolate to elliptical, (3–)4–8(–12) cm × (1–)2.5–4.5(–5) cm, with 17–20 pairs of secondary veins not prominent beneath, lower surface glaucous; stamens 25(–30), stylopodium absent; larger fruit calyx lobes up to 9.5 cm × 1.6 cm. *S. henryana* prefers granite and quartzite soils and occurs in seasonal wet and dry evergreen forest up to 900 m altitude. The density of the wood is about 720 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 141, 253, 258, 297, 417, 628, 677, 748.

Shorea hypochra Hance

Journ. Bot. 14: 242 (1876).

Synonyms *Shorea maritima* Pierre (1886), *Shorea crassifolia* Ridley (1922).

Vernacular names Malaysia: meranti temak, temak bunga, terbak paya (Peninsular). Cambodia: kôki:(r) lu:ëng, kôki:(r) phno:ng, lum'-baô. Thailand: bak hin (peninsular), phanong, phanong yuak (south-eastern). Vietnam: v[ee]n v[ee]n.

Distribution Indo-China towards Peninsular Malaysia and the Riau and Lingga Archipelago.

Uses The timber is used as white meranti. A dammar of good quality ('damar temak') has been yielded on a commercial scale.

Observations A very large tree up to 60 m tall with bole branchless for 24–30 m and up to 165 cm in diameter; leaves ovate to elliptical, 7–18 cm × 4.5–8 cm, thickly leathery, with 15–20 pairs of secondary veins, lower surface cream lepidote, petiole 2–4 cm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 17 cm × 2.6 cm. *S. hypochra* occurs on flat and undulating land near the coast or in seasonal dipterocarp forest at low altitude. The density of the wood is 530–865 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 102, 141, 253, 258, 297, 417, 499, 628, 677, 748.

Shorea javanica Koord. & Valeton

Bull. Inst. Bot. Buitenzorg 2: 3 (1899).

Synonyms *Shorea vandekoppelii* Parijs (1933).

Vernacular names Indonesia: damar kaca (general), damar sibosa (northern Sumatra), mesegar lanang (southern Sumatra).

Distribution Sumatra and central Java.

Uses The timber is used as white meranti. The tree produces a clear resin of high quality which has been exported.

Observations A medium-sized to fairly large tree up to 40 m tall, bole branchless for up to 20(–30) m and with a diameter of up to 150 cm, buttresses up to 1.5 m high; leaves elliptical-oblong to ovate, thinly leathery, (6.5–)10–15 cm × (3.5–)4–8 cm, with 19–25 pairs of secondary veins, lower surface evenly tomentose on the veins, petiole 16–22 mm long; stamens 15, stylopodium narrow; larger fruit calyx lobes up to 18 cm × 1.5 cm. *S. javanica* occurs in primary and secondary forest on dry or periodically inundated places 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. The density of the wood is 450–840 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 27, 204, 258, 344, 461, 522, 623, 707, 708, 719, 743, 748.

Shorea lamellata Foxw.

Mal. For. Rec. 10: 278 (1932).

Vernacular names Indonesia: bunyau (East Kalimantan), damar pakit (South Kalimantan), damar tunam (general). Malaysia: melapi lapis (Sabah), meranti lapis (Peninsular, Sarawak).

Distribution Peninsular Malaysia, Lingga, Singkep and Borneo.

Uses The timber is used as white meranti. The wood produces a clear resin which has been commercially gathered in Borneo.

Observations A large tree up to 55 m tall with bole branchless for up to 35 m and with a diameter up to 175 cm, buttresses up to 3 m high; leaves elliptical to obovate, 7–15 cm × 4–8 cm, with 20–26 pairs of secondary veins, lower surface scabrid tomentose, petiole 1–2 cm long; stamens 15, stylopodium indistinct; larger fruit calyx lobes up to 8 cm × 1.7 cm. *S. lamellata* occurs locally on ridges and undulating land on both sandy and clayey soils up to 650 m altitude. The density of the wood is 460–945 kg/m^3 at 15% moisture content.

Selected sources 30, 100, 102, 258, 344, 476, 677, 743, 748.

Shorea ochracea Sym.

Gard. Bull. Str. Settl. 8: 285, pl. 27 (1935).

Vernacular names Brunei: raruk. Indonesia: damar kebaong (Kalimantan), kontoi tembaga (West Kalimantan), maro (south-eastern Kalimantan). Malaysia: badau raruk (Sarawak), melapi daun besar (Sabah).

Distribution Borneo.

Uses The timber is used as white meranti.

Observations A medium-sized or large tree up to 50 m tall with bole up to 125 cm in diameter and buttresses up to 1.5 m high; leaves broadly elliptical-oblong, 12–18 cm × 7–10 cm, with 25–30 pairs of secondary viens, lower surface bright yellow lepidote, petiole 1.3–2 cm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 10 cm × 2 cm. *S. ochracea* occurs scattered on well-drained clay soils on undulating land and ridges up to 750 m altitude. The density of the wood is 435–735 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 748.

Shorea polita S. Vidal

Sinopsis 15: t. 15D (1883).

Synonyms *Shorea mindanensis* Foxw.

Vernacular names Philippines: damlig (Tagalog), lauan-anite (Sambali), malaanonang (general).

Distribution The Philippines.

Uses The timber is used as white meranti. It is reported that wood extractives have a tumour-inhibiting capacity.

Observations A medium-sized tree up to 30 m tall with bole branchless for 15–20 m and a diameter up to 120 cm, buttresses small; leaves elliptical, thinly leathery, (3.5–)6–9(–14) cm × (1.5–)4–5 (–11.5) cm, with 11–13 pairs of secondary veins, lower surface pale green, petiole 1–2 cm long; stamens 21–25, stylopodium absent; larger fruit calyx lobes up to 13 cm × 2 cm. *S. polita* occurs in primary evergreen and semi-evergreen forest at low altitude. The wood is very difficult to saw by hand and has a density of 480–750 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 175, 258, 578, 579, 748.

Shorea resinosa Foxw.

Mal. For. Rec. 10: 234, pl. 19 (1932).

Vernacular names Malaysia: meranti belang (general), lemesa, sama rupa meranti (Peninsular).

Distribution Peninsular Malaysia, central Sumatra and western Sarawak.

Uses The timber is used as white meranti.

Observations A large tree up to 50 m tall, bole branchless for 18–24 m and with a diameter up to 125 cm, buttresses absent to large; leaves lanceolate to elliptical, 6.5–13 cm × 3.5–7 cm, glabrous, with 10–13 pairs of secondary veins, distinctly yellow beneath, petiole 9–17 mm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 9.5 cm × 2.5 cm, nut excreting resin. *S. resinosa* occurs on leached soils on low hills up to 700 m altitude. The density of the wood is 690–720 kg/m^3 at 15% moisture content.

Selected sources 31, 253, 258, 358, 514, 535, 677, 748.

Shorea retinodes v. Slooten

Bull. Bot. Gard. Buitenzorg, ser. 3, 18: 243, f. 7-8 (1949).

Vernacular names Indonesia: balamsarai, damar mansarai (western Sumatra), damar merilem (northern Sumatra).

Distribution Sumatra.

Uses The timber is used as white meranti. *S. retinodes* is an important source of a clear resin called 'damar mata kucing'.

Observations A large tree up to 55 m tall with bole branchless for 20–30(–35) m and buttresses up to 2 m high; leaves narrowly elliptical to lanceolate, thinly leathery, 5.5–12 cm × 1.8–4.8 cm, with 15–18 pairs of secondary veins, lower surface coppery lepidote, petiole 12–20 mm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 7.5 cm × 1 cm. *S. retinodes* is locally common on slopes up to 1000 m altitude. The density of the wood is 570–910 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 253, 344, 461, 743, 748.

Shorea roxburghii G. Don

Gen. hist.: 813 (1831).

Synonyms *Shorea talura* Roxb. (1832), *Shorea floribunda* (Wallich) Kurz (1873), *Shorea cochinchinensis* Pierre (1889).

Vernacular names Malaysia: meranti temak nipis, temak. Burma: kaban-ywet-they, pantheya, panthitya. Cambodia: popé:l. Laos: khanho:m. Thailand: phayom (general), khayom (northern), khiam (peninsular). Vietnam: s[ees]n c[aaj]t, s[ees]n m[ur], s[ee]n d[or].

Distribution Eastern India, Burma, Thailand, Cambodia, Laos, Vietnam and Peninsular Malaysia.

Uses The timber is used as white meranti. A low-quality resin is obtained from the tree. In Cambodia the bark is used as a masticatory in the betel-quid. The tree also produces a dye.

Observations A small to fairly large tree up to 40 m tall, bole up to 95 cm in diameter, buttresses absent or small; leaves elliptical-oblong, thin, 7.5–19 cm × 2.5–7 cm, with 12–20 pairs of secondary veins, lower surface glabrescent, petiole 14–45 mm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 9 cm × 1.2 cm. *S. roxburghii* is common and occurs sometimes gregarious in dry evergreen, deciduous or bamboo forest with a preference for sandy soils up to 1200 m altitude. The density of the wood is 560–790 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 102, 141, 150, 253, 258, 297, 417, 495, 499, 514, 532, 600, 601, 606, 628, 677, 706, 748.

Shorea virescens Parijs

Feddes Rep. 33: 244 (1933).

Vernacular names Brunei: meranti sulang sulang. Indonesia: belobunyo (East Kalimantan), damar maja (South Kalimantan), kontoi sabang (West Kalimantan). Malaysia: melapi sulang saling (Sabah), meranti sulang sulang (Sarawak). Philippines: manggasinorong-lakihan (general), ak-ak (Bisaya).

Distribution Borneo and the southern Philippines.

Uses The timber is used as white meranti. The tree yields a clear resin of good quality.

Observations A medium-sized to very large tree up to 60 m tall, with bole up to 175 cm in diameter and buttresses up to 3.5 m high, twigs compressed; leaves obovate, 7–15 cm × 4–8 cm, with 14–17 pairs of secondary veins, lower surface tomentose on the veins, dull grey, petiole 15–20 mm long; stamens 15, stylopodium absent; larger fruit calyx lobes up to 8 cm × 1.3 cm. *S. virescens* occurs on flat and undulating land on stoney or sandy as well as clayey soils up to 600 m altitude. The density of the wood is 380–630 kg/m^3 at 15% moisture content.

Selected sources 30, 175, 258, 344, 476, 743, 748.

K.M. Kochummen (general part),
W.C. Wong (properties),
J.M. Fundter (wood anatomy),
M.S.M. Sosef (selection of species)

Shorea Roxb. ex Gaertner f. (yellow meranti)

Fruct. 3: 47 (1805).

DIPTEROCARPACEAE

$x = 7$; *S. multiflora*: $2n = 14$

Trade groups Yellow meranti: lightweight hardwood, e.g. *Shorea balanocarpoides* Sym., *S. faguetiana* Heim, *S. gibbosa* Brandis, *S. longisperma* Roxb., *S. polyandra* P. Ashton.

Vernacular names Yellow meranti: Brunei: selangan kacha. Indonesia: meranti kuning (general), damar hitam (Sumatra), damar kelepek (Kalimantan). Malaysia: meranti damar hitam (Peninsular), yellow seraya (Sabah), lun kuning (Sarawak). Philippines: yellow lauan, manggasinoro (both also including white meranti), lun. Thailand: kalo (Yala, Narathiwat).

Origin and geographic distribution *Shorea* consists of about 194 species, 163 of which occur in Malesia. The genus is distributed from Sri Lanka and India through Indo-China towards Malesia. Within Malesia the species occur eastward to the Moluccas. The genus is absent from the Lesser Sunda Islands but fossil wood has been recorded for Timor. Yellow meranti is not found outside Malesia except for the southernmost part of Thailand. The greatest diversity of the 33 species belonging to the yellow meranti group is found in Borneo (29 species), followed by Peninsular Malaysia (10 species), Sumatra (8 species) and the Philippines (1 species).

Uses *Shorea* is economically the most important timber genus in the Asian humid tropics.

Yellow meranti is used for light constructional work. The sapwood should be excluded in any application or treated suitably, because it is extremely susceptible to powder-post beetle attack. The heartwood is used for a wide range of purposes such as light traffic flooring, door and window frames, planking, ceiling, interior trim, utility furniture and cabinet work, toys, turnery, boxes, and ship and boat building. Generally it is an excellent timber for joinery. It is often used locally when a good firmness is required. The wood is not very durable and therefore application in contact with the ground should be avoided. Yellow meranti is an excellent timber for plywood, both as face and core veneer. The wood is also very suitable for the manufacture of hardboard and particle board, and is used with good results as pulp for making paper. The species of yellow meranti produce a very dark, almost black dammar which is the darkest among dipterocarps. It is, however, of low grade but is sometimes used for torches. In former days the resin of some species was used for blackening teeth when this was a fashion. The bark of some species can be stripped and used to furnish house walls or it can be made into baskets and bins. Fruits are sometimes collected as 'illipe nuts'; they yield a fat which is used in cooking and for other purposes.

Production and international trade For Indonesia only export figures for meranti as a whole are available. The export of sawn meranti timber from Indonesia increased slightly from 1.3 million m^3 (with a value of US$ 249 million) in 1987, to 1.4 million m^3 (with a value of US$ 301 million) in 1989. Much more important in Indonesia is the production and export of plywood (estimated export value in 1990: US$ 3000 million), in which yellow meranti wood contributes a fairly important part, together with red meranti (which contributes the major part), keruing (*Dipterocarpus* spp.) and white meranti.

Yellow meranti is not an important export timber in Peninsular Malaysia. In 1981 the export of sawn yellow meranti was 13 000 m^3 (with a value of US$ 1.0 million) but it declined rapidly. In 1983 the export of sawlogs was 2000 m^3 (worth US$ 90 000). From then on, no export figures of yellow meranti as a separate trade group are available, but some yellow meranti is probably traded as 'mixed light hardwood'. In Sabah and Sarawak, yellow meranti ('yellow seraya') is much more important. In 1987 the export of round logs from Sabah was 890 000 m^3 (with a value of US$ 89 million), and in 1992 the export of logs was 170 000 m^3 and that of sawn timber 202 000 m^3 with a total value of US$ 67 million. No export statistics are available from other countries.

Properties Yellow meranti is a lightweight hardwood. The heartwood is light yellowish-brown, often with a greenish tinge, light brown with a yellowish tinge on exposure. The sapwood is moderately to clearly distinct from the heartwood, and is paler, often more yellow, but it becomes less distinct on exposure. The planed surface is without lustre, and a faint stripe figure is visible on the radial surface. The density is variable, (370–)480–675(–860) kg/m^3 at 15% moisture content. The grain of the wood is generally interlocked, texture moderately coarse to moderately fine (finer than other merantis) and even.

At 15% moisture content the modulus of rupture is 67–102 N/mm^2, modulus of elasticity 10 000–12 650 N/mm^2, compression parallel to grain 40–51 N/mm^2, compression perpendicular to grain 4–5 N/mm^2, shear 8–11 N/mm^2, cleavage 48–60 N/mm radial and 50–65 N/mm tangential, Janka side hardness 3290–3850 and Janka end hardness c. 4300 N.

The rates of shrinkage are fairly low to moderate, from green to 15% moisture content 0.9–1.2% radial and 3.1–3.8% tangential, and from green to 12% moisture content 2.2–2.5% radial and 6.5–7.5% tangential. Yellow meranti dries fast to moderately slowly and with few defects. The air drying of 15 mm and 40 mm thick boards takes about 3 months and 5 months, respectively. In Malaysia kiln-drying schedule J is recommended. Usually the timber dries well without any serious degrade, but the drying of boards over 50 mm thick is more difficult.

Yellow meranti is easy to resaw, cross cut, plane, bore and turn. The planed surface is generally smooth, but bored surfaces of air-dried timber are rough and turned surfaces slightly rough, probably because of the presence of interlocked grain. In general, yellow meranti has better working properties than white meranti (largely owing to the absence of silica), although there is some difference between species, depending on the density of the wood. The nailing characteristics are rated as poor to satisfactory. It is recommended to fill the pores before painting or varnishing. Yellow meranti can be peeled satisfactorily if the logs are free from defects such as knots, brittle heart or decay. Dried veneer is almost flat and the gluing properties are rated as good. The veneer is suitable for face and core veneer. Gluing with urea-formaldehyde produces plywood which meets the German standard. Particle board of density above 610 kg/m^3 and made with 8% resin and 1% wax can meet the requirements stipulated in the British standard.

Yellow meranti is not a durable timber. Graveyard tests conducted in Malaysia indicated an average service life of stakes in contact with the ground of 1.9 years for *S. multiflora* and only 1.1 years for *S. longisperma*. In temperate regions the average service life in contact with the ground is moderate, 10–15 years. The timber is susceptible to attack by dry-wood termites, and slightly susceptible to pinhole borers, but pinholes are less common than in other merantis. In general, yellow meranti is very difficult to treat with preservatives. Using an equal mixture of creosote and diesel fuel in the open tank treatment, the average absorption for *S. longisperma* wood is only 42 kg/m^3 and for wood of *S. multiflora* even less, 19 kg/m^3. The full-cell pressure treatment with copper-chrome-arsenic gives an average absorption of 180 kg/m^3 at a solution strength of 3%.

Wood of *S. gibbosa* contains 52% cellulose, 29% lignin, 16% pentosan, 1% ash and no silica. The solubility is 6.3% in alcohol-benzene, 0.8% in cold water, 3.2% in hot water and 14.1% in a 1% NaOH solution. The energy value is 18 400 kJ/kg.

Description Medium-sized to very large trees up to 60(–75) m tall; bole straight, cylindrical, branchless for up to 35(–45) m and with a diameter of up to 150(–300) cm; buttresses prominent, up to 4(–6.5) m high; bark surface usually appearing scaly, grey or light brown, outer bark fairly thin, chocolate brown, inner bark dull yellowish-brown, exuding a dark brown or blackish resin; mature crown hemispherical or dome-shaped, sympodial. Leaves alternate, simple, entire, glabrous, pinnately veined with scalariform tertiary venation, often glaucous on the lower surface; stipules minute, fugacious. Inflorescence terminal or axillary, paniculate, bracts minute. Flowers secund or distichous, bisexual, 5-merous, actinomorphic, scented; calyx lobes free, hirsute; petals narrow, connate at base, bright to pale yellow, the outer surface hirsute; stamens usually 15, the anthers with 2 pollen sacs, broadly oblong to subglobose, the prominent appendages scabrous towards the apex; ovary usually surmounted by a stylopodium, tomentose, style shorter than the ovary. Fruit usually shortly stalked with the calyx lobes subequal or the outer 3 much elongated, these more or less thickened and saccate at base; nut 1-seeded, free from the calyx, subglobose to ovate, sharply pointed. Seedling with epigeal germination; pericarp splitting irregularly; cotyledons pale yellow or reddish; first two leaves opposite, subsequent leaves arranged spirally, often larger than those on mature trees.

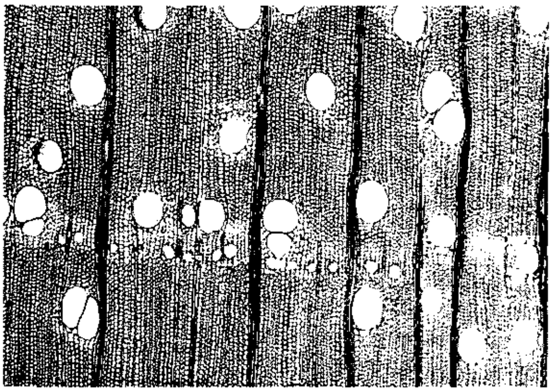
Wood anatomy

– Macroscopic characters:

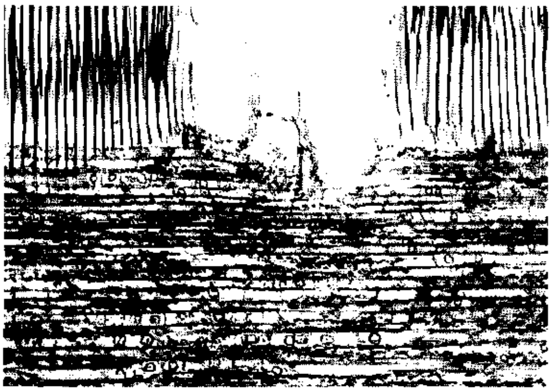
Heartwood pale yellow or light yellowish-brown, often with a greenish tinge, darkening with age, often to light brown with a yellowish tinge; sapwood moderately to clearly distinct from the heartwood, lighter in colour, and in logs often demarcated by staining and dark dammar exudation. Grain usually interlocked but not very deeply so, sometimes wavy. Texture moderately coarse or moderately fine and even; figure inconspicuous, but mottled ray figure occurring on quarter-sawn faces and also a faint ribbon figure occurs due to the interlocked grain. Freshly cut wood smells strongly of tannin. Growth rings indistinct or absent; vessels rather few to moderately numerous, visible to the naked eye, mostly open; parenchyma rather sparse to moderately abundant, fairly distinct, forming dull yellow borders around the pores similar to white meranti but less markedly aliform; rays rather few, dull yellow, visible to the naked eye. Ripple marks usually absent or indistinct to the naked eye. Intercellular canals in more or less long concentric lines on transverse surfaces, usually considerably smaller than the vessels and not visible to the naked eye (but sometimes as large as or larger than the vessels, e.g. in *S. balanocarpoides*, *S. faguetiana* and *S. xanthophylla*), filled with white or yellowish-white contents.

– Microscopic characters:

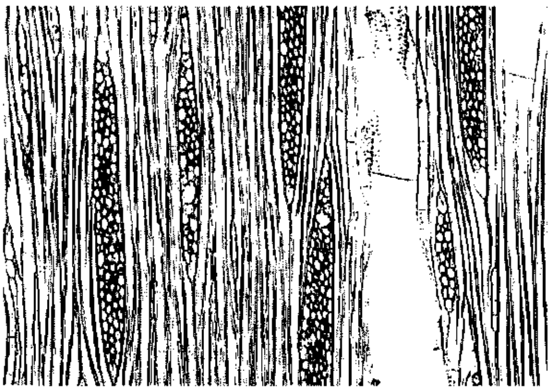
Growth rings indistinct or absent. Vessels diffuse, (2–)6–8(–18)/mm^2, predominantly solitary but oc-



transverse section (×25)



radial section (×75)



tangential section (×75)

Shorea xanthophylla (yellow meranti)

casionally in radial or oblique groups of 2–3, rarely in clusters of 4 (*S. xanthophylla*), round to slightly oval, (80–)200–250(–300) μm in tangential diameter; perforation plates simple; intervessel pits alternate, vestured, 2.5 μm; vessel-ray pits and vessel-parenchyma pits large (over 10 μm in diameter), round and gash-like; tyloses absent or sparse. Fibres on average 1150 μm long, non-septate, thin- to moderately thin-walled, sometimes moderately thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma predominantly paratracheal, consisting of mostly complete or incomplete sheaths to the vessels, in some specimens distinctly aliform and confluent (especially around vertical resin canals, e.g. in *S. hopeifolia*); apotracheal parenchyma enclosing the vertical resin canals and occasionally occurring as short fine lines; diffuse parenchyma infrequent. Rays 4–9(–12)/mm, commonly multiseriate (3–10-seriate, mostly 3–5-seriate), uniseriate rays sometimes present, 15–140 μm wide, 280–4000 μm high, in most species Kribs type heterogeneous II and III mixed; sheath cells present in *S. faguetiana*, absent in other species. Prismatic crystals present in some axial parenchyma cells and ray cells. Silica bodies absent. Radial intercellular canals present, quite fine. Axial canals mostly arranged in long tangential series or lines (but usually shorter than in red meranti); sometimes diffuse canals present, with white contents.

Species studied: *S. acuminatissima, S. balanocarpoides, S. faguetiana, S. gibbosa, S. hopeifolia, S. multiflora, S. xanthophylla*.

In addition to the wood colour and lack of lustre, yellow meranti differs from white meranti in the presence of radial intercellular canals and the absence of silica.

Growth and development The growth rates differ considerably between species: *S. maxima* trees can reach a diameter of 37 cm at an age of 40 years and *S. multiflora* 41 cm, whereas *S. balanocarpoides* and *S. longisperma* grow faster and can reach a diameter of 54 cm and 57 cm, respectively, in 40 years. Experiments in Malaysia showed that *S. maxima* and *S. multiflora* are probably self-incompatible.

Other botanical information Anatomical features of the wood and bark provide useful evidence for the classification of species at infrageneric level. The division of the genus *Shorea* into 4 major timber groups (balau, red meranti, white meranti and yellow meranti) coincides in broad outline with the division of the genus into botanical sections. Timbers of the yellow meranti group belong to the section *Richetioides* Heim.

Ecology *Shorea* species are confined to tropical humid climates with an average annual rainfall exceeding 1600 mm and with less than 6 dry months. Most species occur below 1000 m altitude. The largest numbers of species and of individuals are found on deep, well-drained yellow or red soils in the lowland. Yellow meranti is confined to the aseasonal wet forests, below 1400 m altitude.

Propagation and planting Seeds rapidly lose their viability. Usually the germination rate of fresh seeds is 80–90% but viability is lost within about 12 days. Fresh seeds of *S. maxima* have a germination rate of 95% and they can be stored for 14 days at temperatures of 4–14°C maintaining more than 50% germination. Seeds of other species (e.g. *S. faguetiana, S. hopeifolia, S. longisperma* and *S. multiflora*) can survive at 4°C for about one month; however, chilling injury slowly develops and finally kills the seeds. As in other merantis, stem cuttings can probably be used for propagation, but no experiments on methods of vegetative propagation have been conducted on yellow meranti. When planted into the forest the usual planting distance is 3 m × 3 m.

Silviculture and management Natural regeneration of yellow meranti may be abundant. For instance, seedlings of *S. polyandra* may dominate the regeneration in primary and undisturbed forest in South Kalimantan, together with those of *Eusideroxylon zwageri* Teijsm. & Binnend. In logged-over forest, regeneration of *S. polyandra* is much less; the most commonly occurring seedlings in such forests belong to *Dipterocarpus cornutus* Dyer and *Sindora leiocarpa* Backer ex K. Heyne. This means that enrichment planting with yellow meranti seedlings may be necessary in logged-over forest to ensure an acceptable yield of yellow meranti in the future.

Locally, the density of *S. gibbosa* trees in East Kalimantan has been established at 0.6 trees/ha.

Diseases and pests Many animals such as wild boars, squirrels and various kinds of insects feed on seeds and young plants. The beetle *Alcidodes dipterocarpi* has been reported to cause serious damage to seeds of *S. faguetiana*.

Harvesting Yellow meranti logs usually float in water and can be transported by river. In mixed dipterocarp forest in Indonesia, trees over 50 cm in diameter are harvested, leaving at least 25 healthy trees/ha of 20–49 cm in diameter for future cuts.

Genetic resources Just as in other meranti trade groups, yellow meranti includes common and widely distributed species (e.g. *S. balanocarpoides, S. faguetiana, S. multiflora*) as well as species which occur only locally or scattered (e.g. *S. longiflora, S. maxima*). This may easily lead to endangerment of species if large-scale logging without distinction at species level is practised.

Prospects By comparison with red meranti and white meranti, not much is known about the propagation, planting and silviculture of yellow meranti. Some species grow fairly fast and their timber is of good quality, which seems a justification for more research on propagation techniques and silvicultural aspects.

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Selection of species

Shorea acuminatissima Sym.

Gard. Bull. Str. Settl. 9: 340, pl. 23 (1938).

Vernacular names Brunei: damar hitam runching. Indonesia: damar pakit (northern Kalimantan), kalepek (East Kalimantan), pakit ketuyung (South Kalimantan). Malaysia: barun runching, lun runching (Sarawak), seraya kuning runching (Sabah).

Distribution Borneo.

Uses The timber is used as yellow meranti.

Observations A very large tree up to 76 m tall with tall bole up to 190 cm in diameter, and buttresses up to 2 m high, bark closely square-section fissured, with narrow flat ridges; leaves ovate, 7–10 cm × 3–4 cm, with 9–12 pairs of secondary veins scabrid tomentose beneath, petiole 10–15 mm long; stamens 15, stylopodium narrowly ovoid; larger fruit calyx lobes up to 6 cm × 1.3 cm. *S. acuminatissima* occurs on clayey soils, on hills and ridges usually near the coast and up to 500(–1400) m altitude. The density of the wood is 350–700 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 253, 476, 748.

Shorea balanocarpoides Sym.

Gard. Bull. Str. Settl. 9: 330 (1938).

Synonyms *Balanocarpus pahangensis* Foxw. (1932), *Shorea dolichocarpa* v. Slooten (1956).

Vernacular names Brunei: damar hitam gondol. Malaysia: damar hitam katup, damar katup, merawan lampong (Peninsular).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as yellow meranti. Fruits are collected locally as illipe nuts.

Observations A small to large tree up to 45 m tall with bole up to 65 cm in diameter, and small buttresses up to 1 m high; leaves oblong to broadly ovate, usually with an unequal base, 6–12 cm × 2–7 cm, with 5–7 pairs of secondary veins, glabrous, petiole 10–20 mm long; stamens 15, stylopodium conical; fruit calyx lobes equal, up to 5 mm long. *S. balanocarpoides* is fairly common on yellow sandy loam on undulating country and ridges up to 700 m altitude. The density of the wood is 630–865 kg/m^3 at 15% moisture content.

Selected sources 30, 102, 253, 258, 514, 677, 745, 748.

Shorea blumutensis Foxw.

Mal. For. Rec. 10: 236, pl. 20 (1932).

Vernacular names Indonesia: riung daun lebar, temberas (north-eastern Sumatra). Malaysia: meranti kelim (Peninsular).

Distribution Peninsular Malaysia and north-eastern Sumatra.

Uses The timber is used as yellow meranti.

Observations A medium-sized tree up to 35 m tall with bole of 60 cm or more in diameter, twigs fulvous-tomentose; leaves elliptical-lanceolate, 8–17 cm × 3–6.5 cm, with 14–16 pairs of secondary veins, lower surface shiny, petiole 12–22 mm long; stamens 15, stylopodium narrowly ovoid; larger fruit calyx lobes up to 9 cm × 1.8 cm. *S. blumutensis* occurs in lowland dipterocarp forest up to 500 m altitude. The density of the wood is 870–910 kg/m^3 at 15% moisture content.

Selected sources 253, 258, 677, 748.

Shorea faguetiana Heim

Bull. Mens. Soc. Linn. Paris 2: 975 (1891).

Synonyms *Shorea ridleyana* King (1893) p.p.

Vernacular names Indonesia: bangkirai guruk, karambuku lahung, paramuku (South Kalimantan). Malaysia: damar (hitam) siput (Peninsular), lun siput (Sarawak), seraya kuning siput (Sabah). Thailand: kalo.

Distribution Peninsular Thailand, Peninsular Malaysia and Borneo.

Uses The timber is used as yellow meranti. Lighter-coloured forms are sometimes traded as white meranti. The dammar is of a fairly good quality and is used locally for torches, e.g. in Sumatra. Illipe nuts may be collected from the trees.

Observations A medium-sized to large tree up to 60 m tall with bole up to 145(–175) cm in diameter, and short stout buttresses up to 1.5 m high; leaves elliptical to oblong-lanceolate or ovate, 7–12 cm × 3–5 cm, with 9–12 pairs of secondary veins, glabrous, petiole 10–15 mm long; stamens 15, stylopodium conical; larger fruit calyx lobes up to 6 cm × 1.2 cm. *S. faguetiana* is common on well-drained clay soils on undulating land and especially ridges at 150–700(–1000) m altitude. The density of the wood is 400–835 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 162, 253, 258, 297, 344, 417, 461, 476, 601, 628, 677, 748.

Shorea gibbosa Brandis

Journ. Linn. Soc. Bot. 31: 99 (1895).

Synonyms *Hopea grisea* Brandis (1895).

Vernacular names Brunei: lun gajah. Indonesia: damar buah, damar buah hitam gelung (southern Sumatra), mereng-kuyung (West Kalimantan). Malaysia: damar hitam gajah (Peninsular), lun gajah (Sarawak), seraya kuning gajah (Sabah).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as yellow meranti. *S. gibbosa* is a source for illipe nuts.

Observations A very large tree up to 75 m tall with bole branchless to a fair height and up to 160 cm in diameter, with large buttresses up to 5 m high, twigs silvery-brown, striate; leaves ovate, 5–13 cm × 2–6 cm, papery, with 7–9 pairs of secondary veins, petiole 8–12(–16) mm long; stamens 15, stylopodium indistinct; larger fruit calyx lobes up to 9 cm × 2 cm. *S. gibbosa* is locally common on flat or undulating land with deep clay-rich soils up to 650 m altitude. The density of the wood is 400–815 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 100, 253, 258, 476, 677, 748.

Shorea hopeifolia (Heim) Sym.

Gard. Bull. Str. Settl. 8: 150, pl. 46 (1933).

Synonyms *Shorea ridleyana* King (1893) p.p., *Hopea albescens* Ridley (1916), *Shorea kalunti* Merr. (1925).

Vernacular names Brunei: lun siput jantan. Indonesia: damar kunyit (general), karambuku (South Kalimantan), sirantib limau manis (western Sumatra). Malaysia: damar (hitam) siput jantan (Peninsular), lun jantan (Sarawak), seraya kuning jantan (Sabah). Philippines: kalunti (general), manggasinoro (Tagalog).

Distribution Peninsular Malaysia, Sumatra, Borneo and the southern Philippines (Mindanao).

Uses The timber is used as yellow meranti.

Observations A very large tree up to 70 m tall with bole branchless for up to 35 m and up to 160 cm in diameter, with up to 4 m high buttresses; leaves ovate, 3.5–8 cm × 2–4 cm, papery, undulate, with pore-like domatia at the base beside the midrib, with 9–11 pairs of slender secondary veins; stamens 15, stylopodium absent; larger fruit calyx lobes up to 7 cm × 1.5 cm. *S. hopeifolia* occurs on clay-rich soils on undulating or hilly country, often near streams up to 600 m altitude. The density of the wood is 415–735 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 100, 175, 253, 258, 476, 579, 601, 677, 748.

Shorea laxa v. Slooten

Reinwardtia 3: 345 (1956).

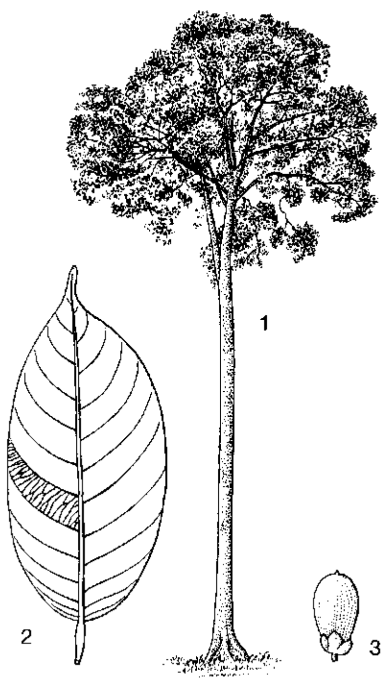
Synonyms *Shorea peltata* Browne (1955) non Sym.

Vernacular names Brunei: damar hitam timbul.

Distribution North-eastern Sarawak, Brunei and south-eastern Sabah.

Uses *S. laxa* yields locally one of the most valuable yellow meranti timber.

Observations A medium-sized to large tree up to 60 m tall with bole up to 160 cm in diameter,



Shorea laxa v. Slooten – 1, tree habit; 2, leaf; 3, fruit.

and prominent buttresses up to 2.5 m high; leaves ovate to elliptical, 7–14 cm × 4–9 cm, leathery, with 8–10 pairs of secondary veins, petiole 15–22 mm long; stamens 15, ovary and stylopodium ovoid-conical; fruit calyx lobes subequal, c. 1 cm long and broad. *S. laxa* occurs in mixed dipterocarp forest on hills near the coast, on sandy soils or ultrabasics.

Selected sources 30, 31, 89, 476, 745, 748.

Shorea longiflora (Brandis) Sym.

Gard. Bull. Str. Settl. 9: 330 (1938).

Synonyms *Balanocarpus grandifolius* Ridley ex Sym. (1934), *Balanocarpus longiflorus* Foxw. ex Sym. (1934).

Vernacular names Brunei: damar hitam paya. Malaysia: barun paya, lun paya, medang tiong (Sarawak).

Distribution Brunei, Sarawak and East Kalimantan.

Uses The timber is used as yellow meranti.

Observations A medium-sized to fairly large tree up to 35 m tall with bole up to 50 cm in diameter, and short buttresses; leaves narrowly ovate to lanceolate, 10–24 cm × 4–6 cm, with 12–15 pairs of secondary veins, petiole 10–12 mm long; stamens 15, stylopodium slender, glabrous; fruit calyx lobes subequal, up to 7 mm long. *S. longiflora* occurs scattered on shallow peat or yellow sandy soils up to 1000 m altitude.

Selected sources 30, 89, 258, 748.

Shorea longisperma Roxb.

Fl. Indica (Carey ed.) 2: 618 (1832).

Synonyms *Parashorea longisperma* (Roxb.) Kurz (1870), *Shorea resina-nigra* Foxw. (1932).

Vernacular names Indonesia: awang sih, kerambukuh (south-eastern Kalimantan), kepala tupe (eastern Sumatra). Malaysia: lun meranti (Sarawak), meranti damar hitam, senggai (Peninsular).

Distribution Peninsular Malaysia, eastern Sumatra and Borneo.

Uses The timber is used as yellow meranti. The sapwood produces a very dark dammar which is of little value but is sometimes used for torches and caulking boats.

Observations A very large tree up to 75 m tall with bole branchless for up to 30 m and up to 165 cm in diameter, with buttresses up to 5 m high; leaves elliptical to ovate, 7–12 cm × 2.5–6 cm, papery, with 10–13 pairs of secondary veins, lower surface pale grey-green pubescent, petiole 10–15 mm long; stamens 15, stylopodium pear-shaped; larger fruit calyx lobes up to 9 cm × 1.5 cm. *S. longisperma* occurs on fertile clay soils, especially on igneous and volcanic rocks up to 1400 m altitude. The density of the wood is 510–690 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 253, 258, 297, 417, 514, 601, 677, 748.

Shorea maxima (King) Sym.

Gard. Bull. Str. Settl. 9: 330 (1938).

Synonyms *Balanocarpus maximus* King (1893).

Vernacular names Malaysia: meranti bahru, meranti sengkawang puteh, resak (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as yellow meranti.

Observations A small to medium-sized tree up to 30 m tall, bole branchless for up 15 m and up to 65 cm in diameter, often not buttressed, branches twisted; leaves elliptical to lanceolate or rarely oblanceolate, 8.5–19 cm × 3.5–7 cm, glabrous, with 7–10 pairs of secondary veins, petiole 10–15 mm long; stamens 10, stylopodium absent; fruit calyx lobes subequal, up to 15 mm long. *S. maxima* occurs scattered on undulating land and hills up to 1300 m altitude. The density of the wood is 640–675 kg/m^3 at 15% moisture content.

Selected sources 102, 124, 253, 258, 318, 514, 677, 748, 811.

Shorea multiflora (Burck) Sym.

Gard. Bull. Str. Settl. 9: 330 (1938).

Synonyms *Balanocarpus penangianus* King (1893), *Balanocarpus latifolius* Brandis (1895), *Balanocarpus multiflorus* (Burck) Sym. (1933).

Vernacular names Brunei: tismantok. Indonesia: damar tanduk (general), meranti piangin (northern Sumatra), puting delatit (Kalimantan). Malaysia: banjutan (Sabah), damar hitam (Peninsular), lun damar hitam (Sarawak).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses *S. multiflora* is an important source of yellow meranti timber.

Observations A small to fairly large tree up to 40 m tall with bole branchless for up to 21 m and up to 115 cm in diameter, buttresses short or absent; leaves ovate-lanceolate, 4.5–7.5 cm × 2–3.5 cm, glabrous, with 8–10 pairs of secondary veins not prominent beneath, petiole 7–10 mm long; stamens (10–)15, stylopodium indistinct; fruit calyx lobes subequal, up to 5 mm long. *S. multiflora* is common in heath or mixed dipterocarp forest on low hills and ridges up to 700 m altitude. The density of the wood is 435–870 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 124, 253, 258, 297, 417, 461, 476, 514, 601, 677, 748.

Shorea polyandra P. Ashton

Gard. Bull. Sing. 22: 286, pl. 32 (1967).

Vernacular names Indonesia: damar jangkar, kelapeh pahit (Kalimantan). Malaysia: damar ketuyang, putang lenit, lodan (Sarawak).

Distribution Borneo.

Uses The timber is used as yellow meranti.

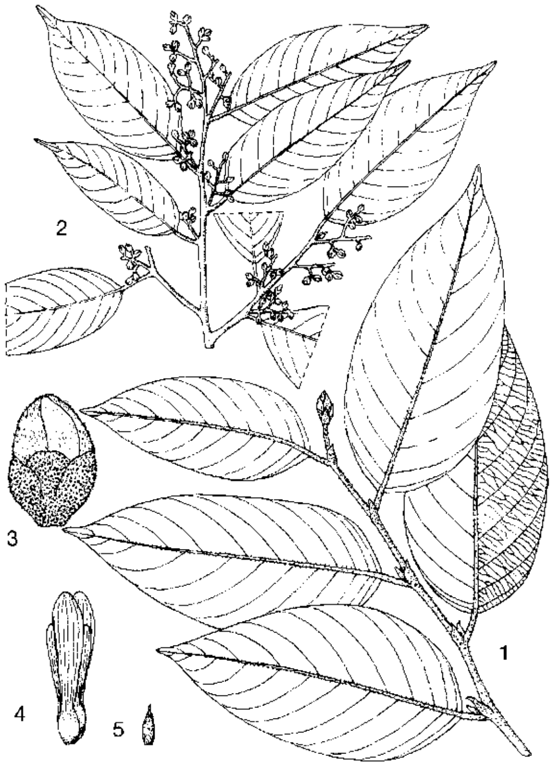
Observations A very large tree up to 70 m tall, buttresses prominent; leaves lanceolate, 8–13 cm × 3–5 cm, papery, with 11–14 pairs of secondary veins, petiole 14–20 mm long; stamens 102–107, anthers narrowly oblong, stylopodium absent; larger fruit calyx lobes up to 8 cm × 1.4 cm. *S. polyandra* is locally abundant on fertile clay-rich soils overlaying calcareous shales or igneous or volcanic rocks up to 600 m altitude.

Selected sources 258, 670, 748.

Shorea xanthophylla Sym.

Gard. Bull. Str. Settl. 9: 342, pl. 24 (1938).

Vernacular names Brunei: dammar hitam barun. Indonesia: nyagat (West Kalimantan). Ma-



Shorea polyandra P. Ashton – 1, sterile twig; 2, flowering twig; 3, flower bud; 4, fruit; 5, nut.

laysia: lun barung, lun kunyit (Sarawak), seraya kuning pinang (Sabah).

Distribution Northern Borneo.

Uses The timber is used as yellow meranti.

Observations A medium-sized to large tree up to 45 m tall with bole up to 65 cm in diameter, buttresses up to 1.5 m high; leaves oblong-lanceolate, 12–25 cm × 4–7 cm, thinly leathery, slightly bullate, with 9–13 pairs of secondary veins, lower surface shiny, petiole 8–15 mm long; stamens 15, stylopodium narrowly conical; fruit calyx lobes subequal, up to 7 mm long. *S. xanthophylla* occurs on low clay hills and hillsides in mixed dipterocarp forest up to 1000 m altitude. The density of the wood is 575–755 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 476, 745, 748.

K.M. Kochummen (general part),
W.C. Wong (properties),
J.M. Fundter (wood anatomy),
M.S.M. Sosef (selection of species)

Shorea Roxb. ex Gaertner f. (balau and red balau)

Fruct. 3: 47 (1805).

DIPTEROCARPACEAE

$x = 7$; $2n = 14$ for the majority of species; counts of $2n = 20$ for *S. obtusa* and $2n = 12$ for *S. siamensis* need confirmation.

Trade groups

- Balau: heavy hardwood, e.g. *Shorea laevis* Ridley, *S. materialis* Ridley, *S. maxwelliana* King and *S. scrobiculata* Burck.
- Red balau: heavy hardwood, e.g. *S. collina* Ridley, *S. guiso* (Blanco) Blume and *S. kunstleri* King.

The wood of *S. laevis* is often traded under the distinctive name 'bangkirai'. *Hopea* species with heavy wood (giam) are often traded as balau.

The timber of some species (e.g. *S. elliptica*, *S. kunstleri*) is either traded as red balau or red meranti, depending on the density of the wood. Hence, the distinction between those trade groups is not sharp.

Vernacular names

- Balau. Brunei: selangan batu. Indonesia: damar laut (Sumatra), anggelam (Kalimantan). Malaysia: selangan batu (Sabah, Sarawak). Philippines: malayakal, yakal, gisok. Burma: thitya. Cambodia: phchök. Thailand: takhian-samphon (Ranong), balao. Vietnam: c[af] ch[aws]c, s[ees]n.
- Red balau. Brunei: red selangan, selangan merah. Indonesia: balau merah. Malaysia: balau laut merah (Peninsular), selangan batu merah (Sarawak, Sabah), red selangan batu (Sabah). Philippines: guijo. Thailand: teng-tani (Lampang, Phrae), lantan (peninsular), chan. Vietnam: chai.

Origin and geographic distribution *Shorea* consists of about 194 species, 163 of which occur in Malesia. The genus is distributed from Sri Lanka and India through Indo-China towards Malesia. Within Malesia the species occur eastward towards the Moluccas. The genus is absent from the Lesser Sunda Islands but fossil wood has been recorded from Timor.

The species of balau and red balau are found from Sri Lanka and southern India through Indo-China and western Malesia. Within Malesia 38 species occur. The greatest diversity is in Borneo (27 species) followed by Peninsular Malaysia (18 species), Sumatra (10 species) and the Philippines (5 species).

Uses *Shorea* is economically the most important timber genus in the Asian humid tropics. Balau is particularly suited for all forms of heavy constructional work such as bridges, wharves, railway sleepers, telegraph and powerline posts, boat building and mine props. Its durability makes it particularly valuable in the tropics, where it can also be used in humid conditions and in contact with the ground. The timber is suitable for various applications in houses, such as wall plates, sills, floor joists, posts, beams, staircases, and door and window frames. It is often used for parquet floors or as a flooring timber, although only the heaviest grades are suitable for heavy duty industrial floors. Other applications of the timber are for launch keels and ribs, fence posts and gates, the framework of cars, railway carriages and wagons, motor lorries, vats and other containers, and joinery. Because of its often slippery surface when wet, it is not suited for ship decks. Being too hard and too dense, it is generally unsuitable for plywood and veneer manufacture, or for hardboard or pulp. When mixed with lighter material, the manufacture of satisfactory particle board is possible.

Red balau is generally less durable than balau; it is rated as moderately durable. Therefore applications of untreated material in contact with the ground or outdoors should be avoided. It is a timber for heavy and moderately heavy constructions and is regarded as a first class flooring and parquet timber with an exceptionally close and glossy surface. It is also a suitable timber for high grade utility furniture. Like balau, the wood is generally too dense for particle board and fibreboard, and its uncertain gluing property makes it less suitable for plywood and veneer.

Several species yield a dammar which is mostly of inferior quality and not useful for varnish. The dammar is, however, sometimes collected from natural exudations to form the main component of 'damar laut' which is used locally for making torches.

The fruits of many species can be boiled and eaten (mainly as famine food). A few species yield fruits from which a fat similar to cocoa butter is obtained (e.g. *S. seminis*). It is used in Europe for manufacturing chocolates and cosmetics and was formerly used in soaps, candles and tallow. The fruits are often called 'illipe nuts' which sometimes leads to confusion with the illipe nut from *Madhuca* spp. (*Sapotaceae*).

The bark and wood of some species (e.g. *S. robusta* Gaertner f., *S. obtusa* and *S. siamensis*) contains tannin.

Production and international trade No export figures for balau and red balau are available for Indonesia. The export of sawn balau timber from Peninsular Malaysia peaked in 1987 with 47 500 m^3 (worth US$ 6.4 million) falling to 27 000 m^3 (worth US$ 4.9 million) in 1990, and 17 500 m^3 (worth US$ 3.8 million) in 1992. In Peninsular Malaysia the price of exported sawn balau timber was US$ 115/m^3 in 1984 and US$ 220/m^3 in 1992. The export of sawn timber of red balau increased in Peninsular Malaysia from only 2400 m^3 (with a value of US$ 400 000) in 1983 to 12 000 m^3 (worth US$ 2.5 million) in 1989; in 1990 the export was 10 500 m^3 (worth US$ 1.8 million), and in 1992 5000 m^3 (worth US$ 1.2 million). The export of balau and red balau is more important in eastern Malaysia. In 1987 export of round logs of balau from Sabah was 526 000 m^3 (with a value of US$ 37.8 million), and of red balau was 33 000 m^3 (with a value of US$ 2.2 million); in 1992 the export of balau logs was 90 000 m^3 and of sawn timber 292 000 m^3 (with a total value of US$ 93 million), and the export of red balau logs was 12 500 m^3 and of sawn timber 750 m^3 (with a total value of US$ 1.5 million).

The export of balau and red balau has never been important in the Philippines. In 1987 21 000 kg processed timber of *S. astylosa* (worth US$ 9100) was exported.

Properties Balau is a heavy hardwood. The heartwood is yellowish- to reddish-brown when freshly cut, changing to red-brown, purple-brown or dark brown on exposure. The heartwood is moderately distinct from the sapwood, which is lighter and yellowish- to reddish- or purplish-brown. The radial section shows a stripe figure, the end surface shows a metallic lustre and is variably glossy. The density is (600–)850–1160 kg/m^3 at 15% moisture content. The grain of the wood is straight to spiral or interlocked, texture moderately fine to moderately coarse and even.

At 40% moisture content the modulus of rupture is 115–125 N/mm^2, modulus of elasticity 18 400–22 100 N/mm^2, compression parallel to grain 60–71 N/mm^2, compression perpendicular to grain 7.5–12.5 N/mm^2, shear 11.5–13 N/mm^2, cleavage 54–88 N/mm radial and 58–133 N/mm tangential, and Janka side hardness 8010–9520 N.

The rates of shrinkage are high when compared, for instance, to the otherwise very similar chengal (*Neobalanocarpus heimii* (King) P. Ashton): from green to 15% moisture content 1.5–2.7% radial and 3.1–3.9% tangential, and from green to oven dry c. 4.2% radial and 9.3% tangential. Balau

dries slowly with moderate to severe end checks and slight to severe splits; surface checks are moderate but the timber does not warp. The air drying of 15 mm and 40 mm thick boards takes about 4 months and 10 months, respectively. In Malaysia kiln-drying schedule B is recommended.
The working qualities of balau are rated as moderately difficult. Sawing properties are moderately easy to slightly difficult for green timber, but air-dried timber is slightly difficult to difficult to saw. Balau is easy to turn and gives a smooth finish. In green condition, it is easy to bore and the finishing is smooth, but boring of air-dried timber is slightly difficult. The planing properties in a green condition range from easy to slightly difficult, giving a smooth finish; the planing of air dried timber is more difficult. Among the species tested, *S. laevis* is the most easy to machine and *S. maxwelliana* the most difficult. The nailing property is rated as poor; the wood splits easily. Balau was found to be unsuitable for hardboard manufacture and for the production of veneer and plywood.
The heartwood is naturally durable, but the sapwood is liable to fungal infestation. In graveyard tests, untreated stakes (50 mm × 50 mm × 600 mm) of *S. maxwelliana* showed an average lifespan of 16 years and those of *S. laevis* of 7.5 years. Untreated railway sleepers of *S. laevis* and *S. glauca* lasted at least 15 years and 11 years, respectively, under tropical conditions. Laboratory tests in Indonesia showed that wood of *S. laevis* is resistant to wood-rotting fungi, but poorly resistant to dry-wood termites. The heartwood is difficult to treat with preservatives, but the sapwood is permeable.
Red balau is also a heavy hardwood. The heartwood is light to dark red-brown or purplish-red, darkening on exposure and losing much of its red colour, fairly distinct from the lighter sapwood (pink, greyish-brown). Planed surfaces occasionally show a stripe figure. The density is generally somewhat less than that of balau: (675–)750–880(–1090) kg/m^3 at 15% moisture content. The grain of the wood is deeply interlocked, texture moderately fine to slightly coarse and even. Generally speaking, red balau is slightly inferior to balau in mechanical properties and durability, but it is markedly superior to dark red meranti. At 55% moisture content the modulus of rupture is 84–105 N/mm^2, modulus of elasticity 13 700–19 000 N/mm^2, compression parallel to grain 43–58 N/mm^2, compression perpendicular to grain 5.5–9.5 N/mm^2, shear 9.5–10.5 N/mm^2, cleavage 67–75 N/mm radial and 77–93 N/mm tangential, and Janka side hardness 4490–6940 N.
The rates of shrinkage of red balau are comparatively high, but generally slightly less than those of balau: from green to 15% moisture content 1.4–2.2% radial and 3.2–3.6% tangential, and from green to oven dry 3.3–6.2% radial and 9.0–11.5% tangential. Red balau dries slowly with only slight seasoning defects. There may be slight cupping, bowing or springing, and moderate checking, slight splitting and surface checking may also occur. The air drying of 12 mm and 25 mm thick boards takes about 4 and 5 months, respectively. In Malaysia kiln-drying schedule G is recommended.
Red balau is usually easier to work than balau but the working qualities are rated as slightly difficult. It is slightly difficult to difficult to saw, but planing is easy, giving a smooth to slightly rough finish. Boring is easy to slightly difficult and turning is easy to difficult. The nailing property is rated from poor (for *S. kunstleri*) to good (*S. guiso* and *S. ochrophloia*).
The wood is moderately durable under exposed conditions and is subject to subterranean termite and fungal attack. In contact with the ground, stakes may last 2–7 years under tropical conditions; the average lifespan in contact with the ground of *S. guiso* wood in Indonesia is 7 years. Wood of *S. elliptica* and *S. guiso* was usually resistant to wood-rotting fungi in laboratory tests in Indonesia. The heartwood is very difficult to treat with preservatives.
The wood of *S. laevis* contains 53–58% cellulose, 24% lignin, 17% pentosan, 0.4–1% ash and 0.1–0.4% silica. The solubility is 3.0% in alcohol-benzene, 0.6–0.8% in cold water, 2.6–3.4% in hot water and 8.9–10.9% in a 1% NaOH solution. The energy value is 16 800–19 300 kJ/kg.

Description Medium-sized to very large trees up to 60(–75) m tall; bole straight, cylindrical, branchless for 6–25(–40) m and with a diameter of up to 180(–300) cm; buttresses prominent, up to 5 m high and very thin, growing away from the bole more or less spirally; bark surface longitudinally cracked or square-section fissured and usually flaky, shedding in thin, flat scales, grey, red or brown, outer bark usually comparatively thin, inner bark yellowish to greenish-yellow or red, exuding a clear, sticky, pale yellowish or brownish resin; crown hemispherical or dome-shaped, sympodial. Leaves alternate, simple, entire, glabrous, pinnately veined with scalariform tertiary venation, often glaucous on the lower surface; stipules and bracts small, fugaceous. Inflorescences terminal or axillary, paniculate. Flowers secund or distichous, bisexual, 5-merous, actinomorphic, scented; calyx lobes free, hirsute; petals free or connate at base, cream, often pink at base, the outer surface hirsute; stamens 15–60, the anthers with 4 pollen sacs, usually broadly oblong, both the appendages and pollen sacs usually barbate; ovary surmounted by a stylopodium, tomentose, style usually shorter than the ovary. Fruit usually shortly stalked with the outer 3 or rarely all calyx lobes much elongated, these more or less thickened at base and saccate, sometimes all calyx lobes short and subequal; nut 1-seeded, free from the calyx, subglobose to ovate, with a long beak. Seedling with epigeal germination; pericarp splitting irregularly; cotyledons reniform-sagittate, greenish-orange or red; first two leaves opposite, subsequent leaves arranged spirally, often larger than those on mature trees.

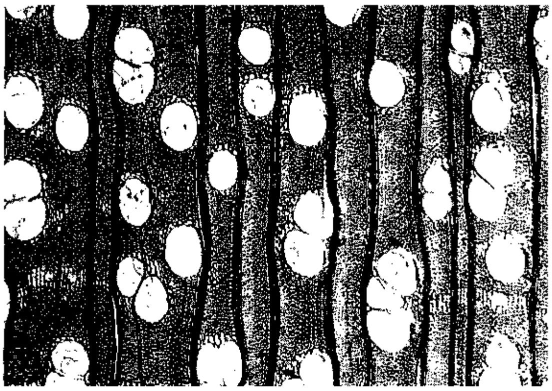
Wood anatomy

- Macroscopic characters:

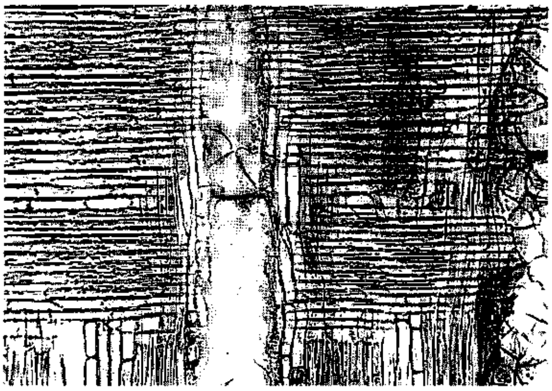
Heartwood yellowish- to reddish-brown when freshly cut, darkening to dark brown or dark purplish-brown on exposure, moderately distinctly demarcated from the lighter sapwood (yellowish-, red- or purplish-brown). Grain straight, spiral or interlocked. Texture varying from fine to coarse, generally moderately coarse to coarse; quartersawn surface often with a stripe figure, end grain shiny with a metallic lustre. Growth rings absent, but the long tangential bands of resin canals with white contents and the parenchyma associated with them may have the appearance of growth rings; vessels fairly evenly distributed, but with a tendency to form short, oblique lines mostly filled with tyloses, but without deposits, visible to the naked eye; parenchyma not distinct without a lens; rays visible to the naked eye but not conspicuous on the radial surface, containing brown deposits. Ripple marks mostly absent.

- Microscopic characters:

Growth rings absent. Vessels diffuse, 2–10(–14)/mm^2, mostly solitary but also in radial or oblique multiples of 2–4, round to oval, with a tangential diameter of 75–300 μm; perforations simple; intervessel pits alternate, dense and vestured, with an average diameter of 5–7 μm; vessel-ray and vessel-parenchyma pits large, round or gash-like, simple; helical thickenings absent; vessels mostly filled with tyloses. Fibres 900–1600 μm long, 14–16 μm in diameter, non-septate, walls 5–7 μm thick, pits minutely bordered, largely confined to the radial walls. Parenchyma scarce to moderate-



transverse section (×25)



radial section (×75)

tangential section (×75)

Shorea maxwelliana (balau)

ly abundant, occasionally abundant (e.g. in *S. exelliptica*, *S. falciferoides*, *S. foxworthyi*), mainly paratracheal consisting of narrow incomplete sheaths around the vessels, often distinctly aliform (e.g. in *S. laevis*), but sometimes (locally) confluent; apotracheal parenchyma diffuse and diffuse-in-aggregates or as concentric bands containing the vertical resin canals, as occasional terminal bands, and as short fine lines of varying widths. Rays 5–12/mm, mostly multiseriate, 3–4(–5)-seriate and frequently under 30 cells high (350–650 μm); uniseriate margins of rays typically only 1 or 2 cells high, with occasional margins 3–4 cells high; most of the rays similar (usually Kribs type heterogeneous II–III, rarely homogeneous). Crystalliferous axial parenchyma strands and/or ray cells with solitary prismatic crystals usually abundant. Silica bodies absent. Intercellular canals smaller than vessels and arranged in long or short concentric (tangential) bands filled with white resin.

Species studied: *S. astylosa*, *S. ciliata*, *S. exelliptica*, *S. falciferoides*, *S. foxworthyi*, *S. glauca*, *S. havilandii*, *S. inappendiculata*, *S. laevis*, *S. lumutensis*, *S. malibato*, *S. maxwelliana*, *S. scrobiculata*, *S. seminis*, *S. submontana*, *S. superba*.

Red balau differs from balau by its more reddish-brown colour, fewer tyloses, and often larger vessel diameter, from red meranti by its greater density, and usually more numerous rays. Balau differs from giam (heavy *Hopea* timber) particularly by less numerous vessels, broader rays and coarser texture.

Growth and development Optimal growth of seedlings of *S. materialis* in terms of increases in height, stem diameter, leaf area and overall dry matter was observed between 30–55% relative light intensities. Seedling growth of *S. laevis* is best under moderate shading and is considerably better than when grown in full sunlight or under heavy shading. As in all dipterocarps, mycorrhizae are essential for good growth. Research in the forest understorey showed that 42% of *S. maxwelliana* seedlings had no ectomycorrhizae. Infected seedlings are taller than seedlings without ectomycorrhizae. Once established, balau saplings are able to persist for a number of years in the understorey under heavy shade, but they need moderate to high light intensities for rapid growth. Balau-producing species grow slowly. Annual diameter growth of *S. siamensis* in Thailand is reported to be only 1–2 mm. In Peninsular Malaysia planted trees of *S. geniculata* and *S. scrobiculata* reached bole diameters of only 27 cm and 18 cm respectively in 40 years. The red balau *S. guiso* grows considerably faster; the annual girth increment of this species was 1.6–2.0 cm in Peninsular Malaysia. Other red balau-producing species also grow comparatively fast, e.g. *S. kunstleri* and *S. ochrophloia*, which may reach a bole diameter of 55 cm in 40 years. Large balau trees can be very old, several hundreds of years at least.

Regrowth from stumps does occur after coppicing, e.g. in *S. siamensis*. The best coppicing power is found in small trees (up to 20 cm in diameter). Coppice shoots grow well. Coppicing may be applied for firewood production.

Balau-producing species flower at irregular intervals of several years with varying intensity, though gregariously, like other *Shorea* species. In a year of heavy flowering, nearly all species in a given area flower. In Peninsular Malaysia and Borneo flowering may occur between March and July. In the Philippines the balau-producing trees usually flower from June to August.

Seed dispersal is usually only over short distances from the mother trees, generally not more than 30 m, as in other *Shorea* species.

Other botanical information Anatomical features of the wood and bark provide useful evidence for the classification of species at infrageneric level. The division of the genus *Shorea* into 4 major timber groups (red meranti, white meranti, yellow meranti, and balau and red balau) coincides in broad outline with the division of the genus into botanical sections. Timbers of the balau group belong to the sections *Shorea* and *Neohopea* P. Ashton. The section *Pentacme* (A.DC.) P. Ashton contains two species, *S. siamensis* and *S. contorta* S. Vidal. The first is classified as a balau; the second, however, is classified as a light red meranti, white meranti or a white lauan (this being the timber trade name for species of the genus *Parashorea*). The section *Pentacme* is botanically rather aberrant from the other sections.

Timber of the red balau group originates mostly from species in section *Shorea*. *S. elliptica* is placed within the section *Rubella* P. Ashton (red meranti timber) but the wood of this species is usually traded as a red balau. In terms of wood anatomy, this species resembles species of the section *Shorea*, which is in accordance with the trade classification. The timber of *S. kunstleri* and *S. inaequilateralis* Sym. is traded either as red balau or red meranti. However, these species belong in the section *Brachypterae* Heim, which otherwise includes red meranti timbers. The distincion between red balau and red meranti is not sharp. Several species may yield both types of timber (de-

pending on the density). Their classification in either one of the groups, as presented here, is debatable. *S. kunstleri* is treated as red balau, *S. inaequilateralis* as red meranti, together with some other species producing both types of timber (*S. albida*, *S. balangeran*).
The wood of several species of *Hopea*, of *Parashorea aptera* v. Slooten and of *Upuna borneensis* Sym. is sometimes traded as balau as well.
The timber of *S. robusta* ('sal') is much used in India.

Ecology *Shorea* species are confined to the tropics with average annual rainfall exceeding 1600 mm and a dry season of less than 6 months. Most species occur below 1000 m altitude. They reach the largest number of species and individuals per species on deep, well-drained soils in the lowland. Comparatively few species are restricted to a single vegetation type or substratum, whereas some species are common to gregarious in a certain habitat but are also found scattered in others. A few species are confined to specific edaphic habitats such as heath (kerangas) forest (e.g. *S. materialis*) or sandy soils (e.g. *S. falcifera*, *S. geniculata*).

Propagation and planting Trials on propagation of balau and red balau have been carried out occasionally. Like other *Shorea* species, the seeds lack dormancy. Experiments in Indonesia showed a maximum germination rate of 70% within 6 days for *S. laevis* seeds after 4 days of storage; the fruit wings were removed and the seeds were sown in shaded nursery beds. However, the survival rate of seedlings is usually low. A maximum of 40% was observed in seedlings of *S. astylosa* in the Philippines, transplanted when about 20 cm tall. Seedlings of *S. guiso* raised in the nursery had a survival rate of only 20%. Attempts to propagate *S. seminis* from cuttings in Malaysia failed. *S. guiso* and *S. seminis* are commercially propagated in East Kalimantan.

Silviculture and management Under selective cutting systems, natural regeneration may be good, at least locally, but is often unevenly distributed (e.g. *S. laevis*). If natural regeneration is inadequate, enrichment planting may be practised using seedlings 20–25 cm high from the forest or nursery. Since most species are slow growers, cutting cycles should be adequately long.

Diseases and pests Seeds and seedlings are regularly attacked by insects. The weevil *Nanophyes shoreae* has been reported to attack and destroy large numbers (more than 90%) of seeds of *S. laevis* in East Kalimantan. Feeding of insects on *S. maxwelliana* seedlings of 10–40 cm tall was found to be less severe than in some red meranti-producing species (*S. leprosula* Miq., *S. acuminata* Dyer), probably because of a higher content of essential oils in the former.

Yield The estimated average standing stock of balau in Indonesia is 4 m^3/ha for trees with a diameter exceeding 50 cm and 4.5 m^3/ha for trees with a diameter exceeding 35 cm.

Genetic resources Balau and red balau as timber groups include many species. Some of them occur widespread and gregariously (e.g. *S. guiso, S. laevis, S. maxwelliana*), but others are much less common or occur only locally (e.g. *S. collina, S. elliptica, S. falciferoides, S. geniculata, S. inappendiculata, S. lumutensis, S. malibato*). Since identification at species level is usually not made before logging, the latter group of species may be liable to genetic erosion or even extinction. Some species are threatened in specific areas and should be protected there, e.g. *S. materialis* and *S. scrobiculata* in Peninsular Malaysia.

Prospects The greatest species diversity of *Shorea* in general and of the balau and red balau groups in particular is found in lowland forest, which is threatened with clearence for agriculture and development projects. In order to protect the various *Shorea* species, immediate steps should be taken to preserve large tracts of lowland forest in different ecological habitats. In these reserves the forest should be kept free from any human disturbance.
Balau- and red balau-producing *Shorea* species are not promising for the establishment of plantations. The more quickly growing meranti-producing species, with lighter timber, are better suited for planting.

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Shorea laevis Ridl. dengan beberapa tahap lama penyimpahan buahnya [The effects of fruit wings separation and shade levels on the germination of Shorea laevis Ridl. seeds of various storage duration]. Laporan No 385. Lembaga Penelitian Hutan, Bogor. 20 pp. |7| Lopez, D.T., 1981. Malaysian timbers – red balau. Malaysian Forest Service Trade Leaflet No 45. Malaysian Timber Industry Board, Kuala Lumpur. 7 pp. |8| Lopez, D.T., 1983. Malaysian timbers – balau. Malaysian Forest Service Trade Leaflet No 78. Malaysian Timber Industry Board, Kuala Lumpur. 9 pp. |9| Martawijaya, A., Kartasujana, I., Kadir, K. & Prawira, S.A., 1986. Indonesian wood atlas. Vol. 1. Forest Products Research and Development Centre, Bogor. pp. 15–23. |10| Sandrasegaran, K., 1965. A note on the growth of Shorea guiso (Blanco) Bl. (membatu). Malayan Forester 28: 320–325.

Selection of species

Shorea astylosa Foxw.

Philipp. Journ. Sc., Bot. 13: 188, pl. 5 (1918).

Synonyms *Shorea ciliata* Foxw. (1918) non King.

Vernacular names Philippines: yakal (Tagalog, Bisaya), yakal mabolo (Tagalog).

Distribution The Philippines.

Uses The timber is used as balau for high-grade constructions. Wood extractives are reported to have tumour-inhibiting properties.

Observations A medium-sized tree up to 30 m tall with bole of up to 120 cm in diameter; leaves ovate, 6.5–12 cm × 2.5–6.5 cm with 8–9 pairs of secondary veins and a dark green petiole; petals narrow, stamens 32, ovary with prominent stylopodium. *S. astylosa* occurs locally in primary evergreen dipterocarp forest at low altitudes but is now endangered. The density of the wood is about 900 kg/m³ at 15% moisture content.

Selected sources 175, 258, 579, 748.

Shorea atrinervosa Sym.

Gard. Bull. Str. Settl. 10: 363, pl. 21 (1939).

Synonyms *Shorea collina* Foxw. (1932) non Ridley p.p.

Vernacular names Brunei: selangan batu hitam. Indonesia: resak bunga, meranti hursik, rikir minyak (Sumatra). Malaysia: balau hitam (Peninsular), selangan tukol (Sarawak), selangan batu hitam (Sabah).

Distribution Peninsular Malaysia, Sumatra and northern Borneo.

Uses The timber is used as balau. Illipe nuts are collected, although *S. atrinervosa* is not an important source.

Observations A large tree up to 50 m tall with bole up to 125 cm in diameter and buttresses up to 3 m high; leaves 8–16 cm × 3.5–9 cm, lower surface white lepidote and with black veins when dry; petals narrow, stamens 25–33 with barbate filaments; fruit calyx lobes unequal, larger three up to 11 cm × 2.5 cm. *S. atrinervosa* is locally common on undulating land and hillsides on clay-rich soils in mixed dipterocarp forest. The density of the wood is 770–1110 kg/m³ at 15% moisture content.

Selected sources 31, 89, 100, 253, 258, 677, 748.

Shorea ciliata King

Journ. As. Soc. Beng. 62(2): 118 (1893).

Vernacular names Malaysia: balau gunong, resak tempurong (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as balau.

Observations A fairly large tree with cylindrical bole and very short buttresses; leaves ovate-lanceolate, (4–)5–13(–17) cm × (1.5–)2.5–5(–8) cm, glaucous and smooth, with 9–11 pairs of secondary veins not prominent beneath; petals narrow, stamens 26–28; fruit calyx lobes unequal, larger three up to 6 cm × 1.5 cm. *S. ciliata* is fairly common on ridges and in hill forest at (300–) 800–1200 m altitude. The density of the wood is 960–1120 kg/m³ at 15% moisture content.

Selected sources 253, 258, 677, 748.

Shorea collina Ridley

Agric. Bull. Straits Fed. Malay States 9: 182 (1910).

Synonyms *Shorea angustiloba* Foxw. (1932).

Vernacular names Malaysia: balau bukit, tekam, terbak paya (Peninsular).

Distribution Eastern parts of Peninsular Malaysia.

Uses The timber is used as red balau.

Observations A medium-sized to fairly large tree up to 38 m tall with bole branchless for up to 27 m and a diameter of 100 cm and more; leaves broadly elliptical-oblong, 9–21 cm × 5–13 cm; petals narrow, stamens c. 55; fruit calyx lobes vestigial, unequal, the larger three up to 5 cm × 1.3 cm. *S. collina* occurs locally in the lowlands. The density of the wood is 865–1025 kg/m³ at 15% moisture content.

Selected sources 253, 258, 444, 677, 748.

Shorea elliptica Burck

Ann. Jard. Bot. Buitenzorg 6: 215 (1887).

Vernacular names Brunei: meranti lang. Indonesia: balau laut batu (general). Malaysia: meranti lang (Sarawak).

Distribution North-western Kalimantan and western Sarawak.

Uses The timber is used as red balau but is sometimes also traded as red meranti.

Observations A fairly large tree up to 40 m tall with bole up to 125 cm in diameter and buttresses up to 1.5 m high, bark deeply fissured; leaves elliptical to oblong, 7–10 cm × 4–9 cm, with 11–16 pairs of secondary veins prominent beneath, upper surface dark green, lower yellow or whitish; petals narrow, stamens 19–20; fruit calyx lobes unequal, larger three up to 8 cm × 1.5 cm. *S. elliptica* is locally common on leached or podzolic soils in mixed dipterocarp forest below 500 m altitude. The density of the wood is 820–1110 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 89, 258, 461, 748.

Shorea exelliptica Meijer

Acta Bot. Neerl. 12: 323, pl. 1 (1963).

Vernacular names Brunei: selangan batu tembaga. Malaysia: balau tembaga (Peninsular), selangan tembaga (Sarawak), selangan batu tembaga (Sabah).

Distribution Peninsular Malaysia and Borneo.

Uses The timber is used as balau.

Observations A medium-sized to very large tree up to 60 m tall, bole up to 95 cm in diameter, buttresses up to 1.5 m high, crown characteristically coppery; leaves oblong to broadly ovate, 9–15 cm × 3.5–7 cm, with 12–18 pairs of secondary veins prominent and purplish-brown scabrid tomentose beneath, lower surface golden to silver lepidote; petals narrow, stamens 30–40; fruit calyx lobes unequal, three larger ones up to 8 cm × 2.4 cm. *S. exelliptica* is fairly common on leached clay soils on undulating land, ridges and plateaux up to 600 m altitude. The density of the wood is 865–1045 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 677, 748.

Shorea falcifera Dyer ex Brandis

Journ. Linn. Soc. Bot. 31: 86 (1895).

Synonyms *Shorea flava* Meijer (1963), *Shorea glauca* Browne (1955) non King p.p.

Vernacular names Malaysia: selangan batu kering (Sarawak).

Distribution East coast of Peninsular Malaysia, north-eastern Sumatra and Sarawak.

Uses The wood is an important source of balau.

Observations A medium-sized to large tree up to 45 m tall with bole up to 160 cm in diameter and buttresses up to 1.5 m high; leaves narrowly ovate, 6.5–12 cm × 2.5–5 cm, lower surface white, with about 10 pairs of secondary veins and an unequal base; petals narrow, stamens 33–34 with barbate filaments; fruit calyx lobes unequal, larger three up to 9.5 cm × 1.8 cm. *S. falcifera* is locally abundant on rocky or sandy hills or flat land near the coast up to about 600 m altitude. The density of the wood is 970–1130 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 258, 474, 748.

Shorea falciferoides Foxw.

Philipp. Journ. Sc., Bot. 13: 189 (1918).

Synonyms *Shorea gisok* Foxw. (1938), *Shorea glaucescens* Meijer (1963), *Shorea balangeran* S. Vidal (1885) non (Korth.) Burck.

Vernacular names Brunei: selangan batu daun nipis. Malaysia: selangan batu laut (Sabah). Philippines: pamayauasan, yakal yamban, yakal gisok (Tagalog).

Distribution The Philippines and Borneo.

Uses The timber is used as balau.

Observations A very large tree up to 60 m tall with bole of up to 180 cm in diameter and prominent buttresses up to 3 m high; leaves broadly ovate or ovate-falcate, thin, 10–18 cm × 4.5–8 cm, with a subequal base and 9–12 pairs of secondary veins, lower surface cream-brown; petals narrow, stamens c. 45, with glabrous filaments; fruit calyx lobes unequal, larger three up to 9.5 cm × 2.2 cm. *S. falciferoides* occurs usually scattered on clay spurs, ridges and hillsides on clay-rich soils in mixed dipterocarp forest, up to 1000 m altitude. The wood has a density of 835–950 kg/m^3 at 15% moisture content.

Selected sources 30, 100, 175, 258, 474, 748.

Shorea foxworthyi Sym.

Gard. Bull. Str. Settl. 8: 272, pl. 19 (1935).

Synonyms *Shorea collina* Foxw. (1927) non Ridley.

Vernacular names Brunei: selangan batu bukit. Indonesia: amperok, lukan (Kalimantan), damar laut daun besar (Sumatra). Malaysia: balau bukit (Peninsular), selangan batu bersisek (Sabah), selangan batu kuning (Sarawak). Thailand: takien rak (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia, north-eastern Sumatra and Borneo.

Uses The wood is an important source of balau.

Observations A very large tree up to 60 m tall with bole up to 125 cm in diameter and tall buttresses up to 4.5 m high, branches golden-tawny pubescent; leaves elliptical, 8–13 cm × 3–6.5 cm, with 10–14 pairs of secondary veins very prominent beneath; petals narrow, stamens 32–41, filaments barbate; fruit calyx lobes large, unequal, larger three up to 10 cm × 2.5 cm. *S. foxworthyi* prefers low-lying, undulating land or hills below 700 m altitude and sandy clay soils. The density of the wood is 855–1090 kg/m^3 at 15% moisture content.

Selected sources 31, 253, 258, 628, 677, 748.

Shorea geniculata Sym. ex P. Ashton

Gard. Bull. Sing. 19: 291, pl. 19 (1962).

Vernacular names Brunei: upun penyau (Dusun). Malaysia: selangan penyau (Sarawak).

Distribution Brunei and Sarawak.

Uses The timber is used as balau. It is regarded as being the hardest and heaviest balau in Brunei.

Observations A large tree up to 50 m tall with bole up to 175 cm in diameter and prominent buttresses up to 3.5 m high; leaves broadly ovate to suborbicular, 11–17 cm × 7–13 cm, with 9–11 pairs of secondary veins becoming black upon drying, lower surface cream lepidote, petiole 4–6 cm long; petals narrow, stamens c. 55; fruit calyx lobes equal, about 1.5 cm × 1.5 cm, nut large, up to 5 cm × 5 cm. *S. geniculata* occurs very locally on deeply leached yellow soils in mixed dipterocarp forest on hills and ridges at low altitudes.

Selected sources 30, 89, 258, 748.

Shorea glauca King

Journ. As. Soc. Beng. 62(2): 117 (1893).

Vernacular names Indonesia: balau bunga, rasak pai, semantok lungkik (western Sumatra). Malaysia: balag tiong, damar laut daun besar, selimbar (Peninsular). Thailand: ek, ku-be (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and western Sumatra.

Uses The timber is used as balau. Old specimens exude a dammar which is purer than that of many other *Shorea* species.

Observations A medium-sized to large tree up to 50 m tall with cylindrical bole branchless for 18–27 m and 120–160(–250) cm in diameter and with prominent buttresses; leaves ovate to lanceolate, 6–15 cm × 2.3–9 cm, thin, with 7–10 pairs of secondary veins hardly raised beneath, lower surface glaucous; petals short, elliptical-oblong, stamens c. 60, with barbate appendages; fruit calyx lobes unequal, larger three up to 7 cm × 1.8 cm. *S. glauca* occurs locally and often semi-gregariously, especially on rocky slopes and ridges, from sea-level up to 500(–600) m altitude. The density of the wood is 840–1135 kg/m^3 at 15% moisture content. See also the table on wood properties.

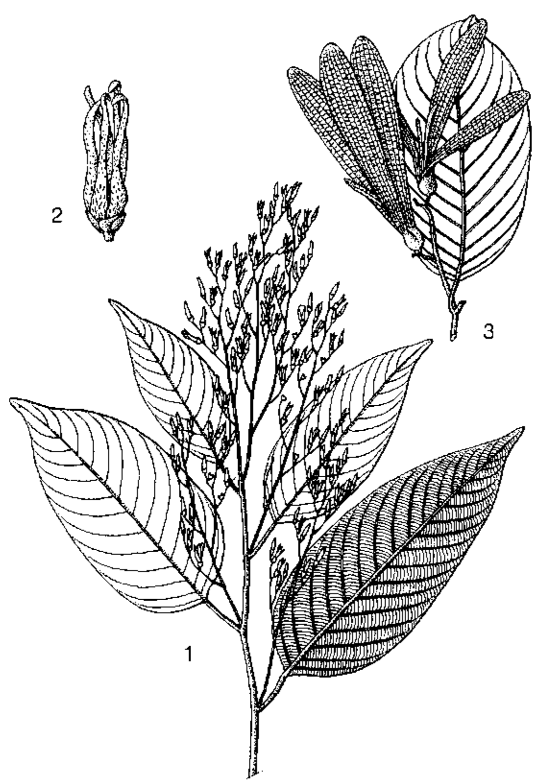
Selected sources 102, 253, 258, 297, 318, 417, 446, 628, 677, 748.

Shorea guiso (Blanco) Blume

Mus. Bot. Lugd.-Bat. 2: 34 (1852).

Synonyms *Shorea vulgaris* Pierre ex Lanessan (1886), *Isoptera burckii* Boerl. (1901).

Vernacular names Indonesia: beraja, damar kenuar batu (Sumatra), damar tampih (Kalimantan). Malaysia: balau, membatu (Peninsular), selangan batu merah (Sabah). Philippines: guijo (Tagalog), taralai (Tarlac), yamban-yamban (Zambales). Cambodia: choë(r) chông, phchŏk, kâm'lé:ng. Laos: chik dông, ningz, s'i:. Thailand: tengtani, phayom, (northern), chan ditaek (south-eastern), kalantan (peninsular). Vietnam: ch[of] d[oof]ng, ch[of] n[us]i.



Shorea guiso (Blanco) Blume – 1, flowering twig; 2, flower; 3, fruiting twig.

Distribution Cambodia, Laos, Vietnam, Thailand, Peninsular Malaysia, Sumatra, Borneo and the Philippines.

Uses The timber is used as red balau especially in the Philippines. Because of its comparatively low density, it cannot be used for the heaviest constructional purposes.

Observations A medium-sized to very large tree up to 60 m tall with cylindrical bole branchless for 15–25 m and up to 200(–300) cm in diameter with prominent buttresses up to 3 m high; leaves oblong-lanceolate, 5.5–14 cm × 2.5–6 cm, thinly leathery, with (11–)15–19 pairs of secondary veins; petals narrow, stamens 20–28, the appendages with few bristles; fruit calyx lobes unequal, up to 5.5 cm × 1 cm, nut up to 8 mm × 5 mm. *S. guiso* is most common in areas with a slightly seasonal climate. It occurs on well-drained red soils in lowland forest up to 600 m altitude, although it is confined to limestone hills in western and central Borneo. The density of the wood is 675–1000 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 31, 89, 175, 258, 297, 417, 444, 472, 476, 483, 497, 595, 628, 677, 748.

Shorea havilandii Brandis

Journ. Linn. Soc. Bot. 3: 82 (1895).

Vernacular names Brunei: selangan batu pinang, tengkawang ayer. Malaysia: selangan pinang, enkabang pinang (Sarawak), selangan batu pinang (Sabah).

Distribution Brunei, Sarawak and eastern Sabah.

Uses The timber is used as balau.

Observations A small to medium-sized tree up to 30 m tall with bole up to 50 cm in diameter and small buttresses up to 0.7 m high; leaves ovate-elliptical, 8–16 cm × 3.5–6 cm, thinly leathery, upper surface dark purplish to wine-red and pubescent along the midrib, lower surface dull khaki-grey, petiole 8–12 mm long; petals narrow, stamens 30–50, the appendages with a single bristle; fruit calyx lobes subequal, short, up to 10 mm × 8 mm. *S. havilandii* is locally common in heath forest and freshwater swamp forest on sandy soils and peat overlying limestone. The density of the wood is about 1090 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 258, 748.

Shorea inappendiculata Burck

Ann. Jard. Bot. Buitenzorg 6: 206 (1877).

Vernacular names Indonesia: damar laut daun besar, damar laut kuning (eastern Sumatra). Malaysia: damar pangin, pelepak, pelepak gunong (Sabah).

Distribution Peninsular Malaysia (north-western Johor only), Sumatra (Langkat only) and Borneo (from Sarawak to eastern Sabah).

Uses The timber is used as balau, especially for boats and houses.

Observations A medium-sized to fairly large tree up to 40 m tall with bole up to 65 cm in diameter and large buttresses; leaves oblong-elliptical, (7–)10–16 cm × (2–)3–8 cm, with 13–24 pairs of secondary veins distinctly depressed above and prominent beneath, lower surface whitish lepidote, petiole 1.5–2.6 cm long; petals narrow, stamens 28–34; fruit calyx lobes unequal, larger three up to 13 cm × 3 cm. *S. inappendiculata* occurs uncommonly on coastal hills in lowland mixed dipterocarp forest. The density of the wood is about 865 kg/m^3 at 15% moisture content.

Selected sources 31, 89, 100, 258, 476, 748.

Shorea kunstleri King

Journ. As. Soc. Beng. 62(2): 116 (1893).

Vernacular names Brunei: damar laut merah. Indonesia: benuas lebar daun (general), empatah tanduk (West Kalimantan), tuyang (East Kalimantan). Malaysia: balau laut merah (Peninsular), selangan merah (Sarawak), seraya sirap (Sabah).

Distribution Peninsular Malaysia, northern Sumatra and Borneo.

Uses The timber is an important source of good quality red balau or red meranti, depending on the density of the wood.

Observations A very large tree up to 60 m tall with bole branchless for 20–34 m and up to 190 cm in diameter, buttresses up to 1.5 m high; leaves broadly ovate, frequently twisted to one side, 8–12 cm × 4.5–7 cm, leathery, with 6–8 pairs of secondary veins hardly raised beneath, usually completely glabrous, petiole geniculate; petals narrowly lanceolate, stamens 15, the appendages more than twice as long as anthers; fruit calyx lobes unequal, larger three up to 8.5 cm × 1.8 cm. *S. kunstleri* occurs locally on leached sandy clay soils on flat land, low hills and ridges up to 800 m altitude, sometimes on ultrabasic soils. The density of the wood is often comparatively low, varying from 610–1090 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 196, 253, 258, 297, 417, 444, 677, 748.

Shorea laevis Ridley

Fl. Mal. Pen. 1: 232 (1922).

Synonyms *Shorea laevifolia* (Parijs) Endert (1935), *Shorea rogersiana* Raizada & Smitinand (1954), *Shorea ciliata* Ridley (1905) non King.

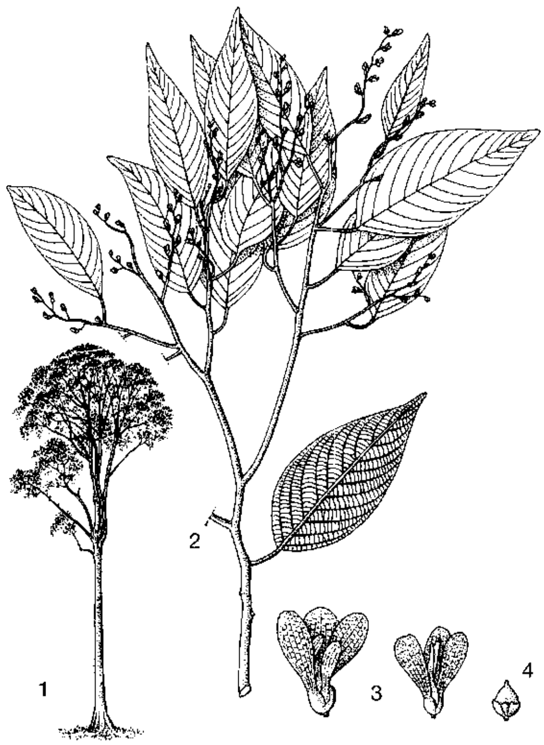
Vernacular names Brunei: penapak, kumus. Indonesia: bangkirai, balau tanduk (general), benuas (Kalimantan). Malaysia: balau kumus (Peninsular), selangan kumus, mikai (Sarawak), selangan batu kumus (Sabah). Thailand: takhian-samphon (peninsular).

Distribution Peninsular Burma, peninsular Thailand, Peninsular Malaysia, northern Sumatra and Borneo.

Uses The wood is used as balau and sometimes traded separately as bangkirai. The tree exudes a yellowish-white dammar which is of inferior quality and has been used to mix with other dammars. The wood yields an excellent charcoal but is regarded as too valuable for this purpose.

Observations A vast and very large tree up to 75 m tall, bole branchless for 18–27 m and up to 210(–240) cm in diameter, with prominent buttresses of up to 6 m high; leaves narrowly ovate-lanceolate, falcate, 6.5–10 cm × 2.5–4 cm, thinly leathery, with 11–14 pairs of secondary veins not prominent on either surface; petals short, oblong, stamens c. 50, the appendages densely barbate; fruit calyx lobes unequal, larger three up to 6.5 cm × 1.0 cm. *S. laevis* is a widespread, often common or even gregarious species, occurring on well-drained soils with a preference for ridges at (0–)200–1000(–1200) m altitude. The density of the wood is very variable and ranges from 600–1160 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 102, 159, 253, 258, 297, 374, 417, 446, 461, 476, 628, 677, 748.



Shorea laevis Ridley – 1, tree habit; 2, flowering twig; 3, fruits; 4, nut.

Shorea lumutensis Sym.

Gard. Bull. Str. Settl. 10: 364, pl. 22 (1939).

Vernacular names Malaysia: balau puteh (Peninsular).

Distribution West coast of Peninsular Malaysia.

Uses The timber is used as balau.

Observations A medium-sized to large tree, bole exceeding 100 cm in diameter and with short and stout buttresses; leaves oblong or elliptical, 7–29 cm × 2.5–7 cm, cream lepidote on the lower surface, with 12–16 pairs of secondary veins drying black beneath; petals narrow, stamens 20–24, of several lengths; fruit calyx lobes unequal, larger three up to 7 cm × 1.5 cm. *S. lumutensis* is common in its restricted area on coastal hills above 100 m altitude. The density of the wood is 975–1125 kg/m^3 at 15% moisture content.

Selected sources 258, 677, 748.

Shorea malibato Foxw.

Elmer, Leafl. Philipp. Bot. 6: 1955 (1913).

Vernacular names Philippines: guisok amarillo (Camarines), guisok madlao (Leyte), yakal malibato (Tagalog).

Distribution The Philippines (Luzon, Leyte and Mindanao).

Uses The timber is used as balau.

Observations A large tree with bole up to 80 cm or more in diameter and prominent buttresses; leaves elliptical to lanceolate, 7–12 cm × 2–5 cm, with 11–14 pairs of secondary veins narrowly depressed above; petals narrow, stamens 35–37, filaments glabrous; fruit calyx lobes unequal, larger three up to 5 cm × 1.3 cm. Formerly, *S. malibato* occurred locally in non-seasonal evergreen forests up to 450 m altitude, but it is now threatened with extinction. The density of the wood is about 890 kg/m^3 at 15% moisture content.

Selected sources 175, 258, 579, 748.

Shorea materialis Ridley

Agric. Bull. Straits Fed. Malay States 9: 183 (1910).

Vernacular names Brunei: selangan batu pasir. Malaysia: balau pasir, balau betul (Peninsular), balau laut (Sarawak).

Distribution Peninsular Malaysia, north-western Borneo and possibly eastern Sumatra.

Uses The timber is used as balau. Small amounts of dammar of fairly good quality are obtained from the tree.

Observations A medium-sized to large tree up to 45 m tall with low-branching bole up to 110 cm in diameter and prominent buttresses up to 2 m high; leaves broadly ovate, falcate with a subequal base, 8–15 cm × 3.5–8.5 cm, with 9–12 pairs of slender secondary veins prominent beneath; petals narrow, stamens c. 30, appendages setose; fruit calyx lobes unequal, larger three up to 9 cm × 3 cm. *S. materialis* occurs locally semi-gregarious and has become rare in Peninsular Malaysia as a result of logging. It occurs on giant podzols and sandstone cuestas in heath forest up to 800 m altitude. The density of the wood is 835–1040 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 318, 677, 748.

Shorea maxwelliana King

Journ. As. Soc. Beng. 62(2): 114 (1893).

Synonyms *Shorea utilis* King (1893), *Shorea barbata* Brandis (1895), *Balanocarpus ovalifolius* Ridley (1920) p.p., *Shorea alba* Ridley (1920).

Vernacular names Brunei: balau kumus hitam. Indonesia: damar bintang, rikir sega, rikir minyak (western Sumatra). Malaysia: damar laut daun kechil, balau kumus hitam (Peninsular), selangan batu asam (Sabah), selangan tandok (Sarawak).

Distribution Peninsular Malaysia, Sumatra and northern Borneo.

Uses *S. maxwelliana* is one of the more important balau-producing species.

Observations A medium-sized to large tree up to 50 m tall with bole up to 160 cm in diameter and prominent buttresses up to 4 m high, bark flaky; leaves ovate-lanceolate, thinly leathery, 6–10 cm × 2.5–4 cm, with 8–10 pairs of secondary veins; petals short, elliptical-oblong, stamens c. 30, with barbate appendages; fruit calyx lobes unequal, thin, larger three up to 10 cm × 1.5 cm. *S. maxwelliana* is locally common on low hill ridges and well-drained soils up to 700 m altitude. The density of the wood is 880–1155 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 253, 258, 297, 318, 417, 446, 461, 677, 748.

Shorea obtusa Wallich ex Blume

Mus. Bot. Lugd.-Bat. 2: 32, pl. 8 (1862).

Vernacular names Burma: thitya. Cambodia: phchök. Laos: chik. Thailand: teng (general). Vietnam: c[af] ch[aws]c (southern).

Distribution Burma, Cambodia, Laos, southern Vietnam and Thailand.

Uses *S. obtusa* is an important source of balau timber used for high-grade outdoor constructions. The bark has tanniferous properties.

Observations A small to medium-sized tree up to 30 m tall, bole branchless for up to 15 m, up to 65 cm in diameter, exuding dull yellowish dammar; bark scaly, thick, brown; leaves variable, generally oblong, 7.0–11.5 cm × 3.5–9.5 cm, sparsely pubescent below, with 15–20 pairs of secondary veins; petals narrow, stamens 26–29, with a short ciliate appendage; fruit calyx lobes unequal, larger three up to 6 cm × 1.1 cm. *S. obtusa* is common in dry deciduous dipterocarp forest at 200–1000 m altitude. The density of the wood is 830–1040 kg/m^3 at 15% moisture content.

Selected sources 235, 258, 628, 748.

Shorea ochrophloia Strugn. ex Sym.

Gard. Bull. Str. Settl. 8: 268, pl. 17 (1935).

Vernacular names Indonesia: katuko andilau (western Sumatra). Malaysia: balau membatu jantan, seraya batu (Peninsular).

Distribution Peninsular Malaysia and western Sumatra.

Uses The timber is used as red balau and is comparatively light in weight.

Observations A large tree with yellow-grey bole exceeding 100 cm in diameter and prominent but usually short buttresses; leaves ovate to elliptical-oblong, base obtuse to subcordate, (4–)6–12 cm × 3.5–6.5 cm, with 13–18 pairs of secondary veins, lower surface scabrid pubescent; petals narrow, stamens 30, the appendages with up to 5 bristles; fruit calyx lobes unequal, larger three up to 7 cm × 1.5 cm. *S. ochrophloia* is closely related to *S. guiso* and occurs locally on well-drained undulating land below 350 m altitude. The density of the wood is 705–960 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 258, 297, 417, 444, 677, 748.

Shorea scrobiculata Burck

Meded. 's-Lands Plantentuin 3: 223 (1886).

Synonyms *Shorea meadiana* Sym. (1939).

Vernacular names Brunei: selangan batu zang. Indonesia: bangkirai padi, palepek gunung, tekam rian (Kalimantan). Malaysia: balau sengkawang, damar laut kuning (Peninsular), selangan zang (Sarawak).

Distribution Peninsular Malaysia (rare), northern and western Borneo.

Uses The timber is used as balau.

Observations A medium-sized to large tree up to 45 m tall with comparatively short bole sometimes exceeding 115 cm in diameter and short buttresses; leaves narrowly ovate to oblong-lanceolate, 5.5–11 cm × 2.5–4 cm, with 10–12 pairs of close secondary veins prominent beneath; petals narrow, pink with a cream margin, stamens 20–30, the appendages with 1(–2) bristle(s); fruit calyx lobes unequal, larger three up to 5 cm × 1.2 cm. *S. scrobiculata* occurs on ridges and hillsides on well-drained and not too sandy soils up to 700 m altitude. The density of the wood is 860–1070 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 258, 677, 748.

Shorea seminis (de Vriese) v. Slooten

Merr., Pl. elmer. born.: 204 (1929).

Synonyms *Shorea schefferiana* Hance (1878), *Isoptera borneensis* Scheffer ex Burck (1886), *Isoptera seminis* (de Vriese) Burkill (1935).

Vernacular names Brunei: engkabang terendak, kawang tikus. Indonesia: tengkawang ayer, tengkawang pelepak, tengkawang terindak (Kalimantan). Malaysia: engkabang chengai, engkabang terindak (Sarawak), selangan batu terendak (Sabah). Philippines: gisok-tapang (Sulu), malayakal (Tagalog), yakal (Chabacano).

Distribution Borneo and the Philippines.

Uses The timber is used as balau. The dammar is said to be of a comparatively good quality but not of any economic value. The fruits are collected locally as illipe nuts but, because of their small size, rarely exported.

Observations A medium-sized to very large tree up to 60 m tall with bole branchless for 25–30 m and up to 130 cm in diameter but usually much less, with prominent buttresses up to 2.5 m high; leaves oblong-ovate to lanceolate, 9–18 cm × 2.5–8 cm, thinly leathery, with 9–15 pairs of slender and rather straight secondary veins; petals narrow, stamens 30–40, the appendages with a few bristles; fruit calyx lobes subequal, up to 2 cm × 1.8 cm. *S. seminis* is typically found along rivers and often growing gregariously at low altitudes or rarely up to 1000 m altitude. The density of the wood is 720–1090 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 102, 175, 258, 318, 476, 579, 677, 748.

Shorea siamensis Miq.

Ann. Mus. Bot. Lugd.-Bat. 1: 214 (1864).

Synonyms *Pentacme suavis* A.DC. (1868), *Pentacme siamensis* (Miq.) Kurz (1870), *Pentacme malayana* King (1893).

Vernacular names Malaysia: meranti temak, temak batu (Peninsular). Burma: eng-yin. Cambodia: phchök rèang', rèang' phnum'. Laos: h'ang, ph'au. Thailand: rang, rang khao (general), lak pao (northern). Vietnam: c[af] ch[aws]c xanh, c[aar]m li[ee]n.

Distribution Throughout Indo-China towards peninsular Thailand and north-western Peninsular Malaysia.

Uses The timber is used as balau. The bark and wood contain respectively 9% and 6% tannin, which is too little to be of importance.

Observations A medium-sized deciduous tree 20–25 m tall with bole up to 60 cm in diameter, buttressed, bark V-fissured; leaves broadly ovate-oblong, papery, 9–12 cm × 6–13 cm, with a deeply cordate to cuneate base; petals broadly elliptical, stamens 15, glabrous, with linear anthers; fruit calyx lobes unequal, larger three up to 12 cm × 1.3 cm. *S. siamensis* occurs in dry dipterocarp forest overlying poor and rocky or limestone soils from sea-level to over 1000 m altitude. The density of the wood is 700–1090 kg/m^3 at 15% moisture content.

Selected sources 102, 258, 628, 677, 748.

Shorea submontana Sym.

Gard. Bull. Str. Settl. 10: 368 (1939).

Synonyms *Shorea costata* King (1893) non (Correa) Presl.

Vernacular names Malaysia: balau gajah (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as balau.

Observations A large tree with rough bole sometimes over 125 cm in diameter and prominent buttresses; leaves ovate to obovate, thinly leathery, 7–20 cm × 4–10 cm, with 9–14 pairs of secondary veins, non-glaucous, petiole 15–33 mm long; petals narrow, stamens c. 20, the appendages with a few bristles; fruit calyx lobes unequal, larger three up to 9 cm × 1.8 cm. *S. submontana* is locally very common on high hills at (350–)800–1000 m altitude. The density of the wood is 895–1090 kg/m^3 at 15% moisture content.

Selected sources 258, 677, 748.

Shorea sumatrana (v. Slooten ex Thorenaar) Sym. ex Desch

Mal. For. 3: 195 (1934).

Synonyms *Isoptera sumatrana* v. Slooten ex Thorenaar (1926), *Isoptera borneensis* King non R. Scheffer ex Burck.

Vernacular names Indonesia: kedawang, sengkawang (Sumatra). Malaysia: balau sengkawan air, sengkawang, tengkawang batu (Peninsular). Thailand: palosale, teng-dong (Pattani).

Distribution South-eastern peninsular Thailand, Peninsular Malaysia and Sumatra.

Uses The timber is used as balau. The fruits are collected as illipe nuts but not on a commercial scale.

Observations A medium-sized to large tree with bole up to 115 cm in diameter and prominent buttresses; leaves elliptical-oblong, about 16.5 cm × 7.5 cm, with 10 pairs of secondary veins sharply prominent beneath; petals narrow, stamens 25; fruit calyx lobes unequal, developed into woody parts forming a spreading rosette around the nut. *S. sumatrana* is closely related to *S. seminis* and typically occurs along banks of slow-flowing rivers. The density of the wood is 630–1120 kg/m^3 at 15% moisture content.

Selected sources 258, 628, 677, 748.

Shorea superba Sym.

Gard. Bull. Sing. 17: 491 (1960).

Vernacular names Brunei: selangan batu tulang ikan. Malaysia: selangan batu daun halus (Sabah).

Distribution Borneo.

Uses The timber is used as balau; *S. superba* is one of the principal sources of balau in Sabah.

Observations A large to very large tree up to 75 m tall with bole branchless for up to 29 m and up to 225(–310) cm in diameter, with prominent buttresses sometimes up to 4 m high; leaves oblong, thin, 7–12 cm × 4–7 cm, with 16–24 pairs of secondary veins, prominent and pilose beneath; petals narrow, stamens c. 30, glabrous except for the setose appendages; fruit calyx lobes unequal, larger three up to 6 cm × 1.2 cm. *S. superba* occurs scattered on well-drained, clayey soils, usually on gentle hillsides up to 600 m altitude. The wood is very variable in density and is sometimes divided into heavier and lighter grades. The density varies between 695-1095 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 30, 100, 258, 476, 748.

K.M. Kochummen (general part),
W.C. Wong (properties),
J.M. Fundter (wood anatomy),
M.S.M. Sosef (selection of species)

Sindora Miq.

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

LEGUMINOSAE

$x = 12$; *S. wallichii*: $2n = 24$

Trade groups Sepetir: medium-heavy hardwood, e.g. *Sindora bruggemanii* de Wit, *S. coriacea* Maingay ex Prain, *S. supa* Merr., *S. velutina* J.G. Baker, *S. wallichii* Graham ex Bentham.

Vernacular names Sepetir: petir. Indonesia: sindur (general), sinampar (Banjarese), sasundur (Dayak, Kalimantan). Malaysia: meketil, saputi (Peninsular), sampar hantu (Sarawak). Philippines: supa, kayu galu. Thailand: makha-tae (central), kling, khaman (peninsular). Vietnam: g[uj], g[ox].

Origin and geographic distribution *Sindora* consists of about 20 species which are confined to Indo-China and western and central Malesia, except for one species which occurs in tropical Africa (Gabon). *Sindora* is absent from the Lesser Sunda Islands and New Guinea.

Uses Sepetir timber occurs in two forms: attractively figured, and more uniformly coloured. The first is less common but is highly appreciated for high-class cabinets and furniture, panelling and other interior finishes and fancy articles. The sometimes streaked heartwood can be successfully peeled and sliced, yielding a very handsome veneer. The more uniformly coloured and less figured material is used for light indoor constructions such as solid panel doors, windows, door and window frames, ceilings and planking. It is a suitable timber for these purposes, because of its relatively low shrinkage, lack of degrade on drying, and small movement when dried. Other general uses of the more uniformly coloured timber are cabinet-making and the manufacture of household utensils and plywood. Sepetir is recommended as an attractive flooring timber to withstand light or sometimes normal pedestrian traffic as in residential buildings, hotels, hospitals, offices and shops. High quality and more heavy material of certain species is sometimes used for poles, joinery, and in heavy constructions like bridges and naval constructions. Low grade material is used for packing cases and pallets.

Many species yield a wood-oil which is used for making paints, varnishes and transparent paper, for caulking boats and adulterating other oils, for illumination and sometimes as a perfume. The wood-oil is sometimes used medicinally against skin diseases and rheumatism and applied as birdlime.

The oil of the seed of *S. siamensis* Teijsm. ex Miq. is sometimes used as a substitute for betel (*Areca catechu* L.), while the fruits of *S. sumatrana* are widely used in local medicine against fevers, serious bleeding in the uterus and eczema on the head.

Production and international trade The export of sawn sepetir timber from Peninsular Malaysia increased from 19 000 m^3 (with a value of US$ 2.5 million) in 1984 to 53 500 m^3 (with a value of US$ 6.9 million) in 1987. Thereafter, the amount of exported sepetir timber decreased to 33 000 m^3 (worth US$ 5.7 million) in 1990, about 17 000 m^3 (worth US$ 3.2 million) in 1991 and 8000 m^3 (worth US$ 2.3 million) in 1992. The export of sepetir from Borneo is more important. For instance, the export of round logs of sepetir from Sabah in 1987 was 47 000 m^3 (with a value of US$ 3.3 million at 68 US$/$m^3$); in 1992 the export of logs was 12 000 m^3 and of sawn timber 8500 m^3 with a total value of US$ 2.6 million. Sepetir has some importance as an export timber in Indonesia and the Philippines, but export figures are not available.

Properties Sepetir is a medium-weight hardwood. The colour of the heartwood is golden brown, darkening on exposure. Dark brown or black streaks are sometimes present, producing handsomely figured wood. The density is (450–)520–790(–900) kg/m^3 at 15% moisture content. The grain is straight but more often shallowly interlocked, texture moderately fine and even.

For *S. coriacea* at 17% moisture content the modulus of rupture is c. 92 N/mm^2, modulus of elasticity 13 600 N/mm^2, compression parallel to grain 46 N/mm^2, compression perpendicular to grain 6 N/mm^2, shear 13.5 N/mm^2, cleavage 57 N/mm radial and 67 N/mm tangential, and Janka side hardness 5210 N.

The rates of shrinkage are medium: from green to 15% moisture content 1.5–2.0% radial and 2.9–5.4% tangential. The timber seasons moderately slowly with no degrade. It can be kiln-dried rapidly, but a mild schedule is recommended. Kiln schedule G (Malaysia) gives good results. Pre-drying before kilning is advised to reduce warping. Form stability of sepetir is good when dry.

The working properties of sepetir vary with the species. In general, stock inclines to be difficult to work. Conversion in a modern mill, however, presents little difficulty. Although the wood does not contain silica, the heartwood has considerable blunting effect on tools, but it usually can be worked to a smooth finish as long as knives are kept sharp. Air-dried sepetir is rated as difficult to saw and cross cut, but planes and bores easily into a smooth surface, and the moderately easy operation of turning produces usually a slightly rough surface. Sepetir is only moderately suitable for bending purposes. Finishing is satisfactory, but filling is required. Its resistance to splitting upon nailing is generally good but some species have pronounced tendency to split upon nailing and screwing, unless pre-bored. Gluing properties are very good.

Sepetir is rated as not to moderately durable; stake tests show an average service life in contact with the ground of only 2.6 years under tropical conditions. Under temperate conditions, the heartwood is rated as durable. As the timber is highly susceptible to powder-post beetle, termite and fungal attack, it should be treated with preservatives when it is not processed immediately. Sepetir is moderately difficult to treat with preservatives. An average absorption of 96 kg/m^3 of a mixture of creosote and diesel fuel is obtained under standard open tank treatment. Using a 3% copper-chrome-arsenic solution and under the full-cell process, sepetir heartwood absorbs only 73 kg/m^3 on average, whereas the average dry salt retention is only 2.2 kg/m^3. The wood may be preserved very well when it is treated with 100% creosote, and has attained an absorption of 140 kg/m^3. Attack by pinhole borers is very rare.

Minyak sepetir 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 volatile oil with an optical rotation of –6.5°. Supa wood-oil from the Philippines has a specific gravity of 0.9202 and optical rotation of –31.3°. It consists mainly of sesquiterpenes.

Description Usually medium-sized but sometimes large, briefly deciduous trees of 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 green, brown or yellow flecked. Leaves alternate, paripinnate, 2–8-jugate; leaflets shortly stalked, usually firmly leathery, often reticulately veined on both surfaces and slightly asymmetric, the midrib on the lower surface often ending in a gland. Inflorescence made up of solitary or gregarious panicles, often velvety pubescent. Flowers sessile or shortly pedicelled; calyx with a short tube, tawny velvety pubescent, and 4 lobes, usually unequal in size, with or 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; ovary 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.

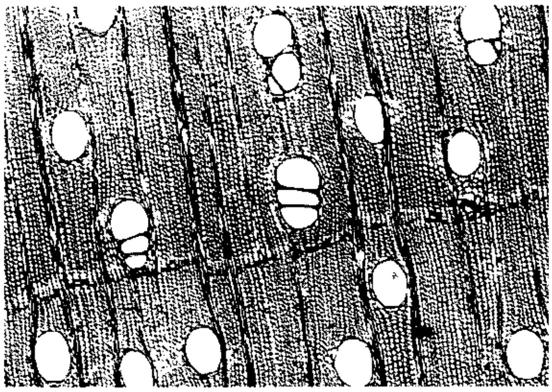
Wood anatomy

– Macroscopic characters:

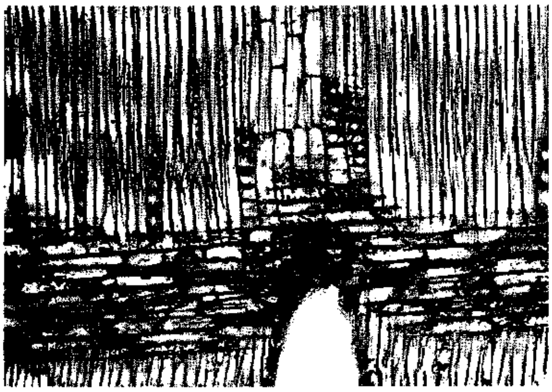
Heartwood distinctly demarcated from the lighter sapwood, pink-brown to shades of golden brown or red-brown, weathering to darker shades, often streaked with darker-coloured layers; sapwood light greyish-brown or beige with a pink tinge. Grain shallowly interlocked. Texture moderately fine and even or occasionally moderately coarse. Wood surface generally without significant lustre. Growth rings distinct, produced by terminal layers of wood parenchyma; vessels commonly filled with deposits; parenchyma vasicentric, tending to aliform and in irregularly spaced apotracheal terminal bands; rays moderately fine, visible to the naked eye, in some species fairly prominent on a radial surface; wood containing characteristic vertical axial canals. Ripple marks absent.

– Microscopic characters:

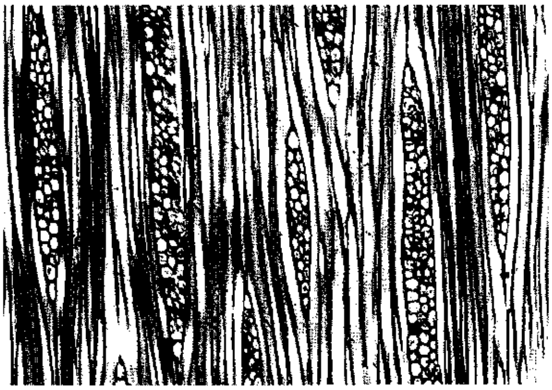
Growth rings distinct and marked by terminal layers of wood parenchyma. Vessels diffuse, 3–9/mm^2, solitary and in radial pairs and multiples of 2–4(–5), occasionally in clusters, sometimes solitary vessels or radial groups predominating, average tangential diameter 100–170(–220) μm; perforations simple; pits vestured, intervessel pits alternate, 4–8(–10) μm, vessel-ray and vessel-parenchyma pits similar but half-bordered; dark-staining gum-like deposits present; tyloses absent. Fibres 1200–1400 μm long, non-septate in most species, but septate in *S. beccariana*, thin- to thick-walled, with simple to minutely bordered pits. Parenchyma predominantly paratracheal, vasicentric, aliform to confluent, also diffuse and sometimes in terminal bands, in 1–2(–3)-celled strands. Rays 6–11/mm, 2–3-seriate, maximum



transverse section (×25)



radial section (×75)



tangential section (×75)

Sindora coriacea

ray height 0.64 mm (Kribs type heterogeneous III). Rhomboidal crystals in chambered cells, generally abundantly present but sometimes absent. Vertical axial canals smaller than vessels present in some terminal layers of wood parenchyma. All elements non-storied.
Species studied: *S. beccariana, S. coriacea, S. echinocalyx, S. velutina, S. wallichii.*

Growth and development Sepetir trees are moderately fast to rather slow-growing. Trees of *S. coriacea* planted in Peninsular Malaysia reached an average diameter of 52 cm after 40 years, but trees of *S. echinocalyx* only 33 cm.
The trees are deciduous and may remain leafless for several weeks. Flowers appear shortly after the new leaves. Fruits take about 2 months to reach maturity. The waxy arils of the seeds are especially attractive to rodents, which disperse the seeds.

Other botanical information The genus *Sindora* is well-defined 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*. The timber of *Copaifera palustris* (Sym.) de Wit (synonym: *Pseudosindora palustris* Sym.) from Borneo has similar properties and uses and is often mixed with sepetir; it is called swamp sepetir.

Ecology Sepetir trees occur generally scattered or sometimes gregarious (Borneo) in lowland dipterocarp forest on flat land and hillsides, up to 300 m altitude, but in Peninsular Malaysia sometimes up to 800 m. They generally favour well-drained soils, which are at least moderately fertile. They are, however, also found on sandstone, shales and volcanic soils (e.g. *S. irpicina*), sandy loam and clay soils (e.g. *S. beccariana*), as well as leached soils (e.g. *S. coriacea*).

Propagation and planting Sepetir seeds survive for more than 3 years without any specific treatment. Germination is usually delayed. In germination tests without pretreatment of the seeds, after about 3 years only 20% of the seeds of *S. echinocalyx* had germinated. 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%. A good 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 sand-humus mixture (1 : 1) appeared to be the most satisfactory potting medium. Average height of seedlings after 7 months is about 20 cm when potted in this mixture, and the seedlings have a high shoot to root ratio (about 3.8). A mixture of ordinary garden soil and sand (2 : 1) gives slightly less good results.

Silviculture and management In logged-over forest the regeneration of sepetir is often abundant. Usually the number of seedlings in logged-over forest is larger than in undisturbed forest, similar to e.g. keruing (*Dipterocarpus* spp.). From Peninsular Malaysia an average of one large tree (over 60 cm in diameter) per 5 ha of undisturbed forest is reported; locally sepetir is more common, up to one large tree per 2 ha.

Harvesting Sepetir logs are usually free from defects after felling. Wood-oil was formerly obtained by hacking the trunk and cutting cavities in its base. Subsequently the flow of oil was increased by firing. This destructive method of harvesting wood-oil was practised in the Philippines, Indonesia and Malaysia.

Yield As sepetir trees occur scattered in natural forest, the yield of timber per ha is often comparatively low. A freshly cut tree of *S. supa* in the Philippines may yield about 10 litres of wood-oil.

Genetic resources Most *Sindora* species are uncommon and occur scattered. Large-scale exploitation of forest, as practised in many places, may seriously threaten these species with extinction, except when the felling cycle is long enough to allow new trees to reach maturity in sustainably managed forest. Extensive planting of sepetir trees is not practised.

Prospects As very little information about sepetir is available, particularly about silvicultural aspects, growing rates and the occurrence of streaked wood, which is highly valued for decorative purposes, more research on these aspects is urgently needed. *S. coriacea* has been suggested as a species suitable for enrichment planting in logged-over forest, but this should be further investigated.

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Selection of species

Sindora beccariana Backer ex de Wit

Bull. Bot. Gard. Buitenzorg, ser. 3, 18: 18 (1949).

Vernacular names Indonesia: sasundur, merdjang, anggi (Kalimantan). Malaysia: tampar hantoe (Sabah, Sarawak).

Distribution Borneo.

Uses The timber is used as sepetir. The bole is said to yield wood-oil.

Observations A medium-sized to fairly large tree up to 35(–40) m tall with a cylindrical bole up to 100 cm in diameter; leaves with 6–8 leaflets, leaflets 3.5–8 cm × 2–4 cm, thickly leathery and puberulous beneath; flowers with 5.5–7 mm long, yellowish hairy calyx lobes lacking spines; pod suborbicular, up to 9 cm long, with numerous spines, wine red. *S. beccariana* occurs scattered in lowland dipterocarp forest on sandy loam or clay soils. The density of the timber is 610–800 kg/m^3 at 15% moisture content.

Selected sources 100, 146, 186.

Sindora bruggemanii de Wit

Bull. Bot. Gard. Buitenzorg, ser. 3, 18: 21 (1949).

Vernacular names Indonesia: tapak tapak (Kalimantan), tampora antu (Palembang, Sumatra), kayu sindoro (Batak, Sumatra).

Distribution Borneo (Kalimantan) and Sumatra.

Uses The timber is used as sepetir.

Observations A medium-sized tree up to 30 m tall, rarely up to 40 m, with cylindrical bole; leaves with (10–)12–16 leaflets; leaflets 4–9 cm × 2–3 cm, leathery and glabrous; flowers with 3.5–6 mm long puberulous calyx lobes having a narrow membranous margin and lacking spines; pod broadly elliptical, up to 15 cm long, with few spines producing an aromatic resin. *S. bruggemanii* grows on non-inundated clayey or sandy-clayey soils at low altitudes, up to 100 m. The density of the timber is 580–770 kg/m^3 at 15% moisture content.

Selected sources 100, 186.

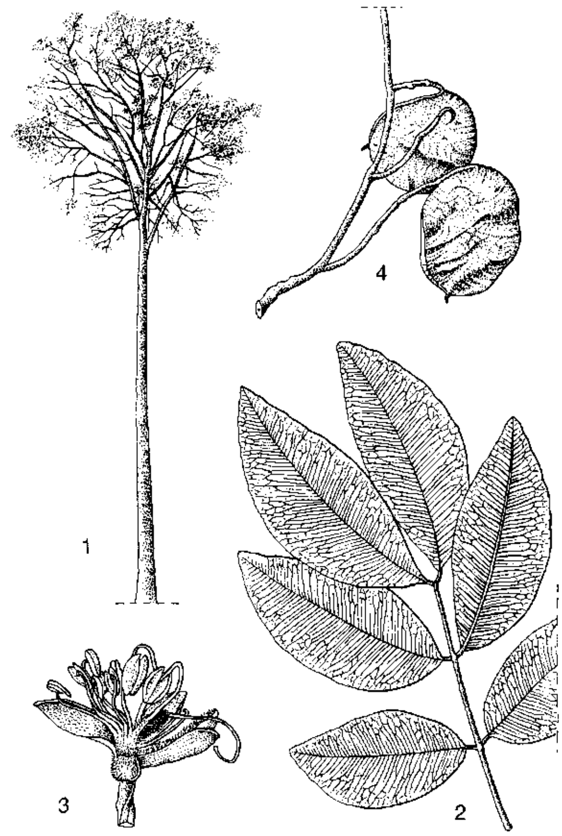
Sindora coriacea Maingay ex Prain

King, Journ. As. Soc. Beng. 66: 206 (1897).

Vernacular names Indonesia: malamari (Batak, Sumatra). Malaysia: sepetir lichin, sepetir minyak, seputih minyak (Peninsular). Thailand: kling (peninsular), khaman (Pattani).

Distribution Peninsular Thailand, Peninsular Malaysia, Sumatra and Borneo.

Uses The wood is rather soft and non-durable



Sindora coriacea Maingay ex Prain – 1, tree habit; 2, leaf; 3, flower; 4, pods.

but often attractively figured and used for ornamental cabinets and furniture as well as for indoor construction. Small amounts of wood-oil are collected for medicinal uses.

Observations A medium-sized to large tree up to 45 m tall with a cylindrical bole branchless for up to 21 m and up to 140 cm in diameter; leaves with 6–8 leaflets, leaflets 6.5–10(–15) cm × 2.5–5(–10) cm, leathery and glabrous; flowers with 6.5–7.5 mm long puberulous calyx lobes lacking spines; pod broadly oblong to ovate, up to 10 cm long, smooth and without spines, but often with sessile glands. *S. coriacea* occurs scattered but widespread in lowland forest on non-inundated sandy and often leached soils. It is an important source of sepetir timber because of its often large size and because it is common in many areas. The density of the timber is 570–760 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 100, 102, 146, 186, 190, 252, 318, 325, 417, 514, 591, 601, 626, 779.

Sindora echinocalyx (Bentham) Prain

King, Journ. As. Soc. Beng. 66: 204 (1897).

Synonyms *Sindora wallichii* auct. non Graham ex Bentham.

Vernacular names Malaysia: sepetir daun nipis (Peninsular). Thailand: ka-te, khanang, makha (peninsular).

Distribution Peninsular Thailand, Peninsular Malaysia and the Riau Archipelago.

Uses The timber is used as sepetir, mainly for indoor construction.

Observations A medium-sized tree; leaves with 6–8 leaflets, leaflets 5–7.5 cm × 2.5–3 cm, firmly leathery and puberulous beneath; flowers with 5–7.5 mm long puberulous calyx lobes slightly spiny towards apex; pod circular to ovate, up to 6.5 cm long, with many stout, hard spines. *S. echinocalyx* is closely related to *S. wallichii* but differs in its leaflets which are distinctly reticulately veined above, its more slender inflorescence axis and its spiny ovary. It occurs particularly on hillsides and ridges up to 800 m altitude, and is locally common. The density of the timber is 620–775 kg/m^3 at 15% moisture content.

Selected sources 186, 190, 325, 514, 626, 779.

Sindora galedupa Prain

Journ. As. Soc. Beng. 66: 483 (1897).

Vernacular names Indonesia: kayu galedupa, ay goa (Moluccas), mobingo (Sulawesi).

Distribution Sulawesi and the Moluccas.

Uses The timber is possibly used as sepetir.

Observations A medium-sized tree; leaves with 6–8 leaflets, leaflets 3.5–12.5 cm × 2.5–6 cm, thinly leathery, puberulous beneath when young but glabrescent; flowers with c. 7 mm long densely puberulous calyx lobes, but with a glabrous margin and lacking spines; pod circular to broadly elliptical, up to 6(–9.5) cm long, smooth and without spines. *S. galedupa* grows in forest and on forest edges from sea-level to 120 m altitude. Not much is known about this species.

Selected sources 186.

Sindora inermis Merr.

Philipp. Journ. Sc. 10: 314 (1915).

Vernacular names Philippines: kayu galu (Magindanao), nito-nitong puti (Bikol), sinsud (Sulu).

Distribution The Philippines (southern Luzon, Mindanao and the Sulu Archipelago).

Uses The timber is used as sepetir, especially for high-grade furniture and interior work, musical instruments and fancy boxes. The pleasantly smelling wood-oil may be used in perfumes.

Observations A medium-sized tree up to 30 m tall with straight, cylindrical bole up to 75(–95) cm in diameter; leaves with 4–8 leaflets, leaflets 6.5–12.5 cm × 4.5–7.5 cm, thinly leathery and glabrous; pod broadly elliptical, up to 7 cm long, smooth and without spines; no information available on flowers. *S. inermis* occurs in lowland forest, also along the seashore and near the mangrove zone. The supply of the timber is very limited. The species is probably closely related to *S. galedupa*.

Selected sources 86, 186, 319, 484, 579.

Sindora irpicina de Wit

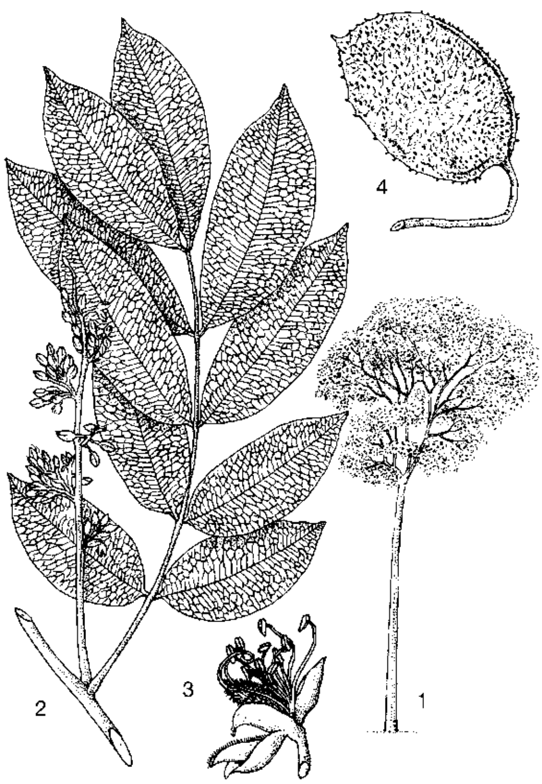
Bull. Bot. Gard. Buitenzorg, ser. 3, 18: 50 (1949).

Vernacular names Indonesia: suda koira, tampar hantu, kasindur (Kalimantan).

Distribution Borneo (eastern and southern Kalimantan, Sabah).

Uses The timber is used as sepetir.

Observations A medium-sized to fairly large tree up to 35 m tall with a cylindrical bole up to 130 cm in diameter; leaves with 8–10 leaflets, leaflets 5–10.5 cm × 2–4 cm, leathery and initially sparsely pubescent but glabrescent; flowers with 8–10 mm long calyx lobes, hairy on both sides and lacking spines; pod elliptical to broadly elliptical, up to 12 cm long, with numerous short, sharp and resinous spines. *S. irpicina* is fairly common in lowland dipterocarp forest on sandstone, shale



Sindora irpicina de Wit – 1, tree habit; 2, inflorescence and leaf; 3, flower; 4, pod.

and volcanic soils. The density of the heartwood is 510–740 kg/m³ at 15% moisture content.

Selected sources 100, 146, 186.

Sindora javanica (Koord. & Valeton) Backer ex K. Heyne

Nutt. pl. Ned. Ind., ed. 2: 728 (1927).

Synonyms *Sindora sumatrana* Miq. var. *javanica* Koord. & Valeton (1895).

Vernacular names Indonesia: uku aka, samparantu (Sundanese, Java).

Distribution Western and central Java.

Uses The timber is occasionally used as sepetir. The wood-oil was formerly used for illumination.

Observations A medium-sized to fairly large tree up to 35 m tall with a straight, columnar bole branchless up to 20 m and up to 70 cm in diameter; leaves with 8–10 leaflets, leaflets 3.5–14.5 cm × 2–6.5 cm, leathery and sparsely puberulous beneath; flowers with 6–9 mm long puberulous calyx lobes lacking spines; pod elliptical to suborbicular, up to 8.5 cm long, with many short, resinous spines with a swollen base. *S. javanica* is an uncommon species of poor, sandy or stony soils in forest below 500 m altitude. The timber is often decoratively streaked.

Selected sources 35, 145, 186, 318, 319.

Sindora leiocarpa Backer ex K. Heyne

Nutt. pl. Ned. Ind., ed. 2: 728 (1927).

Vernacular names Indonesia: sindur (Sumatra, Kalimantan), malapira (Sumatra), marijang (Kalimantan).

Distribution Sumatra, the Riau Archipelago and Borneo.

Uses The timber is used as sepetir. The wood-oil is used in local medicine.

Observations A fairly large tree up to 40 m tall with the crown placed comparatively high up the cylindrical bole which is branchless for up to 25 m and attains more than 100 cm in diameter; leaves with (4–)6(–8) leaflets, leaflets 6–8 cm × 3.5–4.5 cm, (firmly) leathery and glabrous; flowers with c. 5.5 mm long puberulous calyx lobes lacking spines; pod elliptical to ovate, up to 9 cm long, smooth and without spines. *S. leiocarpa* is closely related to *S. coriacea* and *S. inermis* but differs in the leaflets having a rounded to retuse apex. It occurs in primary forest on clayey and sandy soils, usually in non-inundated sites. The timber is rated as non-durable; the density is 460–740 kg/m³ at 15% moisture content.

Selected sources 100, 186, 318, 319, 558.

Sindora siamensis Teijsm. ex Miq.

Ann. Mus. Lugd.-Bat. 3: 86 (1871).

Synonyms *Sindora cochinchinensis* Baillon (1867).

Vernacular names Malaysia: sepetir mempelas (Peninsular). Cambodia: krâkâh'. Laos: têtê 'hoho. Thailand: makha-tae (general), makha-nam (central), makha-yum (northern). Vietnam: g[uj] m[aaj]t, g[ox] m[aaj]t.

Distribution Laos, Cambodia, Vietnam, Thailand and northern Peninsular Malaysia.

Uses The timber is used for planking, poles, joinery, furniture and construction work and also as firewood. The bark is used for partition walls in Thailand, the wood-oil for caulking boats, and the aril of the seed is sometimes used as a substitute for betel.

Observations Usually a small tree, rarely over 15 m tall with bole over 40 cm in diameter, but recorded to sometimes reach 35 m tall with straight, cylindrical bole branchless for at least 12 m; leaves with 6–8 leaflets, leaflets 4–15 cm × 3–8.5 cm, leathery and sparsely puberulous above, more densely puberulous beneath; flowers with 4.5–9 mm long calyx lobes pubescent except for the margin and spiny towards the apex; pod usually irregularly ovate, up to 8.5(–10) cm long, armed with numerous stout spines. *S. siamensis* is often a dominating species in dry dipterocarp forest up to 500 m altitude. Two varieties are distinguished: var. *siamensis* and var. *maritima* (Pierre) K. Larsen & S.S. Larsen, the latter being less common and having much less spiny pods. The density of the wood is about 880 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 102, 186, 190, 235, 578, 626, 779.

Sindora sumatrana Miq.

Fl. Ind. Bat., Suppl. 1(2): 288 (1861).

Vernacular names Indonesia: sindur, tampar hantu (Palembang, Sumatra).

Distribution Sumatra; possibly also Bangka.

Uses The timber is used as sepetir, particularly for furniture. The fruits are collected in Sumatra and traded throughout Indonesia as 'saparantu' to be used in medicines against fever, serious bleeding of the uterus and skin diseases. The wood-oil is used for caulking boats.

Observations A medium-sized to fairly large tree; leaves with 6 leaflets, leaflets 6–11.5 cm × 2.5–6.5 cm, leathery and glabrous; pod circular to broadly elliptical, up to 4 cm long, with many short but stout spines having a swollen base. *S. sumatrana* grows on periodically inundated, sandy soils and is locally common. The timber is often flamed and the density is probably rather high: 700–800 kg/m^3 at 15% moisture content.

Selected sources 186, 318, 319.

Sindora supa Merr.

Philipp. Journ. Sc., Bot. 1, Suppl. 3: 198 (1906).

Vernacular names Philippines: supa (Bikol, Tagalog), baloyong (Batangas), manapo (Tayabas).

Distribution The Philippines (Luzon, Mindoro).

Uses The timber is locally fairly important and used for high-grade furniture and interior work, musical instruments and flooring. The wood-oil is locally used as a lamp-oil, for making varnishes, paints and transparent paper, and medicinally against skin diseases.

Observations A medium-sized tree up to 30 m tall with a straight cylindrical bole branchless for up to 12 m, occasionally up to 180 cm in diameter; leaves with 4–6 leaflets, leaflets 2.5–9 cm × 2.5–5 cm, leathery and glabrous; flowers with 6.5–10 mm long calyx lobes puberulous and with spiny outgrowths all over; pod mostly ovate, c. 5 cm long, with many spines having a swollen base. *S. supa* grows in forests at low and medium altitudes, especially on limestone ridges in regions without a distinct dry season. The timber is often streaked on longitudinal surfaces. The density is reported as about 830 kg/m^3 at 15% moisture content, but it is probably usually less. See also the table on wood properties.

Selected sources 86, 186, 319, 403, 484, 579, 768.

Sindora velutina J.G. Baker

Hook.f., Fl. Brit. India 2: 269 (1878).

Synonyms *Sindora parvifolia* Backer ex K. Heyne (1927).

Vernacular names Indonesia: sindur, kaparantu (Sumatra), kayu bulan (East Kalimantan). Malaysia: sepetir beludu besar, sepetir beludu kechil (Peninsular), ensunut (Sarawak).

Distribution Peninsular Malaysia, Sumatra and Borneo.

Uses The timber is used as sepetir in house-building and for utensils. The wood-oil is used medicinally.

Observations A medium-sized tree up to 30 m tall, rarely up to 40 m, with a straight columnar bole up to 100 cm in diameter; leaves with (8–) 10–12 leaflets, leaflets 3.5–12.5 cm × 1.5–5 cm, firmly leathery and densely velvety pubescent beneath; flowers with 11–13 mm long woolly hirsute calyx lobes lacking spines; pod elliptical, ovate to circular, up to 12 cm long, with numerous slender, stiff spines. *S. velutina* occurs scattered in non-inundated places on sandy or clayey soils, often on hillsides, sometimes in marshy places. The density of the timber is 520–730 kg/m^3 at 15% moisture content.

Selected sources 100, 102, 146, 186, 190, 318, 325, 779.

Sindora wallichii Graham ex Bentham

Hooker's Icon. Pl.: tab. 1018 (1867).

Synonyms *Sindora intermedia* (J.G. Baker) Prain ex King (1897).

Vernacular names Indonesia: tamparhantu, kampas hantu (Sumatra), mahasindut (Kalimantan). Malaysia: sepetir daun tebal (Peninsular).

Distribution Peninsular Malaysia, Singapore, Sumatra and Borneo.

Uses The timber is used as sepetir, e.g. in house building. The pods are used medicinally after childbirth.

Observations A large tree up to 45 m tall with a straight, cylindrical bole at least 65 cm in diameter; leaves with 6–8 leaflets, leaflets 4–10.5 cm × 2.5–5 cm, leathery and glabrous or thinly velvety pubescent beneath; flowers with up to 9.5 mm long, densely pubescent calyx lobes, having long slender spines near the apex; pod ovate, broadly elliptical to circular, up to 9.5 cm long, with many slender, stout spines having a swollen base. *S. wallichii* is closely related to *S. echinocalyx*. It occurs frequently in hill dipterocarp forest up to 300 m altitude in Peninsular Malaysia, more scattered in primary forest below 100 m altitude on sandy or clayey soils in eastern Sumatra, and is apparently rather rare in Borneo. The density of the timber is 530–790 kg/m^3 at 15% moisture content.

Selected sources 100, 102, 146, 186, 190, 318, 325, 779.

E.N. Sambas (general part),
P.B. Laming (properties),
Ani Sulaiman (wood anatomy),
M.S.M. Sosef (selection of species)

Swietenia Jacq.

Enum. syst. pl. Carib. 4, 20 (1760).
MELIACEAE
x = unknown; *S. macrophylla*: $2n$ = 46, 48, 54; *S. mahagoni*: $2n$ = 46, 48, 54, 56

Trade groups Mahogany: medium-weight hardwood, *Swietenia macrophylla* King and *S. mahagoni* (L.) Jacq.

Vernacular names Mahogany: baywood (En). Acajou (Fr). Indonesia: mahoni (general). Thailand: mahokkani-baiyai, mahokkani-bailek (Bangkok). Vietnam: gi[as]i ng[uwj]a.

Origin and geographic distribution *Swietenia* consists of 3 species and is distributed in tropical America between 20°N and 18°S. The area of distribution extends from central Mexico through Central America and the West Indies, including southern Florida, towards Bolivia, Peru and Brazil. At present, mahogany is widely cultivated throughout the tropics including Malaysia, Indonesia and the Philippines.

Uses Mahogany is regarded as the worlds finest timber for high-class furniture and cabinet work. Its popularity is especially due to its attractive appearance in combination with ease of working, excellent finishing qualities and dimensional stability. Mahogany is also often used for interior trim such as panelling, doors and decorative borders. It is used for boat building, often as a decorative wood for luxury yachts and ocean liners, although it is also used when a medium-weight timber with other good qualities is required. It is sometimes applied in boat building as plywood for planking and deck housing. Its outstanding technical qualities make it particularly suitable for precision woodwork such as models and patterns, instrument cases, clocks, printer's blocks and parts of musical instruments; for these purposes, uniform straight-grained material is used. Other minor uses include burial caskets, wood carvings, novelties, toys and turnery.

An oil can be extracted from the seed kernels which might be of some commercial value. The bark is used for dyeing and tanning leather. A gum is produced for Bombay (India) markets from cuts in the bark, both pure and mixed with other gums. Various medicinal uses of various parts of the tree are reported from Central America. The crushed fruit shells have been used as a potting medium. Mahogany is also used in reforestation projects, and has proved to be suitable in areas not protected from grazing. It is used as a shade tree, for example for young plantations of dipterocarps.

Production and international trade Mahogany is one of the most important tropical timbers on the world market. Most mahogany traded is from natural stands, although small quantities are available from planted trees. Main exporting countries are Brazil, Bolivia and Peru. The most important importers are the United States (buying mainly from Brazil) and Great Britain (in 1989 85 000 m^3 of sawn timber). The trade of plantation-grown mahogany in South-East Asia is very limited. Malaysia, Indonesia and the Philippines export only small amounts of sawn mahogany.

Properties Mahogany is a medium-weight timber which is rather soft. The heartwood is reddish or pinkish, the colour darkening with age to a deep red or brown, sapwood usually yellowish and up to 40 mm wide. The density is 500–800(–850) kg/m^3 at 15% moisture content. The grain of the wood is interlocked, sometimes straight, texture fine to moderately coarse. The surfaces are glossy, and the wood is often nicely figured because of the irregular grain.

Tests in Indonesia showed the following mechanical properties at 15% moisture content: modulus of rupture 55–61 N/mm^2, modulus of elasticity 9000–9550 N/mm^2, compression parallel to grain 36–40 N/mm^2, shear 4–7.5 N/mm^2, cleavage 51–55 N/mm radial and 58–64 N/mm tangential, Janka side hardness 2650–3840 N and Janka end hardness 3700–3840 N.

The rates of shrinkage are low, from green to 15% moisture content about 0.9% radial and 1.3% tangential, from green to 12% moisture content 1.2–1.4% radial and 1.8–2.2% tangential, and from green to oven dry 3.0–3.3% radial and 4.1–5.7% tangential. Mahogany seasons well and easily without much checking or distortion. Boards of *S. macrophylla* wood can be air dried in 11 weeks (50 mm thick) and 6 weeks (25 mm thick) from 40% moisture content to 15%. The wood kiln dries satisfactorily when moderate schedules are used (temperatures of 43–76°C and corresponding relative humidity of 75–33%). Boards of 50 mm thick can be kiln dried in approximately 8 days, and boards of 25 mm in 4 days. After drying, the wood is stable in service.

Mahogany saws, planes and moulds easily in both green and dry condition. In general it finishes to a smooth surface, but a woolly surface may occur on bands of reaction wood or interlocked grain. Finishing is easy and the wood takes an excellent polish. Gluing and nailing properties are good, but discoloration in contact with iron, copper and brass may occur under humid conditions. Mahogany slices and rotary cuts into fine and decorative veneer, without preliminary treatment, at a peeling angle of 92°. The veneer can be glued with casein extended with 30% lime, to produce plywood of satisfactory quality. Satisfactory results are obtained with pulping (kraft pulp yield of 49.5%).

The heartwood of trees from natural stands can be reasonably durable, but plantation-grown wood is not considered suitable for applications in contact with the ground. Graveyard tests in Indonesia showed an average service life in contact with the ground of 2.7 years for *S. macrophylla* and 3.3 years for *S. mahagoni*. The wood is resistant to wood-rotting fungi. The sapwood is susceptible to *Lyctus* borer attack and the heartwood may also be attacked by pinhole borers and termites; the wood has little resistance to marine borers. Mahogany is resistant to impregnation with preservatives by pressure methods, but plantation-grown wood can be amenable to boron diffusion techniques.

Wood of *S. macrophylla* contains 47% cellulose, 27% lignin, 16% pentosan, 0.6% ash and 0.1% silica. The solubility is 2.4% in alcohol-benzene, 0.4% in cold water, 4.5% in hot water 4.5% and 19% in a 1% NaOH solution. The energy value of the wood is about 19600 kJ/kg. The essential oils in the wood are rich in sesquiterpenes.

Description Small to large, monoecious but often functionally dioecious trees up to 40(–60) m tall with a straight cylindrical bole branchless for up to 18(–25) m, up to 150(–200) cm in diameter and with broad buttresses; outer bark of older trees scaly, shaggy, deeply longitudinally furrowed and brownish-grey to reddish-brown, inner bark red-brown or pinkish-red; crown dome-shaped. Leaves alternate, usually paripinnate; stipules absent; leaflets usually opposite, entire, glabrous. Inflorescence consisting of small cymes united into axillary panicles. Flowers unisexual, but with well-developed vestiges of the opposite sex; calyx 5-lobed, lobes rounded or obtuse, imbricate; petals (4–)5, contorted, strongly reflexed at anthesis; stamens united into a tube constricted at the apex and bearing 8–10 anthers; disk present; ovary (4–)5(–6)-locular with 9–16 ovules per locule, style with a discoid head blocking the entrance to the staminal tube, with (4–)5 stigmatic lobes. Fruit erect, capsular, woody, ovoid to obovoid, opening by usually 5 valves consisting of a thick outer and thin inner layer, the 5-winged receptacle visible after the valves and seeds have been shed. Seeds winged, flat, imbricate, two rows per locule, hanging down and attached with the wing to the receptacle; cotyledons thin. Seedling with hypogeal, cryptocotylar germination; first two leaves opposite, simple just like the alternate third and fourth leaves, later ones trifoliolate or imparipinnate.

Wood anatomy

– Macroscopic characters:

Heartwood reddish, pinkish, salmon-coloured or yellowish when fresh, darkening to deep red or brown with age, distinct from the yellowish or whitish sapwood. Grain interlocked or sometimes straight, with some irregularities producing an attractive stripe figure on quarter-sawn surfaces such as mottled, fiddle-back, raindrop, wavy or curly figures. Texture fine, moderately fine to rather coarse; wood with golden lustre. Growth rings present but not always distinct, wood rarely ring-porous; vessels mostly diffuse, large to very small and readily visible to the naked eye, with dark, sometimes white gum deposits; parenchyma surrounding pores and pore groups very distinct, paler than background; rays fine and variable in distinctness; ripple marks present or absent, when present uniform or irregular, visible without lens, 18–22 tiers per cm; gum ducts occasionally present in compact peripheral rows and filled with dark red deposits, very distinct on tangential sections.

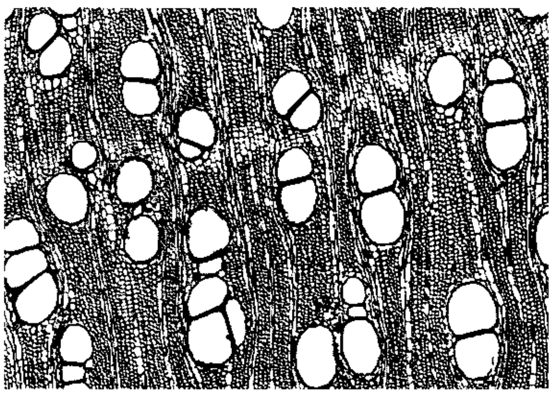
– Microscopic characters:

Growth rings demarcated by concentric lines or bands of parenchyma, and sometimes also by differences in vessel diameter. Wood usually diffuse-porous, but sometimes semi-ring- to ring-porous. Vessels 5–12/mm^2, solitary and in radial multiples of 2 to several pores each, average tangential diameter 130–230 μm; perforations simple; intervessel pits alternate, 2–4(–6) μm; vessel-ray and vessel-parenchyma pits similar but half-bordered; vessel walls without spiral thickenings; gum-like deposits present; tyloses absent. Fibres 1140–1460 μm long, both septate and non-septate fibres occurring together (*S. macrophylla*), thin-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma predominantly paratracheal, vasicentric and in terminal lines or bands and apotracheal diffuse, in 2–4(–6)-celled strands. Rays 5–9/mm, (1–)3–4-seriate, maximum ray height 0.69 mm (mostly Kribs type heterogeneous III). Prismatic crystals present in ray and parenchyma cells. Traumatic axial canals sometimes present. Vessel elements and rays storied.

Species studied: *S. macrophylla, S. mahagoni.*

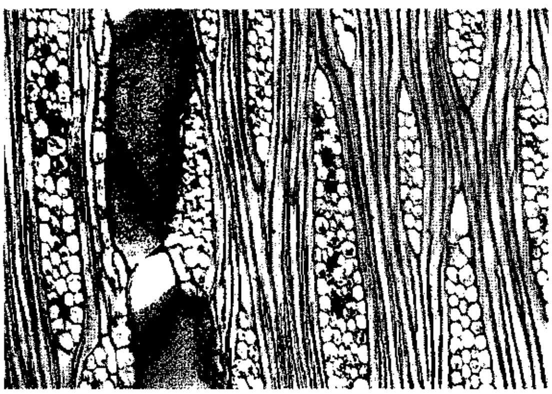
Growth and development Healthy seeds start germinating about 15 days after sowing. Young trees have straight and slender stems, and branches are formed 2–3 m above the ground with a position oblique to the main stem. Initial growth is fast, depending on site conditions. Under optimal conditions, seedlings of *S. macrophylla* may reach 3 m in one year and 6 m in two years. In Indonesia the average height of 10-year-old trees in plantations is 10 m (average diameter 9 cm), and the average height of 40-year-old trees is 25 m (average diameter 35 cm). In Peninsular Malaysia the maximum diameter of trees after 40 years is reported to be 45 cm. However, trees planted in the open field under optimal conditions may occasionally reach 50 cm in diameter in 25 years.

Flowering mahogany trees have male and female flowers (about ten times as many male as female flowers; often only the central flower of a cyme is female), but the flowers of both sexes are very similar. Trees are sometimes functionally dioecious. In mixed inflorescences, male flowers open first, but self-pollination may occur. Fruits may be produced once a year, and trees start to produce



transverse section (×25)

radial section (×75)



tangential section (×75)

Swietenia macrophylla

fruits regularly when about 15 years old. The seeds are provided with a thin tail-like wing that makes them rotate when they fall, and are thus dispersed by wind as far as 500 m from the mother tree.

Other botanical information The name mahogany is applied to several other timbers. African mahogany (species of the genus *Khaya*) is indeed similar to genuine mahogany but is of a lesser quality. The name Philippine mahogany is truly misleading since the timber traded under this name (several species of the dipterocarp genera *Shorea* and *Parashorea*) only superficially resembles true mahogany.
Swietenia belongs to the subfamily *Swietenioideae*, and within this subfamily to the tribe *Swietenieae* which contains 9 genera. It is obviously closely related to *Khaya* but a proposed union of the two does not seem justified, the main differences being the shape of the capsule and that of the seed wing.

Ecology Under natural conditions mahogany thrives in both deciduous and evergreen rain forest and occurs scattered or in small groups, but more than 4–8 trees/ha are rarely encountered. The optimum annual rainfall is 1400–2500(–3500) mm with a dry period of 0–4 months. Mahogany grows from sea-level to 1500 m altitude, in areas with a mean annual temperature of 20–28°C, the range of the coldest and warmest month being 11–22°C and 22–30°C, respectively. Mahogany is largely unspecific as to soil requirements. Within its natural range it has been found on alluvial soils, volcanic soils, heavy clays, lateritic soils, soils derived from limestone, granite and other sedimentary, igneous or metamorphic rock formations and even on shallow rendzinas. In plantations in Java it grows on very poor soils but performs best on deep, fertile, well-drained soils with a pH of 6.5–7.5. It does not tolerate waterlogging. In tropical America mahogany is among the pioneer species reoccupying degraded agricultural land. It has been shown that teak is outcompeted by mahogany in a mixed stand. *S. macrophylla* is reported to be very wind firm (resistant to cyclones) in the Philippines.

Propagation and planting Ripe fruits must be collected to achieve a good germination rate. These open after 2 days of storage and the seeds are very viable. The germination rate of fresh seeds is 60–90%. They can be stored up to 2 months, or longer (up to one year) if kept cool (2–5°C) in sealed containers at about 45% relative humidity. The weight of 1000 seeds of *S. macrophylla* is 400–500 g.
Seeds are sown in the nursery in drills of 2–4 cm deep, or they are pushed into flat beds, leaving part of the wing exposed. The seed-bed should be well manured and shaded, and seedlings should be kept under light shade for 3–6 months. Mahogany seedlings may have a 70% survival rate, even if planted during the dry season, provided they are partially shaded and watered whenever soil moisture drops below 30%. For field planting, bare-root stock, balled seedlings, stumps (stem length 20 cm, root length 20–40 cm, diameter of root collar 0.5–2.5 cm) or striplings are used. The average production of *S. macrophylla* seedlings in the Philippines in the period 1979–1982 was 15 million seedlings/year. Spacing in the field is usually 2.5 m × 2.5 m or 3 m × 3 m.

Silviculture and management Although natural regeneration in *S. macrophylla* stands may be plentiful, it is usual to plant seedlings raised in nurseries. One-year-old mahogany seedlings attain optimal height and diameter growth when fertilized with 3.6 g N, 2.4 g P_2O_5 and 3.6 g K_2O. Phosphorus appears to be the most limiting element for mahogany seedling growth.
Monoculture plantations of mahogany are susceptible to pests, and for that reason mixed plantations with other fast-growing species are often preferred. *Leucaena leucocephala* (Lamk) de Wit and *Paraserianthes falcataria* (L.) Nielsen are used as shade trees in young mahogany plantations.
Thinning usually starts 6 years after planting, and progressively reduces the number of trees to 220–400 trees/ha in plantations of 20 years old, and to 120–150 trees/ha in 35-year-old plantations. The rotation is usually 40–60 years.
S. macrophylla is used for reforestation and afforestation. In the Philippines mahogany is recommended for the revegetation of scrubland and denuded areas, and in the Philippines and Indonesia it is used in agroforestry systems, e.g. in Java with maize, upland rice and cassava.

Diseases and pests In the Philippines stem rot of mahogany trees is caused by *Botryodiplodia theobromae*; it also infests the seeds. In South-East Asia the most destructive pest is the mahogany shoot-borer moth *Hypsipyla robusta* Moore. The attack is commonly noticed on saplings and pole-size trees when terminal shoots show symptoms of dieback, finally resulting in malformed trees. Often, multiple leaders are formed. Options suggested for the Philippines for control of the pest are close spacing to reduce the development of vigorous lateral branches, the planting of *Paraserianthes falcataria* a few years ahead, to provide mild shade for the mahogany planted later (this minimizes lush growth of terminals and laterals), and mixed planting with *Leucaena leucocephala* in alternate rows to provide mild shade. In Java, trees 3–6 years old and 2–8 m tall are most severely damaged by the shoot-borer. *S. mahagoni* is more susceptible to pests and diseases than *S. macrophylla*.

Harvesting Mahogany plantations are clear-cut when the rotation age has been reached (40–60 years) and subsequently replanted with nursery-raised seedlings.
Mahogany logs float in water and can be transported by river. The sapwood is susceptible to staining; an anti-sapstain dip should be used during drying.

Yield In rotations of 50–60 years, average annual volume increments of 15–20 m^3/ha can be achieved for plantations of *S. macrophylla*; on poor sites 7–11 m^3/ha. *S. mahagoni* grows slower, but the quality of the timber is slightly better.

Genetic resources and breeding Populations of mahogany have been depleted through centuries of commercial exploitation in Central and South America. *S. mahagoni* is mentioned as one of the most striking examples of tropical trees which have suffered genetic erosion, and the comparatively few individuals of good genetic stock should be protected. *S. macrophylla* is also becoming rare or even extinct in parts of its natural area of distribution. Both species were proposed but rejected for inclusion in Appendix II of CITES in early 1992. Included species are subject to strict regulations concerning export and trade. The third species of the genus (*S. humilis* Zucc.), which is not planted, is already included in CITES Appendix II.
There is no restriction for trade and export of plantation-grown mahogany. The genetic resources of planted mahogany are reasonably comprehensive because trees have been being planted for many decades and over large areas and are largely still pristine.
Selection work has been carried out recently on an experimental scale in Java (Indonesia), especially towards improving growth and germination rates. The two main mahogany species hybridize freely, and hybrids often show promising features, combining the fast growth of *S. macrophylla* and the good-quality wood of *S. mahagoni*, and greater resistance to diseases and pests.

Prospects Mahogany has very good prospects for large-scale timber production in plantations and for reafforestation. A major problem in plantations is the susceptibility to *Hypsipyla* attack. Research priority should be given to the selection of resistant trees which are fast-growing and have an acceptable wood quality. The establishment of optimal methods of vegetative propagation is urgently needed.

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Selection of species

Swietenia macrophylla King

Hook.f., Icon. pl. 16: t. 1550 (1886).

Synonyms *Swietenia krukovii* Gleason (1936), *Swietenia belizensis* Lundell (1941).

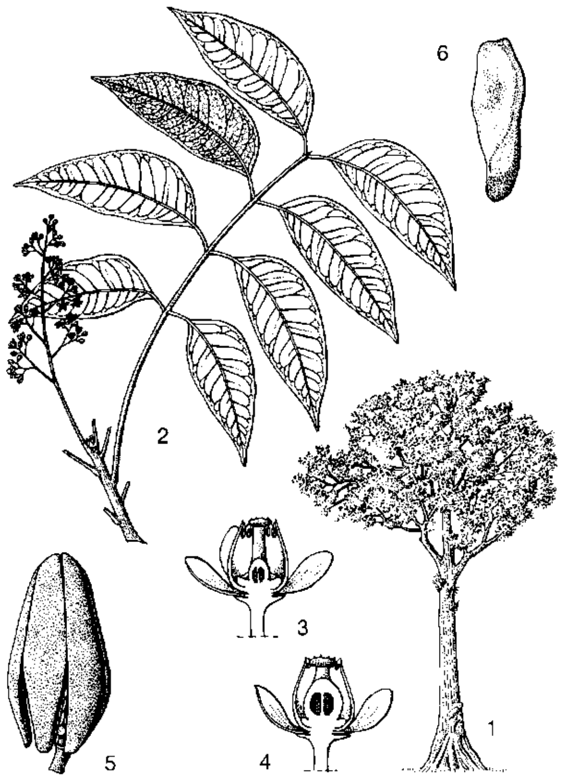
Vernacular names Big-, broad- or large-leaved mahogany, Honduras mahogany (En).

Distribution Native to the mainland of tropical Central and South America from Mexico to Peru and Brazil but absent from the central Amazon. Planted throughout the tropics in reforestation projects and plantations, for instance in Java, Sarawak and especially the Philippines, and planted as a lawn tree in Peninsular Malaysia.

Uses The timber is used as mahogany; the wood is generally less dense and of slightly lower quality than that of narrow-leaved mahogany.

Observations A medium-sized to large tree up to 40(–60) m tall, bole branchless for up to 18(–25) m with a diameter up to 150(–200) cm, buttresses broad and plank-like, up to 5 m high; leaves with (2–)3–6(–8) pairs of leaflets of (8–)9–13(–18) cm × 3–4(–5.5) cm, on young trees sometimes larger; inflorescence 10–18(–20) cm long; flowers with ciliate sepals and petals; capsule 10–15(–22) cm long; seed 7.5–12 cm long. The density of the wood of plantation-grown trees is often somewhat less than that of trees from the forest in the natural area of distribution and weighs 485–840 kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 13, 35, 89, 127, 144, 153, 175, 226, 233, 310, 367, 439, 461, 463, 498, 520, 653, 654, 665, 687, 764, 770, 810.



Swietenia macrophylla King – 1, tree habit; 2, flowering twig; 3, sectioned male flower; 4, sectioned female flower; 5, capsule; 6, seed.

Swietenia mahagoni (L.) Jacq.

Enum. syst. pl. Carib. 4: 20 (1760).

Vernacular names Small- or narrow-leaved mahogany, West Indian mahogany, Spanish or Cuban mahogany (En).

Distribution Native to the West Indian Islands but now very rare due to over-exploitation. Planted throughout the tropics in reforestation projects and plantations, for instance in Java and the Philippines and occasionally in gardens in Peninsular Malaysia.

Uses The timber is regarded as the best quality mahogany.

Observations A small to medium-sized tree up to 30 m tall, bole often short and much-branched, buttresses short and blunt; leaves with 2–4(–5) pairs of leaflets of (4–)5–6(–8) cm × (1.5–)2.5–3.3 cm, on young trees sometimes larger; inflorescence (5–)8–15(–18) cm long; flowers with glabrous sepals and petals; capsule (4.5–)6–10 cm long; seed 2–6 cm long. Plantation-grown wood is usually somewhat less dense than that from trees of the forest and weighs 560–740(–850) kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 13, 35, 153, 233, 434, 439, 461, 520, 539, 653, 654, 665.

S. Prawirohatmadjo (general part),
J. Suranto (general part),
W.G. Keating (properties),
Ani Sulaiman (wood anatomy),
M.S.M. Sosef (selection of species)

Tectona L.f.

Suppl. pl. 20, 151 (1782).
VERBENACEAE
x = unknown; *T. grandis*: $2n = 36$

Trade groups Teak: medium-weight hardwood, *Tectona grandis* L.f. and *T. philippinensis* Benth. & Hook.f.

Vernacular names Teak: teck (Fr). Indonesia: jati (general), deleg, kulidawa (Java). Burma: kyun. Laos: sak. Thailand: sak (general), mai-sak. Vietnam: c[aa]y t[ees]ch, gi[as] t[ij].

Origin and geographic distribution *Tectona* consists of 3 species. The natural distribution of the genus is discontinuous. It occurs in the Indian peninsula, Burma, Laos, Thailand and the Philippines. In the Philippines teak is represented by a distinct and narrow endemic species. Teak is probably not indigenous to Indonesia; there are indications that it was introduced to Java 400–600 years ago. At present it is widely cultivated in many parts of the tropics. Within the Malesian area plantations have been established practically everywhere.

Uses Teak is a well-known and very good general-purpose timber. Its favourable properties make it suitable for a wide variety of purposes. For the export market teak is recommended for ship decking and other constructional work in boat building. It is extensively used for deck houses, rails, bulwarks, latches, weather doors, etc. and for furniture and interior fittings of boats. Being classified as very resistant to teredo activity, teak is an excellent timber for bridge building and other construction in contact with water such as docks, quays, piers and floodgates in fresh water. In house building teak is particularly suitable for interior and exterior joinery (windows, solid panel doors, framing) and is used for floors exposed to light to moderate pedestrian traffic. It is also used quite extensively for the manufacture of furniture and garden furniture. Other applications of teak are for building poles, transmission line poles, fence posts, wall boards, beams, woodwork, boxes, musical instruments, toys, railway sleepers and railcar construction. It is brittle and therefore less suitable for articles requiring high resilience, such as tool handles and sporting goods. The high resistance of teak to a wide variety of chemicals make it ideal for laboratory and kitchen tables as well as for scrubbing towers, vats, pipes and fume ducts in industrial chemical plants. Figured wood produces a very attractive veneer which is extensively used in the manufacture of furniture and interior fitting. Teak is suitable for the manufacture of decorative plywood. Teak wood has also been used for the manufacture of charcoal and as a fuelwood, but is nowadays often considered too valuable for such usage.

Both the bark of the roots and the young leaves produce a yellowish-brown or reddish dye which is used for paper, clothes and matting. Sawdust from teak wood is used as an incense in Java. In traditional medicine a wood powder paste has been used against bilious headaches and swellings and internally against dermatitis or as a vermifuge. The charred wood soaked in poppy juice and made into a paste was used to relieve the swelling of eyelids. The bark has been used as an astringent and the wood oil as a hair tonic.

Production and international trade Burma produces most of the world supply of teak, followed by India, Thailand and Indonesia. The average annual teak timber production in Indonesia (Java) in the period 1984–1988 was 800 000 m^3, which was processed into the following products (in terms of average annual production): 4.4 million m^2 veneer, 54 000 m^2 mosaic parquet, 140 000 m^2 laminated parquet and parquet blocks, 194 000 m^2 wall panelling, decking and finished flooring, 100 000 m skirting, 26 000 m^2 overlay plywood, 475 000 beams, and 580 solid doors. The export of sawn teak timber from Indonesia in 1989 was 46 000 m^3 (with a value of US$ 29.4 million). Since 1990 the export of sawn teak timber from Indonesia has been restricted to meet the demand of the local furniture industry.

Teak was by far the most important export timber in Thailand until all logging in natural forest was banned in 1989. The highest production for export of teak from natural forest was reached in 1980 with 97 000 m^3, but export decreased, with some fluctuations, to 39 000 m^3 in 1985, and 25 000 m^3 (all processed teak) in 1990. The above-mentioned ban, the depletion of natural teak stands and the high demand on the local market have caused the sharp decline of the amounts of teak exported.

The allowable annual cut of teak in the natural deciduous forests of Burma is 350 000 t. The area planted with teak in Java is about 1 million ha, which is 45% of the total area of plantation forest. Natural stands of teak in Thailand cover about 2.5 million ha, the plantations 170 000 ha. In other South-East Asian countries, teak is planted on a comparatively small scale and the production is small. However, plantations receive great interest, e.g. in Papua New Guinea where teak fetches very high prices and where the export of teak logs is banned, in Peninsular Malaysia where plantations on an experimental scale in the far northwest show very encouraging results, and in Sabah where the export of sawn teak timber in 1992 was only 12 m^3 with a value of US$ 4600 (US$ 383/m^3). Prices of teak wood are very high (e.g. even in 1989 as much as 640 US$/$m^3$ for sawn Java teak on the export market), and hence teak is mainly used as a luxury wood.

Properties Teak is a medium-weight timber which is rather soft and has a very characteristic appearance. The heartwood is often dull yellowish when freshly cut but it turns golden brown or sometimes dark greyish-brown after exposure, often streaked greyish or blackish; the sapwood is yellowish-white or pale yellowish-brown and up to 50 mm thick. The wood is oily to the touch, and when freshly cut it has a smell reminiscent of leather. The density is (480–)610–750(–850) kg/m^3 at 12% moisture content. The grain of the wood is straight, wavy or slightly interlocked, texture rather coarse and uneven.

At 12% moisture content the modulus of rupture is 85–106(–148) N/mm^2, modulus of elasticity (8600–)10 000–13 400 N/mm^2, compression parallel to grain (43–)47–60(–72) N/mm^2, compression perpendicular to grain 6–7.5 N/mm^2, shear 8–14.5 N/mm^2, cleavage (60–)77–82 N/mm radial and (75–)87–91 N/mm tangential, Janka side hardness 3730–4510(–4800) N and Janka end hardness 4150–4500 N.

The rates of shrinkage of teak are very low, from green to 12% moisture content 0.7–1.5% radial and 1.1–2.5% tangential, and from green to oven dry 2.5–3.0% radial and 3.4–5.8% tangential. Teak dries very well but rather slowly. Boards of 1 cm thick take 15 days to air dry from 40% to 15% moisture content, boards of 2.5 cm thick 30 days and boards of 4 cm thick 50 days. Boards of 2.5 cm thick can be kiln dried from 40% to 10% moisture content in 5–6 days at a drying temperature of 60–80°C, and a corresponding relative humidity of 80% to 40%. In particular, care is required in determining initial and final moisture contents, as large variations in drying rates occasionally occur. The timber is very liable to colour change, and high initial temperatures should be avoided. During kiln drying a condensate of butyric acid is formed which may corrode metal kilns (unless made of aluminium or stainless steel). Teak has low movement values and a good form stability.

Teak is not difficult to work, but requires some effort, mainly because of the presence of silica (up to 1.5%). Tools tipped with tungsten carbide are recommended for sawing and planing operations. The wood is difficult to chisel with a hollow square mortiser, but turns well. The nail-holding capacity is good, but pre-boring is recommended; the screw- and staple-holding capacity is also good. Gluing is only successful on freshly machined or newly sanded surfaces. The wood bending properties vary and are usually classified as moderate; there is a tendency to buckle, and the wood is only suitable for bends of moderate curvature. Staining and polishing require freshly machined surfaces or a pretreatment with thinner. However, teak can be varnished and polished beautifully. It is easy to cut into smooth, tight veneer of uniform thickness at a temperature of 90–95°C. The veneer dries flat and split-free with low shrinkage. Owing to its beautiful figure, teak is in great demand as face veneer.

Teak heartwood is rated as durable to very durable. Stake tests show an average service life in contact with the ground of up to more than 10 years under tropical conditions and more than 25 years under temperate conditions. Graveyard tests in Indonesia indicate that the durability is significantly influenced by tree age; wood from 75-year-old trees has an average service life in contact with the ground of 7 years, but wood from 20-year-old trees only 2.5 years. Teak is very durable under cover. In India there are examples of teak wood several hundreds or even over 1000 years old, and still in good condition. The heartwood is resistant to termites, and, although not immune, to marine borer attack. The sapwood is reported to be liable to attack by powder-post beetles (*Lyctus* sp.). The heartwood is difficult to treat with preservatives, although carbolineum and natrium fluoride reportedly may penetrate to a fair depth.

Burma teak is usually slightly superior to Java teak regarding strength properties, while teak from Thailand is slightly less strong and less heavy than Java teak. Java teak and Malabar teak are preferred for figured material.

The wood contains 47.5% cellulose, 30% lignin, 14.5% pentosan, 1.4% ash and 0.4–1.5% silica; the solubility is 4.6% in alcohol-benzene, 1.2% in cold water, 11.1% in hot water and 19.8% in a 1% NaOH solution. The fine dust produced in machining operations may cause irritation of the skin or bronchial asthma and rhinitis after inhalation; a well-functioning dust extractor fan is recommended. The substances responsible for the allergic reactions are probably lapachol and desoxylapachol, though they are not always present in the wood. The resistance of teak wood to termites and fungi is due to the presence of tectochinon and other anthrachinones; naphthochinones and naphtoles also seem to play a role in the resistance to fungal attack. The energy value of the wood is 21 350 kJ/kg.

Description Small to large deciduous trees of up to 50 m tall; bole generally straight and branchless for up to 20(–25) m, diameter up to 150(–250) cm, at base fluted or with low buttresses; bark soft; branches tetragonal. Leaves deciduous, decussate or ternate, simple, the blade ovate-lanceolate to broadly ovate, cuneate at base, margin entire or denticulate, softly hairy on both surfaces, petiolate. Inflorescence with many flowers in terminal or axillary cymes, bracts very small. Flowers bisexual, actinomorphic, small; calyx gamosepalous, shortly 5–7-lobed, persistent, finally enclosing the fruit; corolla gamopetalous, 5–7-lobed with a short tube and patent or reflexed lobes, glabrous, white or bluish; stamens 5 or 6, inserted at the base of the corolla tube, exserted, anthers dorsifixed, 2-celled, opening by longitudinal slits; ovary ovoid, 2-carpellate, 4-celled, one ovule per cell, style terminal, with a shortly bifid stigma with subequal branches. Fruit drupaceous, subglobose or slightly tetragonal, woody, with a thin, subcarneous exocarp and thick, bony, 4-celled endocarp. Seed without endosperm. Seedling with epigeal germination; cotyledons equal, petiolate, with a notched or emarginate apex; all leaves decussate.

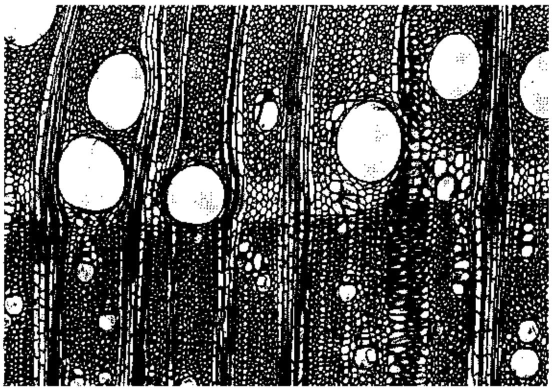
Wood anatomy

– Macroscopic characters:

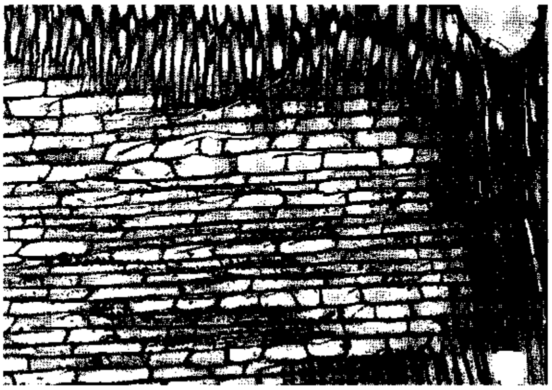
Sapwood white, yellowish-white to pale yellowish-brown; heartwood golden brown, dark golden brown, sometimes ageing to dark brown or dark greyish-brown, the colour varying considerably with locality. Grain straight or wavy, sometimes interlocked. Texture moderately coarse to coarse and uneven; wood generally dull with rather rough oily feel, strongly and characteristically scented when fresh. Growth rings distinct and generally conspicuous to the naked eye.

– Microscopic characters:

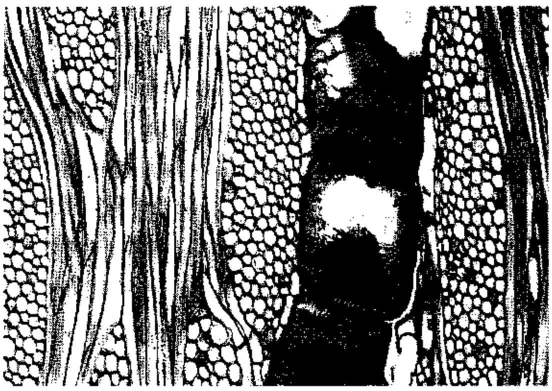
Growth rings distinct, marked by thick-walled latewood fibres and differences in vessel diameter. Wood ring-porous; earlywood vessels extremely large to very large, with largest pores of 340–370 μm in diameter, solitary or in radial rows of 2–3 (mostly 2), transition from the earlywood to latewood gradual to more or less abrupt, latewood vessels medium-sized to small or very small with maximum diameter of 50–290 μm, solitary or in radial rows of 2–5; perforations simple; intervessel pits alternate, mainly round, 5–7 μm; helical



transverse section (×25)



radial section (×75)



tangential section (×75)

Tectona grandis

thickenings absent; yellowish or reddish-brown gummy deposits mainly present in the smaller vessels; tyloses fairly abundant. Fibres 700–1400 μm long, septate, walls variable in thickness with thicker walls towards the latewood, interfibre pits simple to minutely bordered and confined to the radial walls. Parenchyma both apotracheal and paratracheal; apotracheal parenchyma extremely sparse, restricted to occasional diffuse strands of 4(–8) cells; paratracheal parenchyma in thin vasicentric sheaths, but in the earlywood region in the form of a wide, 2–10(–20)-seriate paratracheal band in which the first row of earlywood vessels is partially or wholly embedded. Rays 4–7/mm, 1–6 or more cells wide (mostly 4-seriate or more), mostly about 0.5 mm in height but up to 0.9 mm in some samples, heterogeneous, with one row of upright to square cells but some rays tending to be homogeneous. Crystals absent. Vitreous silica present in some vessels and parenchyma. Yellowish or reddish-brown gummy deposits fairly abundant in the parenchyma and rays of heartwood.
Species studied: *T. grandis*.

Growth and development The fruit splits open on one or two sides when germination starts; the radicle emerges first, and soon afterwards the cotyledons emerge. A single fruit often produces several seedlings (usually 2). The primary root is long, but gradually disappears after lateral roots have developed. The root system is superficial, often not deeper than 50 cm, and roots may extend laterally up to 15 m from the stem.

The central axis is sympodial and all side axes are orthotropic and equal. Young shoots are formed from lateral buds at the base of the terminal inflorescence. Consequently, the central axis branches after flowering. Its length at the moment of first flowering is very important in silviculture. When it is long (it may reach up to 10 m), the final bole form is positively affected, but early flowering trees may develop extremely wide crowns and short boles. The occurrence of the first inflorescence is determined by both genetic and environmental factors.

Teak is a strong light demander, and the optimum for its growth lies at 75–100% of full sunlight. Seedlings are very intolerant of shade. In seasonal climates teak is deciduous. Trees grown in non-seasonal climates are semi-deciduous. However, teak continues to develop growth rings. Young trees usually easily recover from damage by fire. Frequent fires may even result in a thickened rootstock from which, under favourable conditions, a new, more vigorous shoot may develop. In Thailand flowering normally starts at the age of 8–10 years. However, trees have been observed to flower at the age of 3 months, while a few specimens of superior phenotype did not flower before the age of 27 years. Flowers usually appear during the rainy season, and trees tend to flower synchronously. In Thailand, flowering occurs particularly in June – September and fruiting in November – January. In Java, teak flowers every year at the beginning of the rainy season (October – November), and only a few flowers (about 1%) develop into fruits. Fruits fall gradually during the dry season (May – September).

Pollination is by insects; in Thailand in particular by bees. The individual flower has a one-day cycle and the optimum pollination period is between 11.30 h and 13.00 h. Teak is mainly self-incompatible (96–100%). Although fruit set in Thailand is low (0.5–5%), 6–60% of fruit set can be achieved by artificial pollination. Fruits develop to full size in about 50 days after pollination, but are mature at 120–200 days after pollination. They are dispersed by wind over 10–15 m, but fruits are also transported by running water after heavy rainfall.

The initial growth of teak is rapid. At an age of 5 years an average height of 13 m and a stem diameter of 10 cm is not unusual, after 10 years 16.5 m and 15 cm, and after 20 years 21.5 m and 23.5 cm. After 15–20 years growth slows down. In stands of 80 years old the maximum height of trees is about 45 m, with a maximum diameter of 75 cm.

Other botanical information *Tectona* is the only genus of the tribe *Tectonae* which is classified within the subfamily *Viticoideae*. It differs from other tribes in this subfamily by the deviating type of the drupe. Features of the wood anatomy indicate that *Tectona* is closely related to the genera *Clerodendrum*, *Gmelina* and *Premna* and enable the genus to be divided into two sections, viz. sect. *Tectona* (with *T. grandis*) and sect. *Leiocarpae* Briq. (with *T. philippinensis* and *T. hamiltoniana* Wallich). Like *T. philippinensis*, *T. hamiltoniana* has a very localized natural distribution, i.e. in central Burma.

Ecology Teak occurs naturally in various types of tropical deciduous forest. It is often a dominant member of mixed deciduous forest, where its main associates are *Xylia* spp., *Afzelia xylocarpa* (Kurz) Craib, *Terminalia* spp. and *Lagerstroemia* spp. The forest floor is often covered by bamboos. The various teak forest formations can be grouped into three main types: moist natural teak formations (annual rainfall of (1300–)1500–2500 mm), dry natural teak formations (annual rainfall 760–

1500 mm) and Indonesian teak formations (annual rainfall 1200–2000 mm). Teak thrives best and reaches its largest dimensions in a humid tropical climate but it needs a marked dry season. Optimal growth is attained with an annual rainfall of 1200–2500 mm of which 75% falls in the rainy season. Teak generally occurs scattered but can form almost pure stands under favourable conditions. Teak forests are generally situated on hilly or undulating country but are known from alluvial flats as well. Their altitudinal limit lies around 1000 m where they give way to oak and pine forests. The most suitable soil is a deep and well-drained, fertile alluvial-colluvial soil with a pH of 6.5–8.0 and a relatively high Ca and P content. Teak does not tolerate flooding or infertile lateritic soils. Young teak plants show a remarkable capability to recover after fire. Teak is a pioneer species, but with a long lifespan. In contrast to many other pioneer species, teak is able to persist and dominate and to naturally regenerate towards the climax phase of succession in most parts of its natural range.

Propagation and planting Natural regeneration of teak is particularly abundant in forests exposed to fires, and often occurs patchwise. Seeds collected from the forest floor are generally used to establish plantations. It is recommended to collect seeds from trees older than 20 years. The weight of 1000 seeds of *T. grandis* is 500–1250 g. Seed is often collected from selected seed stands. The seeds have a rather low germination rate, usually less than 50%, but sometimes up to 80%. Germination usually starts after 10 days but may extend over 2–3 months. In Thailand seedlings are kept in nursery beds for about one year. Then the rootstock is dug up, the stem cut off, and the stump is planted into the field. Direct sowing into the field at the beginning of the rainy season is often practised in Java. Soaking the seeds for 2 days, drying them for 1 day, and repeating this procedure 4 times promotes germination. Seeds can be stored for up to several years without difficulty, provided they are kept under cover. Stumps can be stored for up to one year.

Teak can be successfully propagated by tissue culture. Stem segments and leaf stalks taken from seedlings or trees yield callus when cultured on a modified Murashige and Skoog medium. Root formation occurs within 2 months after planting the explants on the same medium with 3.5 ppm naphthalene acetic acid and 0.25 ppm benzylamino purine.

Normal spacing in the field is 2 m × 2 m, 3 m × 1 m, 3 m × 3 m, 4 m × 2 m or 4 m × 4 m, depending on site conditions.

Silviculture and management In natural teak forest in Thailand a selective cutting system is used, with minimum girth limit of 180 cm at breast height. For teak plantations the clear-cutting system is used. Replanting is often carried out after cutting. The cutting cycle for plantations is 50–80 years. The site is completely cleared before planting, usually by means of fire.

Frequent weeding in the first years after planting is necessary, as seedlings are easily suppressed by weeds. Regular thinnings are needed to obtain well-shaped logs. In plantations in Java with an initial spacing of 3 m × 1 m, thinning starts 3–4 years after planting, with a frequency of 4 years until the age of 15 years, from then on with a frequency of 5 years until the age of 25 years, and thereafter once every 10 years until the felling age, which is usually 80 years. Frequency of thinning depends on site conditions, i.e. more frequent in better sites. Teak trees coppice well; regrowth from the stumps of felled trees is sometimes a real problem in the establishment of new plantations.

Teak plantations must be protected from fire and grazing animals, as the soil is often susceptible to erosion. Interplanting with other species is difficult because of the fast initial growth of teak, but with *Leucaena* spp., *Acacia* spp. and perhaps *Shorea* spp. it seems possible. It is sometimes underplanted with bamboos. In Java, teak is often planted in the 'tumpangsari system'. In this agroforestry system teak is planted together with agricultural crops, and often also *Leucaena leucocephala* (Lamk) de Wit. However, after about 2 years the shade under the young trees usually precludes sufficient growth of the crop.

Diseases and pests Diseases can be conveyed by bacteria such as *Pseudomonas solanacearum* and fungi such as *Corticium salmonicolor*. Wood borers frequently attack the stems, e.g. *Xyleutes ceramicus* in Thailand and *Xyleborus destruens* in Indonesia. Leaf-eating caterpillars such as *Hyblaea puera* and *Pyrausta machaeralis* may defoliate branches. Termites such as *Neotermes tectonae* may damage the trees, although many provenances show a high resistance. Seeds can be infested by larvae of *Lepidoptera* and *Coleoptera* (longhorn beetles). Crowns are often infested by semi-parasitic mistletoes (*Loranthus* spp.).

Harvesting Stems are usually girdled two years before logging. This practice kills the trees, and makes felling and transport easier; the logs dry and are then transportable by water. With modern felling and transportation techniques, girdling is nowadays redundant. Fresh logs are sometimes coated with tar or lime at both ends to prevent splitting. Cattle and buffalo are still often used to transport of the logs over short distances; for long-distance transportation trucks or trains are used. Sometimes transport is by river.

Yield The average yield of teak plantations in Java is 60–100 m^3/ha, including thinnings. Occasionally the final harvest may yield as much as 390 m^3/ha in stands 80 years old. The mean annual volume increment is (1–)3–6(–15) m^3/ha.

Genetic resources and breeding The natural area of distribution of *T. grandis* is large, and it often occurs commonly or even gregariously or is dominant. Therefore, it is not easily liable to genetic erosion. Its occurrence in different habitats, resulting in substantial provenance variation, gives potential for selection. This has been recognized in Indonesia and Thailand, where there are ongoing selection programmes and clonal seed orchards are being established.

The two other *Tectona* species, *T. hamiltoniana* and *T. philippinensis,* have a small area of distribution and need conservation. They are rarely planted, but their potential value for teak breeding should be investigated.

Breeding programmes have been established in Thailand, Indonesia and Papua New Guinea. In Thailand there is a long-term teak-breeding project, using 400 selected trees. The improvement programmes mainly concentrate on breeding for superiority in vigour and form, and also for pest resistance (e.g. against *Xyleutes ceramicus*) and preferred wood characteristics (e.g. colour, texture and hardness).

Prospects Teak is a good example of a high-quality timber which can be obtained from plantations. Adequate methods of vegetative propagation are indispensable for large-scale establishment of plantations with superior trees. Tissue culture on an experimental scale shows promising results with shoot tips and nodal segments, but more research is needed, especially on the behaviour of trees resulting from tissue culture.

Literature |**1**| de Guzman, E.D., Umali, R.M. & Sotalbo, E.D., 1986. Guide to Philippine flora and fauna. Vol. 3. Dipterocarps, non-dipterocarps. Natural Resources Management Center, Ministry of Natural Resources and University of the Philippines, Manila. pp. 359–360. |**2**| Haslett, A.N., 1986. Properties and uses of the timbers of western Samoa. Plantation-grown exotic hardwoods. Ministry of Foreign Affairs, Wellington. pp. 22–24. |**3**| Hedegart, T., 1976. Breeding systems, variation and genetic improvement of teak (Tectona grandis L.f.). In: Burley, J. & Styles, B.T. (Editors): Tropical trees. Variation, breeding and conservation. Linnean Society, London. pp. 109–123. |**4**| Kaosa-ard, A., 1981. Teak (Tectona grandis), its natural distribution and related factors. Natural History Bulletin of the Siam Society 29: 55–72. |**5**| Krishna Murty, A.V.R.G., 1975. Bibliography on teak, Tectona grandis Linn.f.: a survey of the world literature covering about 2961 references with abstracts to the more important ones. Kishore, Dehra Dun. 402 pp. |**6**| Martawijaya, A., Kartasujana, I., Kadir, K. & Prawira, S.A., 1986. Indonesian wood atlas. Vol. 1. Forest Products Research and Development Centre, Bogor. pp. 40–45. |**7**| Ng, F.S.P, 1979. Teak. Nature Malaysiana 4(3): 36–41. |**8**| Noerhadi, E., 1980. Vegetative propagation of Tectona grandis L. and Pinus merkusii Jungh. et de Vriese using tissue culture. Duta Rimba 42: 11–15. |**9**| van Alphen de Veer, E.J., 1957. Teak cultivation in Java. Tropical Silviculture. FAO Forestry and Forest Products Studies 2, No 13. FAO, Rome. pp. 216–232. |**10**| Webb, D., Wood, P.J. & Smith, J., 1980. A guide to species selection for tropical and sub-tropical plantations. Tropical Forestry Papers No 15. Commonwealth Forestry Institute, University of Oxford. p. 249.

Selection of species

Tectona grandis L.f.

Suppl. pl: 151 (1782).

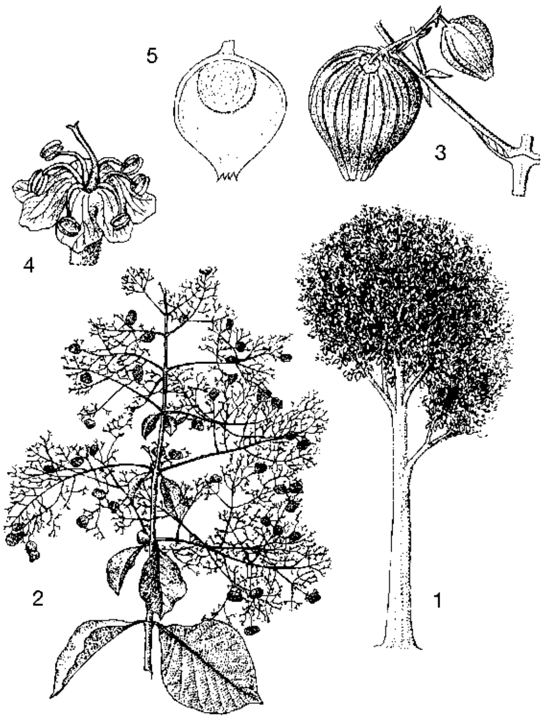
Synonyms *Tectona theka* Lour. (1790).

Vernacular names Teak (En). Teck (Fr). Indonesia: jati (general), deleg, kulidawa (Java). Philippines: djati (Sulu), dalanang (Panay Bisaya). Burma: kyun. Laos: sak. Thailand: sak (general), mai-sak. Vietnam: c[aa]y t[ees]ch, gi[as] t[ij].

Distribution *T. grandis* occurs naturally in peninsular India, Burma, Thailand and Laos. It was probably introduced to Java several hundred years ago and now occurs more or less naturally. It is cultivated on a large scale both inside and outside the Malesian region.

Uses As given for the genus.

Observations A medium-sized to large tree up to 50 m tall, bole straight and branchless for up to 20(–25) m, with a diameter up to 150(–250) cm, sometimes fluted or with low buttresses at base, bark surface with longitudinal cracks, greyish-



Tectona grandis L.f. – 1, tree habit; 2, fruiting twig; 3, fruits with inflated calyx; 4, flower; 5, fruit with opened calyx.

brown, inner bark with red and sticky sap; leaves broadly ovate, (11–)20–55 cm × (6–)15–37 cm (but much larger on suckers), stellate-floccose; inflorescence about 40 cm × 35 cm; flowers 3–6 mm long, calyx campanulate, corolla white with pink on the lobes; fruit enclosed by an inflated calyx. Several morphological forms have been distinguished, principally by leaf characters. *T. grandis* generally occurs in deciduous forest on fertile, well-drained soil up to 1000 m altitude. The density of the wood is (480–)610–750(–850) kg/m^3 at 12% moisture content. See also the table on wood properties.

Selected sources 55, 58, 59, 80, 84, 88, 94, 102, 103, 145, 153, 159, 168, 175, 190, 226, 310, 315, 336, 351, 359, 364, 387, 390, 391, 395, 408, 409, 417, 418, 441, 461, 509, 516, 519, 534, 543, 549, 579, 610, 624, 636, 698, 724, 754, 757, 763.

Tectona philippinensis Benth. & Hook.f.

Gen. pl. 2: 1152 (1876).

Vernacular names Philippines: Philippine teak (general), bunglas (Panay Bisaya), malapangit (Tagalog).

Distribution The Philippines (Luzon).

Uses The wood is used for heavy construction.

Observations A small tree up to 15 m tall, bole with a diameter up to 50 cm; leaves elliptical-ovate to ovate-lanceolate, 8–15 cm × 3–6 cm, glabrous or nearly so on the upper surface, the lower surface white verrucose; flowers nearly 8 mm long, calyx funnel-shaped, corolla white; fruit enclosed by a non-inflated calyx. *T. philippinensis* occurs in thickets and secondary forest at low altitude.

Selected sources 84, 175, 223, 282, 390, 391, 579.

C. Phengklai (general part),
T. Smitinand (general part),
J. Kartasubrata (general part),
P.B. Laming (properties),
S.C. Lim (wood anatomy),
M.S.M. Sosef (selection of species)

Tetramerista Miq.

Fl. Ind. Bat., Suppl.: 534 (1861).

THEACEAE

x = unknown

Trade groups Punah: medium-heavy hardwood, a single species, *Tetramerista glabra* Miq., Fl. Ind. Bat., Suppl.: 534 (1861).

Vernacular names Punah. Brunei: amat, entuyut, terepit. Indonesia: punak (general), kayu malaka (Sumatra), carega (Kalimantan). Malaysia: tuyot (Sabah), entuyut, pokon hujun (Sarawak).

Origin and geographic distribution The genus *Tetramerista* consists of 3 species. It is confined to western Malesia. *T. glabra*, the only species used for timber, occurs in Peninsular Malaysia, Singapore, Sumatra, Borneo (Sarawak, Brunei, Sabah, East Kalimantan) and adjacent islands.

Uses Punah is a suitable timber for indoor construction. It is used for purlins, ceilings, flooring, posts, beams, door and window frames, and all other interior joinery and structural work not in contact with the ground. Punah is not particularly suitable for decorative purposes, e.g. for furniture. However, it is used for boxes and crates, and, when treated, for railway sleepers.

The tree produces a sour and fresh, red fruit which is used in fruit salads.

Production and international trade Punah is a commercially important timber, although mostly only locally. No trade and export figures are available, but fairly large quantities of this timber are traded in Sumatra and Peninsular Malaysia. A small amount of timber is exported, e.g. to Japan. In East Kalimantan punah is often traded in combination with keruing (from *Dipterocarpus* spp.). In most coastal districts of Sarawak, Brunei, Sabah and East Kalimantan moderate supplies are available.

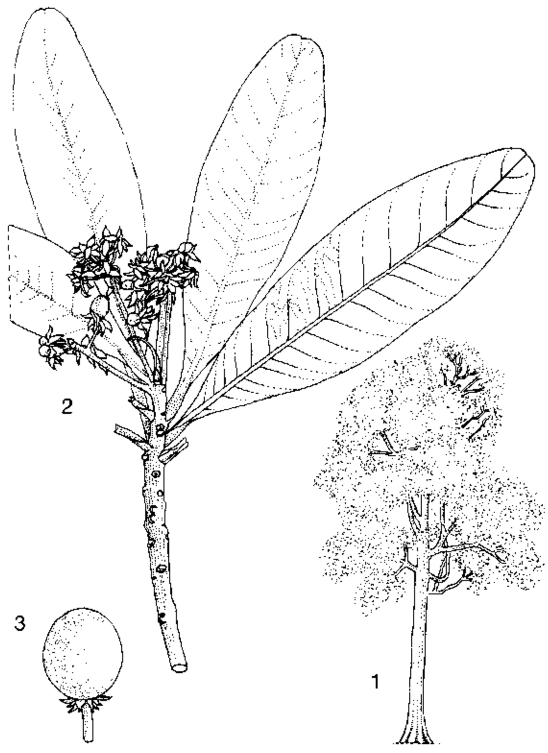
Properties Punah is a moderately heavy and moderately hard timber. The heartwood is yellowish-pink, very light brown to straw-coloured when fresh, becoming slightly darker during drying, towards pinkish-brown, sometimes with splashes of orange-brown tinge or with darker coloured streaks. The sapwood is generally not differentiated from the heartwood when fresh but fairly well demarcated and lighter in colour when dry. The wood lathers when rubbed with water, and often contains a wax-like substance with an unpleasant smell when wet, but with a rather fragrant smell when dry. The density is 625–800 kg/m^3 at 15% moisture content. The grain is straight, shallowly interlocked or spiral, texture coarse but even.

The modulus of rupture is 66–86 N/mm^2 for green timber and 87–105 N/mm^2 at 19% moisture content, the modulus of elasticity is 12 800–13 500 N/mm^2 in green condition, and 15 400–15 800 N/mm^2 at 19% moisture content and compression parallel to grain is 31.5–34.5 N/mm^2 in green condition and 49–64 N/mm^2 at 19% moisture content, compression perpendicular to grain c. 4 N/mm^2 in green condition and 5 N/mm^2 at 19% moisture content, shear c. 9 N/mm^2 when green and 10 N/mm^2 at 19% moisture content, cleavage c. 43 N/mm radial and 80 N/mm tangential at 19% moisture content; Janka side hardness is 4050–4320 N in green condition, and 4670–5220 N at 19% moisture content, Janka end hardness 4450 N at 75% moisture content. See also the table on wood properties.

The rates of shrinkage of punah are high, from green to 15% moisture content 3.2% radial and 4.5% tangential, from green to oven dry 6.1% radial and 10.7% tangential. Punah seasons fairly rapidly, but end and surface checks as well as splitting are recorded, and it is prone to sap stain. It takes 2.5 months to dry 15 mm thick boards to air-dry condition, 3.5 months for 25 mm thick boards and over 4 months for 40 mm thick boards. For drying, kiln schedule C (Malaysia) is recommended. The stock should be properly weighted down to reduce warping, and end-coating should be applied before kilning to reduce end splits.

Punah is easy to work. It saws easily, and blunting effects on tools are generally not severe, but sawteeth may become gummed up. Finish after planing and turning tends to be rough and fibrous; finishing requires considerable sanding. Boring and turning are rated as easy. It can be bored to a smooth finish with a two-winged, twist-fluted auger. The nail-holding capacity is good, but pre-boring for screwing is necessary to avoid splitting of thin boards. Punah glues well.

The timber is only moderately durable; stake tests show an average life of 3–4 years under tropical conditions. It is, however, rated as durable for interior work. Punah is liable to termite attack, and during seasoning a moderate amount of fungal staining is reported. The timber is moderately difficult to impregnate. Using the open tank system, the average absorption of a 1 : 1 mixture of creosote and diesel is 64–72 kg/m^3, and 130 kg/m^3 when using a pressure treatment. Other tests show figures of 111 kg/m^3 and 145 kg/m^3, respectively, for the same treatments. Treated railway sleepers have shown an average service life of 20 years.



Tetramerista glabra Miq. – 1, tree habit; 2, flowering twig; 3, fruit.

The fine sawdust may cause allergic reactions.

Description A medium-sized to fairly large tree up to 40 m tall, with straight bole up to 100(–150) cm in diameter and branchless up to 15 m, without distinct buttresses but ridged and fluted at the base; outer bark rough, shallowly and irregularly fissured, flaky, soft and thick, red-brown to dark brown, inner bark thick, up to 1.3 cm, soft and fibrous, pinkish-red outside to pinkish-cream inside; crown open, having a few large ascending branches and laterally spreading smaller branches; branchlets stout, rather pale. Leaves alternately and arranged spirally, mostly more or less clustered near tips of twigs, simple and entire, oblanceolate to narrowly obovate, 6.5–30 cm × 3–8.5 cm, at base running down the short stalk and forming narrow wings, acute to notched at apex, leathery, glabrous and shiny, punctate with black glands beneath, with 12–20 pairs of secondary veins and faint or invisible tertiary venation, without stipules. Inflorescence a long pedunculate axillary panicle or umbel-like raceme. Flowers bisexual, actinomorphic, 2–2.5 cm across, with 2 sepal-like bracts at the base, 4-merous; sepals oblong, petals lanceolate, about as long as sepals; stamens with filaments flattened at the base and oblong-sagittate anthers glandular at base; ovary 4-locular, each locus with a single ovule. Fruit a globose to ellipsoid berry, c. 3 cm × 2.5 cm, surrounded at the base by the persistent bracteoles, sepals and petals, 4-seeded. Seeds oblong, 1–2 cm long. Seedling with epigeal germination.

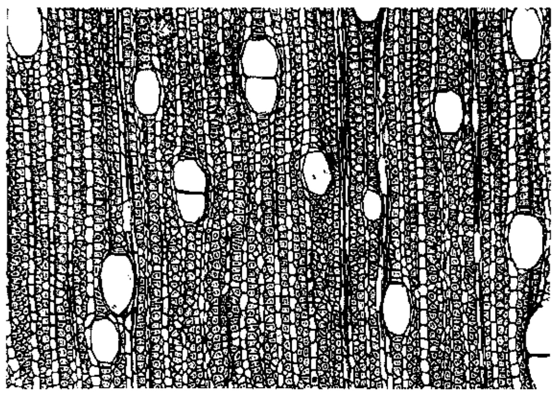
Wood anatomy

– Macroscopic characters:

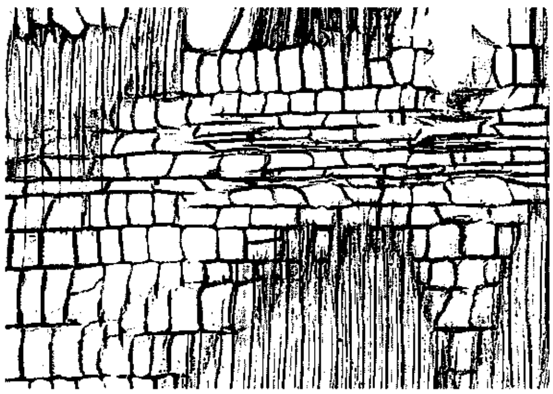
Sapwood not defined from heartwood when fresh but fairly clearly demarcated in seasoned timber; heartwood straw-coloured or yellow-pink, weathering to a pink-brown with an orange-brown tinge. Grain straight, shallowly interlocked or spiral. Texture coarse but even. Planed surface rather dull (without lustre). Growth rings absent; vessels visible to the naked eye and sparsely filled with tyloses; pinkish deposits common; rays of two distinct sizes, the broader rays distinct to the naked eye and conspicuous on the radial surface.

- Microscopic characters:

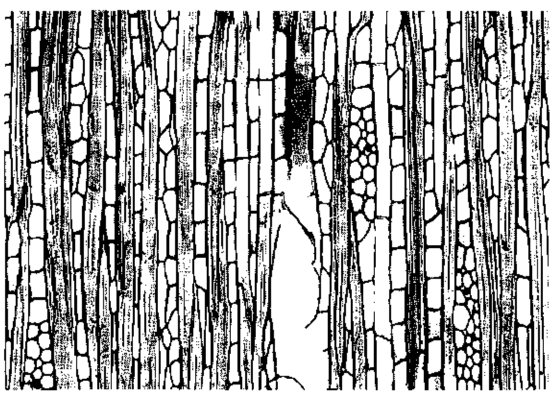
Growth rings absent. Vessels diffuse, 2–3/mm^2, mainly in multiples of 2–6 or more, rarely solitary or in clusters, multiples sometimes with narrow and short radial tails, oval to polygonal, average tangential diameter 200 μm or more; perforations mostly simple, occasionally scalariform; intervessel pits alternate, minute and round, 2–6 μm; ves-



transverse section (×25)



radial section (×45)



tangential section (×45)

Tetramerista glabra

sel-ray and vessel-parenchyma pits similar but half-bordered; helical thickenings absent; reddish-brown gum-like deposits present; tyloses infrequent. Fibres 2000–3300 μm long, non-septate, mostly thick-walled, with simple to minutely bordered pits mainly confined to the radial walls. Parenchyma abundant, apotracheal, diffuse or diffuse-in-aggregates, in 4–8-celled strands. Rays, about 10/mm, of two distinct sizes, 1(–2)-seriate and 4–5-seriate (rarely more), broad rays often several mm high, mostly Kribs type heterogeneous I with up to 10 to very many marginal rows of square to upright cells. Raphides often present in enlarged procumbent cells in the multiseriate rays. All elements non-storied.

Growth and development The growth of seedlings and saplings is reported to be fairly rapid. In Peninsular Malaysia punah has been found flowering and fruiting throughout the year.

Other botanical information Punah is the only commercially important timber tree species of the genus *Tetramerista*. The genus was formerly included in either *Ochnaceae, Marcgraviaceae, Ternstroemiaceae* or treated as a separate family *Tetrameristaceae*. Until the taxonomic relationships within the rather heterogeneous family of *Theaceae* have been unravelled, it seems best to be conservative and to treat the genus as a member of this family. Sterile specimens of punah may be mistaken for *Dillenia* spp., *Campnosperma* spp. or *Tristania* spp. Punah may be vegetatively distinguished from these species by the completely entire margin of the leaf, the very faint or invisible tertiary venation and the lack of intramarginal veins.

Ecology Punah grows in lowland forest, generally in freshwater or peat-swamp forest, and occasionally in 'kerangas' (heath forest) vegetation, on sites where the soil is waterlogged and is fibrous and peaty, or on podzols. The tree obviously demands a strongly acid soil. It is a typical inhabitant of coastal dipterocarp swamp forest.

Propagation and planting Natural regeneration from seeds is often quite abundant, but only a few seedlings survive. Seeds have delayed germination, germinating after 13–36 weeks.

Silviculture and management The management system used for mixed dipterocarp forest may be successfully put into practice for punah. In swamp forest in western Peninsular Malaysia, Sumatra and Sarawak, punah is locally common, in some areas averaging 1 large tree per ha, but stands of 5–8 trees of commercial size per ha may occur. However, in most areas punah occurs very scattered. Young trees are reported to coppice freely.

Diseases and pests Densely congested inflorescences with tiny gall flowers are often found, probably caused by insects or viruses.

Harvesting Severe heartwood shakes may occur when the trees are felled. These shakes become rapidly filled with a wax-like substance which is dark and acid and causes an unpleasant smell.

Fresh logs are sinkers, so have to be transported over land or fastened to floating logs when transported by river.

Genetic resources Punah is a valuable timber, but if it is cut without a good management system, this species may be liable to genetic erosion as it is only locally common and abundant and is ecologically restricted.

Prospects Punah is a poorly studied timber species. Research on silvicultural aspects is particularly urgently needed. Punah may be a promising species for planting in swamp areas.

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Other selected sources 102, 146, 159, 190, 318, 334, 416, 448, 508, 581, 694, 781.

K. Sidiyasa (general part),
W.G. Keating (properties),
S.C. Lim (wood anatomy)

Upuna Sym.

Bull. Jard. Bot. Buitenzorg, sér. 3, 17: 88, f. I–II, pl. 1–3 (1941).

DIPTEROCARPACEAE

$x = 11$; $2n = 22$

Trade groups Upun: heavy hardwood, a single species, *Upuna borneensis* Sym., Bull. Jard. Bot. Buitenzorg, sér. 3, 17: 88, f. I–II, pl. 1–3 (1941).

Vernacular names Upun. Brunei: upun batu. Indonesia: balau penyau (general), cangal tanduk (South Kalimantan), penyau tanduk (West Kalimantan). Malaysia: penyau (Sarawak).

Origin and geographic distribution The monotypic genus *Upuna* is endemic to Borneo where it occurs in South and West Kalimantan, Sarawak, Brunei and Sabah; it is rare in East Kalimantan. It is the only Malesian genus of the family *Dipterocarpaceae* which is not recorded (presently and fossil) from mainland South-East Asia or Sri Lanka.

Uses Upun is suitable for all heavy constructional work where strength and durability are essential, such as bridges, wharves and mining timber. Locally (e.g. in Brunei), it is popular for boat building, and it is suited for heavy-duty furniture and heavy-duty flooring, although it is rather brittle and does not take glue well.

Production and international trade Upun is not an export timber. This is due to its scattered occurrence and to its popularity for local uses. Upun is possibly sometimes traded as balau (*Shorea* spp.), giam (*Hopea* spp.) or resak (*Cotylelobium* spp. and *Vatica* spp.)

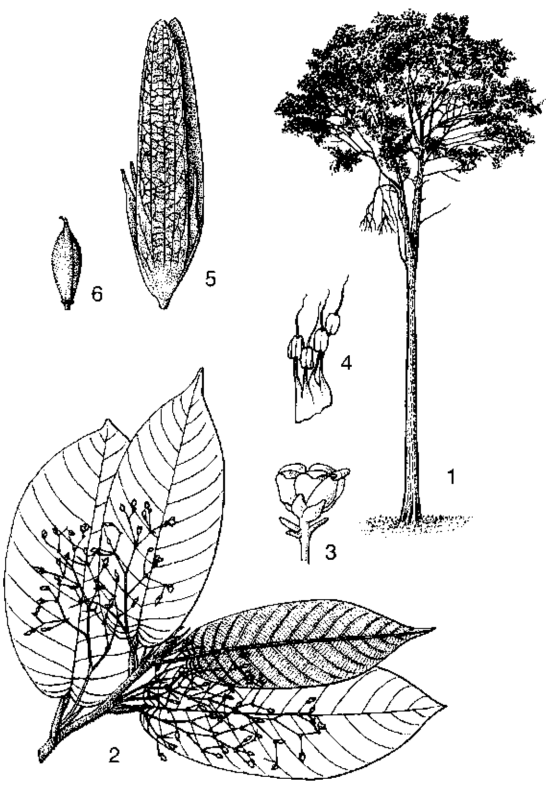
Properties Upun is a heavy and hard timber. The colour of the heartwood is dark brown, and the heartwood is clearly demarcated from the much lighter (light yellow-brown) sapwood. The density is 935–1040(–1140) kg/m^3 at 15% moisture content. The grain is straight to shallowly interlocked, texture fine to slightly coarse and even.

At 15% moisture content the modulus of rupture is 156–163 N/mm^2, modulus of elasticity 17 300–17 800 N/mm^2, compression parallel to grain 87–95 N/mm^2 and shear 18–20.5 N/mm^2. See also the table on wood properties.

Shrinkage of upun during drying is low when compared to similar timbers such as balau or resak: from green to 15% moisture content 0.5–1.8% radial and 1.5–3.2% tangential. The timber air dries moderately slowly, but faster than other heavy timbers, and without many seasoning defects, although slight checks and end splits may develop. Boards of 15 mm thick take about 3 months to air dry from green to 15% moisture content, 40 mm thick boards take 4–5 months.

Although upun does not contain silica, it is difficult to saw owing to the dense and somewhat resinous nature of the wood. Saws should be cleaned from resin regularly. Planing and boring are easy and give a smooth finish, although grain pick-up may occur on the radial surface during planing, and the finish after boring may be slightly rough. The nailing properties are rated as poor. It does not glue well, and has proved to be rather brittle.

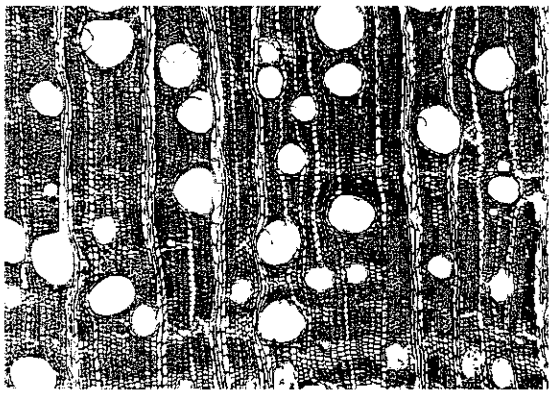
Upun is a very durable timber. Graveyard tests



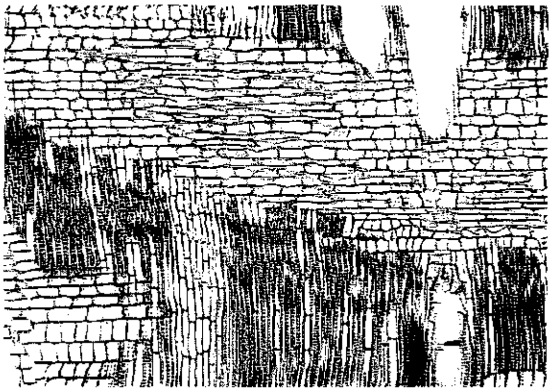
Upuna borneensis Sym. – 1, tree habit; 2, flowering twig; 3, flower; 4, stamens; 5, fruit; 6, nut.

with stakes in Malaysia showed an average service life in contact with the ground of 10 years. The wood is resistant to attack by termites, powder-post beetles and fungi, but logs are slightly susceptible to pinhole borer attack. Upun is very difficult to treat with preservatives, but this is usually not necessary as the wood has great natural durability. Using the open tank method and an equal mixture of creosote and diesel fuel the heartwood absorbs hardly any preservative, and even the sapwood is resistant to preservative treatment.

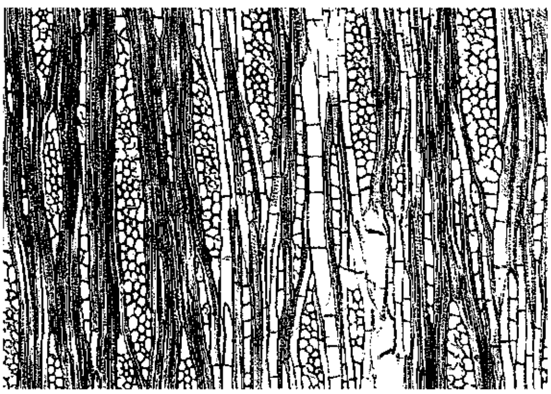
Description Large trees up to 55 m tall; bole tall, cylindrical, branchless for up to 25 m, up to 190 cm in diameter, buttresses many, single or grouped, up to 2 m high, blunt; bark surface with square-section fissures and flat-topped flaking ridges, dark purple-brown to chocolate-brown, outer bark up to 1.5 cm thick, hard, inner bark up to 1 cm thick, pale yellow to cream; branches ascending, bending down at the tips, rather crooked, twigs terete, densely tomentose. Leaves alternate, simple, entire, softly leathery, oblong to obovate, 9–24 cm × 4–9.5 cm, with a cordate base and an up to 5 mm long acumen, with 12–20 pairs of veins curving near the margin, lower surface white tomentose with a prominent midrib; petiole geniculate, 1–3 cm long; stipules subpersistent, subulate, up to 2 cm long, scar small. Inflorescences cymose, borne in the axils of the uppermost leaves, many-branched, up to 15 cm long, densely pale chocolate-brown tomentose and glandular; bracts up to 10 cm × 3.5 cm. Flower bud narrowly ovoid, acute, up to 5 mm × 2 mm; calyx lobes fused at base, imbricate, densely tomentose outside; petals 5, broadly ovate, subacute, becoming reflexed apically, sparsely tomentose on the parts exposed in bud, deep purple with dark yellow margins; stamens 25–30, in several verticils, filaments broad at base, those of the outer row tapering abruptly, anthers subglobose with a slender, glabrous appendage about 3 times longer than the anther; ovary ovoid-globose, without a distinct stylopodium, tomentose, style 2–3 times longer than the ovary, pubescent in the lower half. Fruit a triangular nut, enclosed by a fruit calyx with a narrowly cuneate base, the lobes valvate, united into a basal cup but not fused with the nut, unequal, lanceolate, the larger 2 up to 13 cm × 2.7 cm, subacute, the smaller 3 up to 7.5 cm × 1.7 cm; nut narrowly ovoid, acute, up to 3.2 cm × 1.5 cm, densely fulvous tomentose, with a distinct style remnant. Seed with a distinct arillode. Seedling with epigeal germination; cotyledons subequal, cordate;



transverse section (×25)



radial section (×45)



tangential section (×45)

Upuna borneensis

first pair of leaves opposite, subsequent leaves arranged spirally, often much larger than those of mature trees.

Wood anatomy

– Macroscopic characters:

Sapwood light yellow-brown, sharply differentiated from the heartwood which is greenish- or yellowish-brown when freshly cut and darkens on exposure. Grain straight to shallowly interlocked. Texture moderately fine and even. Wood almost featureless except that because of their large size the intercellular canals stand out clearly on longitudinal surfaces. Stripe figure usually inconspicuous, planed surface sometimes glistening because of the abundance of tyloses, radial longitudinal surfaces often with a slightly mottled 'silver figure'.

– Microscopic characters:

Growth rings indistinct. Vessels diffuse, 5–11/mm^2, exclusively solitary, round to oval, average tangential diameter 210 μm; perforations simple; intervessel pits alternate, vestured, round to oval, 6–10 μm; vessel-ray and vessel-parenchyma pits similar but half-bordered; helical thickenings absent; tyloses abundant. Fibres 1200–2000 μm long, non-septate, thick-walled, with moderately conspicuously bordered pits in both radial and tangential walls. Parenchyma moderately abundant to rather sparse; apotracheal parenchyma diffuse, diffuse-in-aggregates, or in uniseriate discontinuous lines or in marginal bands associated with the resin canals, in 5–10-celled strands; paratracheal parenchyma scanty to vasicentric. Rays, 6–12/mm (average 9/mm), of two distinct sizes, fine rays uniseriate (rarely 2-seriate), broad rays 3–4(–6) cells wide, up to 1.5 mm high, Kribs type heterogeneous II with 3–4 rows of upright marginal cells; sheath cells usually present. Crystals and silica absent. Vertical intercellular canals present, variable in size, diffuse, in short or long tangential lines; canals empty or filled with white gum-like resin. All elements non-storied.

Upun wood differs from balau and giam by its solitary vessels and diffuse resin canals, from resak by generally fewer vessels.

Growth and development The trees grow slowly, as can be expected from such a heavy and hard timber. The scanty information available indicates that after 40 years upun may have reached a bole diameter of only 28 cm; the growth rate is comparable with that of many balau-producing species.

Other botanical information The genus *Upuna* is remarkable botanically. It has several features which are regarded as comparatively primitive, such as the presence of multicellular glandular hairs and the cymose inflorescence. On the other hand, it possesses derived characters such as the curving corolla lobes and the fused base of the calyx. The arillode on the seed is a rare feature within the family *Dipterocarpaceae.* The genus shows similarities with *Monotes* of the African subfamily *Monotoideae* but also with the genera *Anisoptera*, *Cotylelobium*, *Stemonoporus* and *Vatica* of the subfamily *Dipterocarpoideae.* Features of the wood anatomy point to a closer relationship to the latter four genera, especially to *Anisoptera* and *Vatica.*

Ecology Upun occurs scattered and is only very locally abundant, in primary lowland mixed dipterocarp forest. It prefers well-drained, deep, sandy soils with a low clay content, on hills (often subcoastal) and ridges up to 350 m altitude.

Propagation and planting As in other dipterocarp species, the seeds of upun have no dormancy. They germinate rapidly and lose their viability within a few weeks.

Silviculture and management Natural regeneration is reported to occur frequently and locally abundantly.

Harvesting Upun logs sink in water and therefore cannot be transported by river.

Genetic resources As upun has only a limited area of distribution and is generally not common, but is locally a popular timber, it is at risk of genetic erosion and extinction.

Prospects Although upun shows very interesting wood properties, particularly concerning strength and durability, not much is known about this timber. This is because of its limited area of distribution and scattered occurrence. It does not seem to be a promising species for cultivation in timber plantations as it is a very slow grower.

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Other selected sources 258, 578.

M.S.M. Sosef (general part),
J.E. Polman (properties),
S.C. Lim (wood anatomy)

Vatica L.

Mant. pl. 2: 152 (1771).
DIPTEROCARPACEAE
$x = 11$; *V. odorata*, *V. pauciflora*, *V. rassak*, *V. stapfiana*: $2n = 22$

Trade groups Resak: medium-weight to heavy hardwood, e.g. *Vatica maingayi* Dyer, *V. mangachapoi* Blanco, *V. oblongifolia* Hook.f., *V. odorata* (Griffith) Sym., *V. rassak* (Korth.) Blume.
Resak often includes timber of the genus *Cotylelobium* and sometimes also that of *Upuna*. The timber of some *Vatica* species (e.g. *V. flavovirens*, *V. teysmanniana*) is traded in Indonesia under the name 'giam', which may cause confusion because this is the trade name for the heavy wood of *Hopea* spp.

Vernacular names Resak. Papua New Guinea: vatica. Philippines: narig. Cambodia: chrama:hs. Thailand: tamsao (peninsular), phancham (central), yang-nu (Phrae). Vietnam: l[af]u t[as]u.

Origin and geographic distribution *Vatica*, consisting of about 80 species, occurs from eastern and southern India, Sri Lanka and Burma, through Thailand and Indo-China, to southern China (Hainan) and Malesia. It is found throughout Malesia, except for the Lesser Sunda Islands.
In the Malesian region, Borneo is richest in species (about 35, 23 endemic), followed by Peninsular Malaysia (21), Sumatra (11) and the Philippines (7). Towards the east (the Moluccas, New Guinea) only a single species occurs, *V. rassak*, which is the most widespread, occurring westwards up to Borneo and northwards up to the southern Philippines.

Uses Resak is used for piling (also in contact with the ground or water), construction of houses (beams, posts, rafters, boards, door and window frames) and ships (keels, ribs), flooring, turnery, cabinet making, and railway sleepers. Less heavy resak timber is also used for furniture, package and pallets and as a substitute for keruing (*Dipterocarpus* spp.), e.g. in Japan. Although resak is a fairly hard and durable timber, its uses are restricted because of the often comparatively small size of the trees.
The resin is occasionally used for caulking boats and for illumination ('damar rasak'). The bark was formerly used to prevent frothing while boiling the sap of the sugar palm for sugar manufacture, and to arrest fermentation of toddy.

Production and international trade No statistics are available on the total trade and export of resak, but most of the timber is traded from Borneo, particularly Sarawak and Sabah. Resak is exported on a comparatively small scale, especially to Japan. In 1987, the export of round logs from Sabah was only 1400 m^3 with a value of US$ 83 000, but in 1992 it was 13 000 m^3 of logs and 600 m^3 of sawn timber with a total value of US$ 2.4 million. Commercially, resak from *Vatica* is among the least important timbers of the dipterocarps, mainly because the trees are often small, and occur scattered; moreover, the logs are sinkers, which hampers transport. However, resak is in demand for local house construction. It is often traded together with timber from *Cotylelobium* spp.

Properties Resak is a medium-weight to heavy and hard timber. The heartwood is reddish-brown to brown with a green tinge, darkening on exposure to dark reddish-brown. The sapwood is light yellowish-brown and clearly differentiated from the heartwood in fresh logs, but less sharply defined when dry. The density is 490–1155(–1220) kg/m^3 at 15% moisture content. The grain is straight or only slightly interlocked, texture fine and even.
Tested at green condition, the modulus of rupture is 56–105 N/mm^2, modulus of elasticity 10 200–18 100 N/mm^2, compression parallel to grain 29–61 N/mm^2, compression perpendicular to grain 5–12 N/mm^2, shear 4–13 N/mm^2, cleavage 44–61 N/mm radial and 52–105 N/mm tangential, and Janka side hardness 2570–8990 N.
The rates of shrinkage are moderate to large, from green to 12% moisture content 1.4–2.2% radial and 3.4–5.4% tangential, from green to oven dry 3.3–4.8% radial and 5.0–9.6% tangential. Resak is

moderately slow in drying. Thicker tangential boards tend to cup badly because of the great difference between tangential and radial shrinkage values. Surface checking and splitting can be common on tangential surfaces. It takes about 3 months to air dry 15 mm thick boards, and about 5 months to dry 40 mm thick boards from green to air-dry condition. Seasoning stacks should be weighted and stickers closely spaced. Being a hard and heavy timber, resak needs to be dried very slowly to avoid surface checking. Kiln-drying schedule B (Malaysia) is recommended. Preliminary air drying to below 30% moisture content is advisable.

Resak is rather difficult to saw because of the presence of a large amount of gummy resin which may clog sawteeth. The presence of this resin may also interfere with the planing of the timber, although the final finish may be smooth. Boring is easy and has a smooth finish, turning is slightly difficult. In general, resak timber is hard to peel but it has been reported as being suitable for sliced veneer.

Resak is usually classified as moderately durable to very durable. Wood of *V. cuspidata* has an average service life in contact with the ground of 14 years under normal Malaysian conditions. Graveyard tests in Indonesia showed that wood of *V. teysmanniana* had an average service life in contact with the ground of 10 years, but wood of *V. rassak* only 2 years. Resak is not considered resistant to marine borer attack. The heartwood of the heavier resak timber is not very susceptible to powder-post beetles and very resistant to termite attack, but is less resistant to pinhole borer attack. However, wood of *V. rassak* may have poor resistance to dry-wood termites. Resak is generally regarded as being very difficult to treat with preservatives, but for most applications, treatment is not required.

Wood of *V. rassak* contains 45% cellulose, 12% pentosan, 0.3% ash and up to 0.1% silica. The solubility is 1.6% in cold water, 3.6% in hot water and 12.2% in a 1% NaOH solution. The energy value is 20 200 kJ/kg.

The resin from the wood and bark ('damar rasak', particularly from *V. rassak*) is light yellow to light brown, and coagulates to a semi-transparent and brittle, yellow, brown or reddish solid mass.

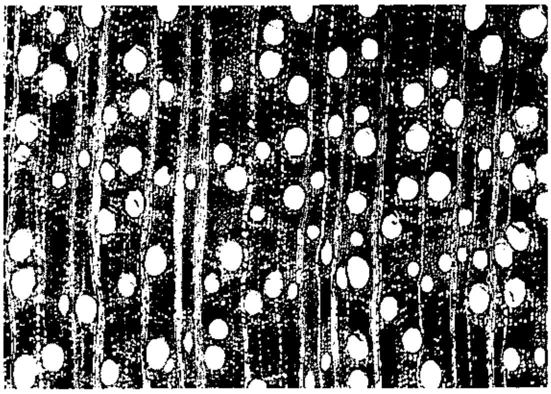
Description Small to medium-sized trees, rarely fairly large, up to 40 m tall with frequently sinuate bole, but sometimes straight and cylindrical, up to 125 cm in diameter but usually much less, buttresses thick, rounded and concave but usually small or absent; outer bark thin, smooth and hoop-marked, often grey mottled, becoming patchily flaked in large trees, occasionally scroll-marked, inner bark pinkish-brown or pale brown, homogeneous, with darker phloem fibres; crown irregular and oblong, sympodial; young twigs and other young parts usually caducous powdery tomentose. Leaves alternate, simple and entire, with curved secondary veins and reticulate tertiary venation; petiole not geniculate; stipules small, soon caducous. Inflorescences racemose or sometimes partially cymose, irregularly branched and short, rarely spreading, few- to many-flowered. Flowers bisexual, actinomorphic, 5-merous, ovoid to lanceolate in bud; sepals fused at base or more or less free, subequal, densely hairy; petals free, contorted, narrowly oblong, hairy, white to pale yellow; stamens (5–)15, in 3 whorls, short, filaments broad at base, tapering below anthers, anthers broadly oblong, with short but stout appendage to connective; pistil 1, ovary superior or semi-inferior, broadly ovoid or conical, densely pubescent, style short but stout and columnar, stigma prominent, often obscurely 3-lobed. Fruit a broadly ovoid or globose nut, surrounded by a fruit calyx with equal or unequal lobes, adnate to the fruit or not and fused with each other (forming a cup) or not, sometimes fruit sepals corky, sometimes reflexed. Seedling with epigeal or hypogeal germination; usually with non-photosynthetic magenta to pale yellow cotyledons remaining within the fruit; first pair of leaves usually opposite with interpetiolar stipules, subsequent leaves arranged spirally.

Wood anatomy

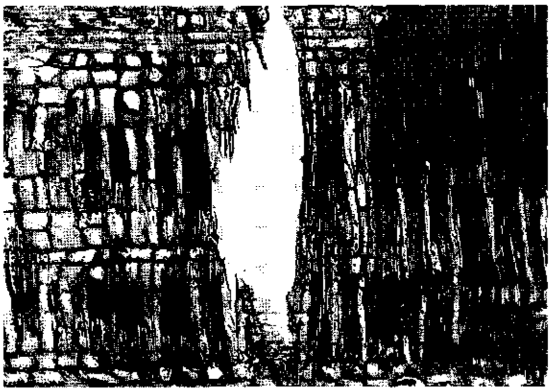
– Macroscopic characters:

Heartwood red-brown, sometimes with an olive tinge, darkening on exposure to dark red-brown, clearly demarcated from the pale yellow-brown sapwood. Grain straight to shallowly interlocked. Texture fine and even; occasionally silver figure present on quarter-sawn surfaces. Growth rings usually indistinct; vessels small to moderately large, visible to the naked eye, moderately numerous to numerous, vessel lines conspicuous on longitudinal surfaces, particularly in species with large pores, tyloses variable in amount, usually abundant; parenchyma moderately abundant, rather indistinct with hand lens; rays of two sizes, fine and wider rays individually distinct to the naked eye; ripple marks absent. Axial intercellular canals approximately half the size of largest vessels, scattered singly or in pairs, rarely in tangential series, empty or filled with chalky white deposits of dammar.

– Microscopic characters:
Growth rings indistinct. Vessels diffuse, 11–50/mm^2, with varying proportions solitary, ranging from predominantly solitary (over 95%) to proportions less than 90% solitary, short multiples in *V. coriacea, V. granulata, V. havilandii, V. javanica, V. oblongifolia, V. pauciflora, V. rassak* and *V. umbonata*, uniformly distributed, mostly round to oval, sometimes slightly angular, average tangential diameter (60–)120–150 μm; perforation plates almost exclusively simple, multiple perforations of complex form occasionally present in *V. granulata*; intervessel pits rare in species with predominantly solitary pores, loosely alternate when present, tending opposite to scalariform in *V. granulata, V. havilandii, V. mangachapoi, V. sarawakensis* and *V. umbonata*, vestured, pit border diameter 5–7 μm; vessel-ray pits simple, rounded, large, c. 20 μm; tyloses variable in amount, few to abundant. Fibres 1.5–1.7 mm long, non-septate, moderately thick- to very thick-walled (in species with denser wood), bordered pits distinct to indistinct, mainly in radial walls. Parenchyma paratracheal, partially surrounding pores, to aliform with short wings, diffuse to diffuse-in-aggregates, occasionally forming short lines several cells wide, surrounding axial intercellular canals; fine terminal or initial bands present in *V. borneensis, V. coriacea, V. havilandii, V. nitens* and *V. sarawakensis*, in 2–6-celled strands. Rays of 2 sizes, 6–8/mm, uniseriate and multiseriate 4–7(–10) cells wide, up to 1.5 mm high, weakly heterocellular with 1–3 rows of square to upright marginal cells (Kribs type heterogeneous III and II), uniseriates few, short; sheath cells occasionally present. Silica invariably absent. Large prismatic crystals present in ray cells of many species. Horizontal intercellular canals absent; axial intercellular canals diffusely scattered, sometimes in pairs, (40–)60–150(–200) μm in diameter, commonly occluded.
Species studied: *V. borneensis, V. coriacea, V. dulitensis, V. granulata, V. havilandii, V. javanica, V. maingayi, V. mangachapoi, V. micrantha, V. nitens, V. oblongifolia, V. pauciflora, V. odorata, V. rassak, V. sarawakensis, V. umbonata, V. venulosa, V. vinosa.*
The diffuse axial gum canals distinguish resak (*Vatica* and *Cotylelobium*) from *Dipterocarpus, Dryobalanops, Hopea* and *Shorea*. *Anisoptera* can be distinguished from *Vatica* by its larger vessels and the lower density and distinctive yellowish colour of the wood. *Vatica* is readily separated from *Cotylelobium* by the absence of silica. The



transverse section (×25)



radial section (×75)

tangential section (×75)

Vatica harmandiana

larger vessel frequency and more frequent radial multiples distinguish *Vatica* from *Upuna*.

Growth and development The growth rate of resak trees is usually rather slow. However, a *V. pauciflora* tree planted in Peninsular Malaysia was reported to flower when only 5 years old. *V. rassak* may flower almost annually.

The fruits of some species (e.g. *V. pauciflora, V. rassak, V. umbonata*) seem to be adapted to dispersal by water: they are large, have short sepals and a thick corky pericarp. Other species with wing-like fruit sepals may be dispersed by wind, but undoubtedly the vast majority of the comparatively heavy fruits fall very close to the parent tree.

Other botanical information The large variability of fruit calyx characters in *Vatica* s.l. as described here has led to the genus being subdivided into 3 sections. Some taxonomists prefer to value these sections as different genera: *Vatica* s.s. having 5 equal calyx lobes (about 22 species in Malesia), *Sunaptea* having 2 long and 3 short fruit calyx lobes (about 27 species in Malesia), and *Pachynocarpus* with thick, corky calyx fused to the fruit (2 species in Malesia). On sectional level, *Pachynocarpus* is often merged with section *Vatica*.

The group as a whole is characterized by the uniform flowers and also by characteristics of the wood anatomy. *Vatica* is closely related to the small genus *Cotylelobium*, which provides similar timber, but which differs in the leaf venation (secondary veins anastomosing to form a distinct intramarginal vein), its narrower and hairy anthers and longer style, and the presence of silica in the xylem. *Cotylelobium* is sometimes considered as belonging to the genus *Sunaptea* having a similar fruit calyx. *Vatica* trees are often difficult to identify unless fruiting.

Ecology Resak is common but occurs scattered in lowland primary rain forest, the trees often becoming more numerous inland. It often occurs in forest on alluvial soils and near rivers, and on hills, particularly on ridges. *Vatica* species sometimes grow semi-gregariously, e.g. *V. pauciflora*, *V. rassak* and *V. umbonata* on river banks and floodplains, but occasionally also on dry ridge crests. Some species occur in hill forest up to 1600 m altitude; above 1000 m *V. dulitensis*, *V. granulata*, *V. oblongifolia* and *V. odorata* are found. The various species show a wide range of soil requirements. They may grow in heath forest (kerangas), on podzols (e.g. *V. coriacea*) or on yellow sandy soils (e.g. *V. borneensis*, *V. oblongifolia*). Resak trees are usually understorey trees, and only occasionally occupy the main canopy (e.g. *V. rassak* in the more seasonal areas of New Guinea).

Propagation and planting Seeds lose their viability within a few weeks. Fresh seeds have a high germination rate, and germination starts after 3–6(–10) weeks. Natural regeneration is often abundant when openings in the canopy are present, but only few seedlings reach maturity. The seedlings need shade.

Seeds can be sown in the nursery. The best germination media for *V. mangachapoi* are sand, sawdust, or a mixture of both. Seedlings can be transplanted into the field when 30–50 cm tall. Planting should be done in the shade and with a spacing of 3 m × 2 m. Propagation by stump cuttings taken from seedlings about 1 m tall is possible. *V. pauciflora* was successfully propagated from cuttings of 4-year-old stems by treatment with 0.2% indole butyric acid, and by taking short cuttings of one leaf and one bud from half-ripe wood of juvenile plants. Stump transplants of *V. odorata* in Peninsular Malaysia and of *V. pauciflora* in Indonesia showed a high survival rate.

Inoculation with mycorrhiza improves shoot/root ratio and increases the growth rate of seedlings. In experiments with *V. pauciflora*, inoculation with *Scleroderma* sp. showed better results than with *Russula* sp. and *Boletus* sp.

Silviculture and management Resak is too small and growth rates are too low to justify silvicultural investment. Natural regeneration can be stimulated by opening the canopy 3–5 years before logging operations start, following the selective cutting system. After logging, resak may regenerate vigorously. However, as most species grow slowly, particularly the heavy species, adequately long cutting cycles are necessary.

Diseases and pests The fungus *Fusarium sacchari* has been reported to cause brown leaf-spots, defoliation and bark necrosis at the root collar and on roots of *V. pauciflora*.

Harvesting In Indonesia, *Vatica* spp. are harvested selectively with a diameter limit of 50 cm at breast height. The main defect of the logs is hollowness, especially in large trees. Many logs of resak timber sink in water and must be transported over land or rafted together with floating logs. This hinders the exploitation of stands, although resak trees often occur near rivers.

Genetic resources Most *Vatica* species occur scattered in primary forest, which makes them liable to genetic erosion in areas where large-scale logging operations are carried out. Some species are rare, e.g. *V. bantamensis* (Hassk.) Miq., of which apparently only a few trees are left in western Java at the Ujungkulon Nature Reserve.

Prospects Little information is available on propagation, silviculture and growth of resak. Some species showed promising results in experiments with regeneration and enrichment planting after selective logging. However, many others are probably slow growers (those with heavy wood), and research should be directed towards the more fast-growing species (with comparatively lighter wood), such as *V. rassak*.

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Selection of species

Vatica bella v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 9: 102 (1927).

Vernacular names Malaysia: resak keluang, damar keluang (Peninsular).

Distribution Southern Peninsular Malaysia.

Uses The timber is used as resak.

Observations A large tree, up to 50 m tall with bole up to 45 cm in diameter; leaves elliptical to obovate, 5–14 cm × 2–6 cm, with (9–)11–12 pairs of secondary veins, glabrous except midrib, petiole 5–15 mm long; inflorescences congested, up to 2 cm long; flower buds up to 8 mm long; nut up to 25 mm long, surrounded by 5 equal fruit calyx lobes, spreading and becoming reflexed. *V. bella* is locally common in mixed dipterocarp forest below 250 m altitude, more rare in hill forest up to 500 m. The wood is not very heavy; oven-dry weight is recorded as 670–760 kg/m^3, and density at 15% moisture content is 740–915 kg/m^3.

Selected sources 102, 253, 425, 677, 748.

Vatica borneensis Burck

Ann. Jard. Bot. Buitenzorg 6: 230 (1887).

Synonyms *Vatica urbanii* Heim (1891), *Sunaptea borneensis* (Burck) Heim (1892), *Sunaptea urbanii* (Heim) Heim (1892).

Vernacular names Brunei: resak kemudi.

Distribution North-western Borneo (Sarawak, Brunei).

Uses The timber is used as resak.

Observations A fairly large tree, up to 35 m tall with straight, cylindrical bole up to 65 cm in diameter and small buttresses; leaves elliptical, 6–10 cm × 2.5–5 cm, with 7–9 pairs of secondary veins, glabrescent, petiole 15–25 mm long; inflorescences up to 5 cm long; flower buds up to 10 mm long; nut globose, to 10 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, all free to the base. *V. borneensis* is locally frequent on leached sandy soils on ridges and coastal hills up to 900 m altitude. The wood is hard and durable, with a density of 945–1045 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 748.

Vatica coriacea P. Ashton

Gard. Bull. Sing. 19: 314 (1962).

Synonyms *Sunaptea coriacea* (P. Ashton) Kosterm. (1987).

Vernacular names Brunei: resak daun tebal. Malaysia: resak daun tebal (Sarawak).

Distribution North-western Borneo (Sarawak, Brunei).

Uses The timber is used as resak.

Observations A medium-sized tree, c. 20 m tall with straight cylindrical bole up to 50 cm in diameter and small buttresses; leaves obovate, 6.5–15 cm × 2–6 cm, with 10–11 pairs of secondary veins, glabrescent, petiole 10–15 mm long; inflorescences lax, up to 20 cm long; flower buds up to 18 mm long; nut globose, up to 8 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, all free to the base. *V. coriacea* occurs locally frequently on podzols in heath forest (kerangas) and on rendzinas over limestone. The wood is hard and durable.

Selected sources 30, 748.

Vatica cuspidata (Ridley) Sym.

Mal. For. 3: 200 (1934).

Synonyms *Sunaptea cuspidata* Ridley (1920), *Vatica maingayi* auct. non Dyer.

Vernacular names Malaysia: resak daun runching (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as resak.

Observations A medium-sized to fairly large tree with bole up to 75 cm in diameter and inconspicuous buttresses; leaves elliptical to oblong-lanceolate, 7–18 cm × 3–6 cm, with 10–17 pairs of secondary veins, glabrescent, petiole 20–40(–50) mm long; inflorescences up to 7 mm long; flower buds up to 6 mm long; nut ovoid, up to 8 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, all free to the base. *V. cuspidata* is closely related to *V. maingayi* but differs in the more densely pubescent petioles and often more numerous secondary veins. It is common on coastal hills and on inland ridges. The wood is heavy, hard and very durable, with density of 865–1200 kg/m^3 at 15% moisture content. See also the table on wood properties.

Selected sources 297, 417, 425, 677, 748.

Vatica dulitensis Sym.

Gard. Bull. Str. Settl. 8: 35 (1934).

Vernacular names Malaysia: resak tiong (Sarawak).

Distribution Northern Borneo (Sarawak, Brunei, Sabah, northern East Kalimantan).

Uses The timber is used as resak. The resin is said to be used for torches.

Observations A medium-sized tree, up to 30 m tall with cylindrical, frequently crooked bole up to 50 cm diameter and with very small or without buttresses; leaves narrowly obovate to elliptical-lanceolate, 4–11 cm × 1–3 cm, with 10–12 pairs of secondary veins, glabrescent, petiole 6–10 mm long; inflorescences to 2.5 cm long; flower buds up to 6 mm long; nut globose, up to 8 mm long, with 5 equal fruit calyx lobes, becoming rotate to reflexed. *V. dulitensis* is locally abundant on shale ridges at 700–1350 m altitude; it occurs occasionally in undulating land in the lowland, on clayey soil. The wood is fairly heavy, with density of 740–900 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 748.

Vatica dulitensis Sym. – 1, tree habit; 2, flowering twig; 3, fruiting twig; 4, flower.

Vatica flavovirens v. Slooten

Bull. Bot. Gard. Buitenzorg, sér. 3, 17: 252 (1942).

Vernacular names Indonesia: hulodiri puteh, hulodiri motaha (Tobala, Sulawesi), awalasa (Buginese, Sulawesi).

Distribution South-eastern Sulawesi.

Uses The timber is used as resak.

Observations A medium-sized to fairly large tree, up to 40 m tall; leaves narrowly elliptical to lanceolate, 8–21 cm × 2–7 cm, with 12–14 pairs of secondary veins, glabrescent, petiole 13–25 mm long; inflorescences up to 14 cm long; flower buds up to 10 mm long; nut subglobose, up to 7 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, all free to the base. *V. flavovirens* is locally common on hill slopes up to 400 m altitude. The density of the wood is 990–1060 kg/m^3 at 15% moisture content.

Selected sources 748.

Vatica granulata v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 9: 112 (1927).

Vernacular names Brunei: resak ranting bersisek, resak pengasoh.

Distribution Borneo.
Uses The timber is probably used as resak.
Observations A medium-sized tree, up to 30 m tall with crooked or straight, cylindrical bole up to 65 cm in diameter and small buttresses; leaves narrowly obovate, 10–20 cm × 3–7 cm, with 12–14 pairs of secondary veins, glabrescent, petiole 12–20 mm long; inflorescences and flowers unknown; nut ovoid, up to 40 mm long, coarsely granulate, with 5 equal and reflexed fruit calyx lobes. Two subspecies are distinguished: subsp. *sabaensis* P. Ashton differs from subsp. *granulata* in its larger stipules and larger fruit calyx lobes. *V. granulata* is widespread and locally abundant on ridges at 500–1200(–1700) m altitude. The density of the wood is 800–920 kg/m^3 at 15% moisture content.
Selected sources 30, 748.

Vatica harmandiana Pierre
Fl. forest. Cochinch. fasc. 15, text accomp. pl. 239 (1890).
Synonyms *Vatica cinerea* King (1893), *Sunaptea cinerea* (King) Ridley (1922), *Sunaptea lankaviensis* (Ridley) Ridley (1922).
Vernacular names Malaysia: resak laut (Peninsular). Cambodia: chrama:hs (Kampot). Thailand: sadao-pak (Saraburi, Satun), sak don (Trang), sak hin (peninsular). Vietnam: l[af]u t[as]u (Kiên Giang).
Distribution Southern Burma, Thailand, Cambodia, Vietnam and northern Peninsular Malaysia.
Uses The timber is used as resak, particularly for building houses and for constructional purposes.
Observations A small to medium-sized tree, rarely exceeding 20 m tall, with bole up to 40(–70) cm in diameter; leaves elliptical to lanceolate, 5.5–14 cm × 1.5–5 cm, with (6–)9–11(–12) pairs of secondary veins, glabrescent, petiole 5–11(–15) mm long; inflorescences up to 10 cm long; flower buds up to 8(–10) mm long; nut subglobose, up to 7 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes united at base into a cup. *V. harmandiana* occurs particularly on rocky places like dry ridges and headlands, on limestone, and in bamboo forests, up to 600 m altitude. It is reported as one of the few dipterocarps that thrives in exposed situations. The wood is heavy (890–1155 kg/m^3 at 15% moisture content), hard, and yellowish-brown.
Selected sources 102, 235, 253, 425, 628, 677, 748.

Vatica havilandii Brandis
Journ. Linn. Soc. Bot. 31: 133 (1895).
Vernacular names Brunei: resak degong. Malaysia: resak degong (general).
Distribution Peninsular Malaysia and northern Borneo (Sarawak, Brunei, Sabah).
Used The timber is used as resak.
Observations A small to medium-sized tree, sometimes 30 m tall, with cylindrical, often sinuate bole up to 35 cm in diameter, but usually less, and small buttresses; leaves narrowly oblong to obovate, 8–17 cm × 2.5–5 cm, with 15–20(–22) pairs of secondary veins, sparsely and caducous powdery hairy but glabrescent, petiole 10–12 mm long; inflorescences up to 8 cm long; flower buds up to 5 mm long; nut globose, up to 12 mm long, completely hidden but free from the 5 equal fruit calyx lobes. *V. havilandii* is rather uncommon, occurring generally only very locally in mixed dipterocarp forest on hills in coastal areas. The trees are usually too small to be of importance for their timber. The wood is reported as durable and has a density of 825–880 kg/m^3 at 15% moisture content.
Selected sources 30, 89, 425, 677, 748.

Vatica javanica v. Slooten
Bull. Jard. Bot. Buitenzorg, sér. 3, 16: 451 (1940).
Vernacular names Indonesia: kayu tenjo (general).
Distribution East Kalimantan and West Java.
Uses The timber is probably used as resak.
Observations A medium-sized tree, up to 27 m tall; leaves elliptical-oblong to obovate, 13–24 cm × 6–10 cm, often boat-shaped with concave lower surface, with 22–25 pairs of secondary veins, often bullate between the veins, glabrescent; inflorescences up to 12 cm long; flower buds up to 11 mm long; nut globose, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. Two subspecies are distinguished: subsp. *scaphifolia* (Kosterm.) P. Ashton (synonyms: *Vatica scaphifolia* Kosterm., *Sunaptea scaphifolia* (Kosterm.) Kosterm.) occurs locally abundant in lowland dipterocarp forest on well drained undulating land in East Kalimantan; subsp. *javanica*, which has no boat-shaped and no bullate leaves, is rare in primary forest at 950 m altitude in West Java. The density of the wood is about 610 kg/m^3 at 15% moisture content.
Selected sources 748.

Vatica lowii King

Journ. As. Soc. Beng. 62(2): 103 (1893).

Synonyms *Sunaptea lowii* (King) Ridley (1922).

Vernacular names Malaysia: resak pipit (Peninsular). Thailand: phancham dong (peninsular).

Distribution Peninsular Thailand and Peninsular Malaysia (Perak, Kelantan).

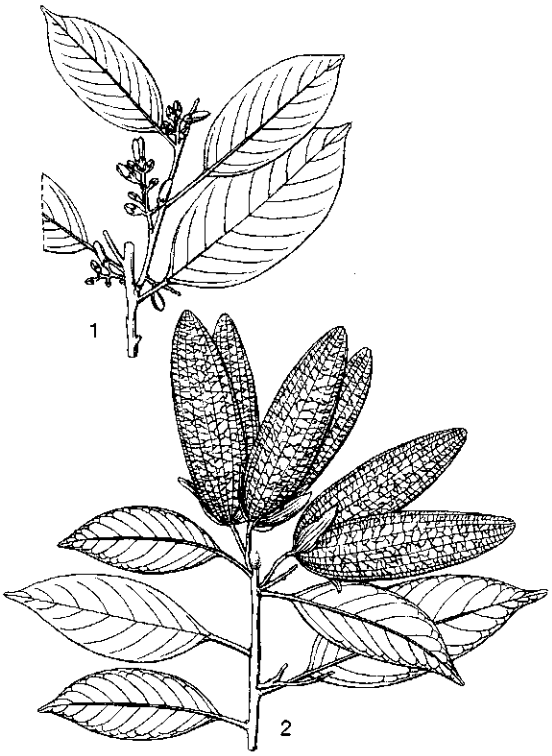
Uses The timber is used as resak.

Observations A small to medium-sized tree, up to 25 m tall with bole up to 50 cm in diameter; leaves elliptical-lanceolate, 5–14 cm × 2–5 cm, with 11–14 pairs of secondary veins, glabrescent, petiole 6–16 mm long; inflorescences shortly branched, up to 3.5 cm long; flower buds up to 5 mm long; nut subglobose, up to 5 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. *V. lowii* is locally abundant, on coastal hills and inland ridges up to 750 m altitude. The density of the wood is 840–1025 kg/m^3 at 15% moisture content.

Selected sources 425, 508, 628, 677, 748.

Vatica maingayi Dyer

Fl. Brit. India 1: 302 (1874).



Vatica maingayi Dyer – 1, flowering twig; 2, fruiting twig.

Synonyms *Sunaptea maingayi* (Dyer) Ridley (1922).

Vernacular names Malaysia: resak lidi, jenuong (Peninsular), resak daun merah (Sabah).

Distribution Peninsular Malaysia, Singapore, Sumatra (Palembang) and northern Borneo (Sarawak, Sabah).

Uses The timber is used as resak.

Observations A medium-sized tree, with bole up to 60 cm in diameter and buttresses very small or absent; leaves elliptical, 5.5–12.5 cm × 1–5 cm, with 9–11 pairs of secondary veins, glabrescent, petiole 10–25 mm long; inflorescences short, up to 4 cm long; flower buds up to 10 mm long; nut globose, up to 7 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. *V. maingayi* is closely related to *V. cuspidata, V. nitens* and *V. lowii*, but differs from the former 2 species especially in having fewer secondary veins and from the latter species in the larger size of the major fruit calyx lobes. It is locally frequent on flat land and hillsides up to 500 m altitude. The wood is reported to be heavy (density 865–985 kg/m^3 at 15% moisture content) and hard.

Selected sources 100, 102, 253, 425, 677, 748.

Vatica mangachapoi Blanco

Fl. Filip. ed. 1: 401 (1837).

Synonyms *Sunaptea mangachapoi* (Blanco) Kosterm. (1987).

Vernacular names Malaysia: resak julong (Peninsular), resak bajau (Sabah). Philippines: narig (general).

Distribution Peninsular Thailand, northern Peninsular Malaysia, the Philippines and northern Borneo (Sarawak, Brunei, Sabah).

Uses The timber is used as resak, particularly for house, ship and bridge building and for other purposes where strength and durability are required.

Observations A small to medium-sized tree, up to 30 m tall with cylindrical, often sinuate and low-branched bole up to 60 cm in diameter and small buttresses; leaves elliptical, 6–11 cm × 3–5 cm, with 7–9 pairs of secondary veins, glabrescent, petiole short, 5–11 mm long; inflorescences up to 14 cm long; flower buds up to 12(–20) mm long; nut subglobose, up to 6 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes free to the base. Two subspecies are distinguished: subsp. *mangachapoi* (synonyms: *Vatica patula* Sym., *V. reticulata* King non (Thwaites) A.DC.), which is common, especially on dry ridges up to 800 m altitude throughout the range of the species, and occurs also on podzols in kerangas (heath forest), and shallow peats and white sand in Borneo; subsp. *obtusifolia* (Elmer) P. Ashton (synonym: *Vatica obtusifolia* Elmer) which differs in its smaller, thickly coriaceous, more obtuse leaves and smaller inflorescences, and which occurs very local in the Philippines (Palawan) and Sabah on rocky places in the lowland. The wood is heavy, with density of 690–1175 kg/m³ at 15% moisture content. See also the table on wood properties.

Selected sources 30, 89, 100, 175, 265, 425, 472, 484, 497, 578, 579, 628, 677, 748.

Vatica micrantha v. Slooten

Bull. Bot. Jard. Buitenzorg, sér. 3, 17: 246 (1942).

Vernacular names Brunei: resak hijau. Malaysia: resak bulu (Sabah).

Distribution Borneo.

Uses The timber is used as resak.

Observations A medium-sized to fairly large tree, up to 35 m tall, with straight cylindrical bole up to 50 cm in diameter and small buttresses; leaves elliptical-oblong to lanceolate, 4.5–16 cm × 1.5–6 cm, with 8–11 pairs of secondary veins, shortly hairy on veins beneath, often bullate in between the veins, petiole 5–10 mm long; inflorescences up to 7.5 cm long; flower buds up to 13 mm long; nut ellipsoid, up to 14 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. *V. micrantha* occurs widespread in mixed dipterocarp forest, especially on sedimentary rocks up to 600(–1300) m altitude. The wood is fairly heavy with a density of 830–930(–1010) kg/m³ at 15% moisture content.

Selected sources 30, 100, 748.

Vatica nitens King

Journ. As. Soc. Beng. 62(2): 104 (1893).

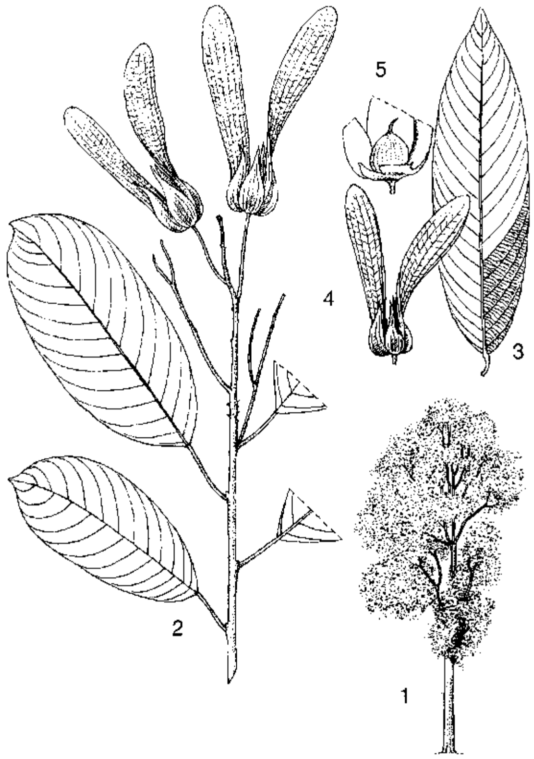
Synonyms *Sunaptea nitens* (King) Ridley (1922), *Vatica cuspidata* Browne (1955) non (Ridley) Sym.

Vernacular names Malaysia: resak daun panjang (Peninsular).

Distribution Peninsular Malaysia and northern Borneo (Sarawak, Brunei, Sabah).

Uses The timber is used as resak.

Observations A medium-sized to large tree, up to 40 m tall with straight, cylindrical bole up to 70 cm in diameter and small buttresses; leaves narrowly oblong, 10–17 cm × 3.5–5.5 cm, with 12–22 pairs of secondary veins, glabrescent, petiole 10–20 mm long; inflorescences up to 11 cm long; flower buds up to 7 mm long; nut globose, large,



Vatica nitens King – 1, tree habit; 2, fruiting twig; 3, leaf; 4, fruit; 5, nut.

up to 30 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. *V. nitens* occurs scattered in mixed dipterocarp forest on low hills and ridges up to 600 m altitude. In Brunei it is reported to be one of the best resak timbers; it is one of the few common *Vatica* species reaching large dimensions. The density of the wood is 710–975 kg/m³ at 15% moisture content.

Selected sources 30, 102, 253, 425, 677, 748.

Vatica oblongifolia Hook.f.

Trans. Linn. Soc. 23: 160 (1862).

Vernacular names Brunei: resak mambangan, resak daun panjang.

Distribution Borneo.

Uses The timber is used as resak.

Observations A medium-sized to fairly large tree, up to 35 m tall, with straight, cylindrical bole up to 50 cm in diameter and small buttresses; leaves oblong, broadly oblong, obovate, narrowly obovate or narrowly elliptical, (6.5–)10–31 cm × (2.5–)4–10.5 cm, with 10–27 pairs of secondary veins, glabrescent, petiole 15–50 mm long; inflorescences compressed, up to 8 cm long; flower buds to 15 mm long; nut globose, up to 20 mm long, with 5 equal usually reflexed fruit calyx lobes. *V. oblongifolia* is a variable species, especially in the shape and size of petioles and leaves, in the number of secondary veins and in the size of the fruit calyx lobes. It can be recognized by its depressed twigs and short, dense, wine-red indumentum of young parts. Five subspecies are distinguished. It is locally abundant on a variety of soils. The density of the wood is reported to vary from 700–1065 kg/m³ at 15% moisture content.

Selected sources 30, 89, 100, 461, 748.

Vatica odorata (Griffith) Sym.

Journ. Mal. Br. Roy. As. Soc. 19: 156 (1941).

Vernacular names Brunei: resak ranting kesat. Indonesia: damar kunyit, rasak gunung, cangal padi (Kalimantan). Malaysia: resak ranting kesat, resak biabas (Sarawak). Philippines: Mindanao narig. Cambodia: chrama:hs thma:(r), trâlak mosau, trâlak sbaèk. Laos: (maiz) s'i:, s'i: da:n, s'i: püak ba:ng. Thailand: phancham (central), yang-nu (northern), chan, khi- mot (eastern). Vietnam: t[as]u tr[aws]ng, l[af]u t[as]u, t[as]u v[or] v[af]ng.

Distribution Southern Burma, Thailand, Laos, Cambodia, Vietnam, southern China, Peninsular Malaysia, Borneo and the Philippines (Luzon, Leyte, Mindanao).

Uses The timber is used as resak. The resin is possibly sometimes used as an inferior 'damar rasak'.

Observations A medium-sized to large tree, up to 40 m tall, with straight, cylindrical bole up to 20 m long and up to 70 cm in diameter and small buttresses; leaves narrowly elliptical to ovate, (4–)8–16 cm × (1.5–)3–5.5 cm, with 11–15 pairs of secondary veins, glabrescent, petiole (3–)8–20 mm long; inflorescences up to 7 cm long; flower buds up to 8 mm long; nut globose, up to 7 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes united at base in a cup up to 5 mm deep. Three subspecies are distinguished: subsp. *odorata* (synonyms: *Sunaptea odorata* Griffith, *Vatica faginea* Dyer, *Vatica curtisii* King) distributed from Burma to Borneo, occurring scattered on dry ridges in more or less seasonal areas; subsp. *mindanensis* (Foxw.) P. Ashton (synonym: *Vatica mindanensis* Foxw.), common on ridges at 1000–1200 m altitude in non-seasonal areas of northern Borneo and the Philippines and differing in a longer petiole and leaf drying greyish; subsp. *brevipetiolata* Pham Hoang Hô from northern Vietnam, differing in having smaller petioles and leaves. The wood has a density of 735–1060 kg/m³ at 15% moisture content.

Selected sources 30, 100, 102, 175, 235, 253, 318, 425, 484, 579, 628, 748.

Vatica pachyphylla Merr.

Philipp. Journ. Sc. 13: 311 (1918).

Synonyms *Sunaptea pachyphylla* (Merr.) Kosterm. (1985).

Vernacular names Philippines: thick-leafed narig (general), manapo (Tayabas, Polillo), dadiangao (Camarines).

Distribution The Philippines (eastern Luzon, Polillo).

Uses The timber is used as resak, for house, ship and bridge building and other purposes where strength and durability are required.

Observations A medium-sized tree, up to 30 m tall with straight bole up to 60 cm in diameter and very small buttresses; leaves elliptical, 7–15 cm × 3–7.5 cm, thickly leathery, with 10–11 pairs of secondary veins, pubescent on veins beneath, petiole 17–23 mm long; inflorescences stout, up to 7 cm long; flower buds up to 9 mm long; nut broadly ovoid or subglobose, up to 8 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes free to the base. *V. pachyphylla* occurs scattered in non-seasonal evergreen dipterocarp forest up to 80 m altitude. The wood is fairly heavy, with a density of 830–870 kg/m³ at 15% moisture content.

Selected sources 175, 484, 579, 748.

Vatica pauciflora (Korth.) Blume

Mus. Bot. Lugd.-Bat. 2: 31 (1852).

Synonyms *Vatica wallichii* Dyer (1874), *Vatica lamponga* Burck (1887), *Vatica sumatrana* v. Slooten (1927).

Vernacular names Indonesia: resak padang, resak rawang (Sumatra). Malaysia: resak laru, resak ayer, resak paya (Peninsular). Thailand: sak, klusi (peninsular), sak nam (Songkhla, Satun). Vietnam: t[as]u [is]t hoa.

Distribution Southern Vietnam, peninsular Thailand, Peninsular Malaysia, Sumatra and Bangka.

Uses The timber is used as resak, particularly for house building. The wood is used as firewood.

Observations A small to medium-sized tree, up to 32 m tall with straight bole up to 20 m long and up to 40(–50) cm in diameter and small buttresses; leaves elliptical to lanceolate, 6.5–20 cm × 2–8 cm, with 6–9 pairs of secondary veins, glabrescent, petiole 10–18 mm long; inflorescences irregularly branching, up to 9 cm long; flower buds up to 10 mm long; nut ovoid, up to 30 mm long, with 5 equal, incrassate fruit calyx lobes, adpressed to the base of the nut. *V. pauciflora* is common on river banks and in freshwater swamps, the same habitat as for *V. umbonata*; the latter species differs in the larger, more corky fruit calyx lobes fused to the nut, but it is otherwise very similar. *V. pauciflora* is one of the very few *Vatica* species that has been subject to tests on growth, propagation, mycorrhizae and pests and diseases. The bole is often too short and thin to be important; the density of the wood is 550–960 kg/m^3 at 15% moisture content.

Selected sources 102, 204, 235, 253, 305, 318, 425, 495, 508, 510, 599, 628, 677, 748.

Vatica perakensis King

Journ. As. Soc. Beng. 62(2): 103 (1893).

Synonyms *Sunaptea perakensis* (King) Ridley (1922), *Vatica songa* v. Slooten (1927).

Vernacular names Malaysia: resak puteh (Peninsular).

Distribution Peninsular Malaysia (Kedah, Perak) and central Sumatra.

Uses The timber is used as resak.

Observations A small to medium-sized tree, up to 35 m tall with straight bole up to 45 cm in diameter; leaves lanceolate to oblanceolate, 6–14 cm × 2–4 cm, with 11–13 pairs of secondary veins, glabrescent, petiole 10–20 mm long; inflorescences up to 5 cm long; flower buds c. 8 mm long; nut ovoid, up to 10 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, free to the base. *V. perakensis* is common in coastal hills and on low ridges up to 600 m altitude. The timber is said to be hard and strong.

Selected sources 102, 253, 318, 425, 677, 748.

Vatica rassak (Korth.) Blume

Mus. Bot. Lugd.-Bat. 2: 31 (1852).

Synonyms *Vatica papuana* Dyer (1878), *Vatica moluccana* Burck (1887), *Vatica celebensis* Brandis (1895).

Vernacular names Indonesia: resak danau (Kalimantan), damar hiru (Moluccas), damar dereh (Sulawesi). Malaysia: resak irian, resak danau, resak ayer (Sabah). Philippines: tawi-tawi narig.

Distribution Borneo, the southern Philippines (Tawi Tawi), Sulawesi, the Moluccas and New Guinea.

Uses The timber is used as resak; it is suitable for general construction where no sudden bending or shocks are likely to occur. The wood is used as firewood. The resin is collected as 'damar rasak' and used for caulking boats and illumination.

Observations A medium-sized to fairly large tree, up to 40 m tall with straight bole branchless for up to 22 m and up to 50 cm in diameter, fluted at base and with low or without buttresses; leaves oblong to narrowly elliptical, 13–32 cm × 5–11 cm, thickly leathery, with (10–)16–20 pairs of secondary veins, sparsely hairy on veins beneath, petiole 20–25 mm long; inflorescences irregularly branched, appearing fascicled, up to 14 cm long; flower buds up to 14 mm long; nut oblong to ovoid, large, up to 50 mm long, minutely corky verrucose, with 5 equal, incrassate and reflexed fruit calyx lobes. *V. rassak* is locally abundant on river banks and dry ridges up to 500 m altitude. The timber belongs to the lighter resak timbers, with a density of 490–650 kg/m^3, rarely up to 890 kg/m^3, at 15% moisture content; it is not very durable and somewhat brittle. See also the table on wood properties.

Selected sources 100, 175, 318, 359, 461, 735, 748.

Vatica sarawakensis Heim

Bull. Mens. Soc. Linn. Paris 2: 970 (1891).

Synonyms *Vatica ramiflora* v. Slooten (1927).

Vernacular names Malaysia: resak sarawak, resak daun besar (Sarawak, Sabah).

Distribution Borneo (Sarawak, Brunei, Sabah, South and East Kalimantan).

Uses The timber is sometimes used as resak.

Observations A small to medium-sized tree, up to 25 m tall but usually much less with straight bole up to 30 cm in diameter and small buttresses; leaves oblong to obovate, large, 22–35 cm × 7–15 cm, with 15–28 pairs of secondary veins, sparsely hairy on veins beneath, petiole 10–20 mm long; inflorescences many-branched, up to 12 cm long; flower buds up to 8 mm long; nut subglobose to ovoid, up to 25 mm long, verrucose, with 5 subequal fruit calyx lobes becoming reflexed. *V. sarawakensis* occurs scattered in mixed dipterocarp forest on clayey soils in hills up to 1000 m altitude. Because of the small size of the trees, the timber is not much used; the density of the wood is 705–895 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 748.

Vatica scortechinii (King) Brandis

Journ. Linn. Soc. Bot. 31: 122 (1895).

Vernacular names Malaysia: resak langgong (Peninsular).

Distribution Peninsular Malaysia.

Uses The timber is used as resak.

Observations A medium-sized to fairly large tree, up to 40 m tall with bole up to 55 cm in diameter; leaves oblong-lanceolate or oblanceolate, 13–40 cm × 5–16 cm, with 14–25 pairs of secondary veins, glabrescent, petiole 13–25(–40) mm long; inflorescences up to 9 cm long; flower buds up to 14 mm long; nut subglobose, up to 15 mm long, with 5 equal fruit calyx lobes, reflexed at base but curved up distally. *V. scortechinii* occurs locally on undulating land and ridges up to 1800 m altitude. The wood has a density of 690–830 kg/m^3 oven dry.

Selected sources 102, 253, 425, 677, 748.

Vatica stapfiana (King) v. Slooten

Bull. Jard. Bot. Buitenzorg, sér. 3, 9: 129 (1927).

Synonyms *Pachynocarpus stapfianus* King (1893).

Vernacular names Malaysia: resak mempening, resak laru. Thailand: sak (Ranong).

Distribution Cambodia, peninsular Thailand, Peninsular Malaysia and Sumatra.

Uses The timber is used as resak.

Observations A small to medium-sized tree, rarely exceeding 20 m tall with bole rarely exceeding 35 cm in diameter; leaves elliptical-obovate, 12–25 cm × 5–12 cm, thickly leathery, with 7–9 (–15) pairs of secondary veins, sparsely hairy or glabrescent beneath, petiole 17–30 mm long; inflorescences somewhat congested and irregularly branched, up to 10 cm long; flower buds up to 12 mm long; nut ovoid, large, up to 40 mm long, with 5 equal fruit calyx lobes fused with the verrucose, corky pericarp. *V. stapfiana* occurs scattered in lowland dipterocarp forest up to 500 m altitude, in valleys and on stream banks, as well as on hills. It is closely related to *V. umbonata* and seems to hybridize with it. The wood is fairly heavy, with an oven dry density of 550–880 kg/m^3. See also the table on wood properties.

Selected sources 102, 235, 253, 417, 425, 508, 628, 677, 748.

Vatica teysmanniana Burck

Ann. Jard. Bot. Buitenzorg 6: 230 (1887).

Synonyms *Sunaptea teysmannii* Heim (1892).

Vernacular names Indonesia: resak ayer, resak paya (Sumatra), resak badouw (Bangka).

Distribution Eastern Sumatra, Bangka.

Uses The timber is used as resak, particularly for house and bridge building.

Observations A medium-sized to large tree, up to 45 m tall with straight, cylindrical bole (often slightly bent in upper part) branchless for up to 30 m and up to 60 cm in diameter and low buttresses; leaves narrowly elliptical to lanceolate, 9.5–34 cm × 3–11 cm, with 13–17 pairs of secondary veins, glabrescent, petiole 13–25 mm long; inflorescences lax and spreading, up to 15 cm long; flower buds up to 12 mm long; nut globose, up to 6 mm long, surrounded by 2 longer and 3 shorter fruit calyx lobes, fused into a cup at base and adnate to the nut. *V. teysmanniana* grows in mixed swamp forest. It is locally favoured for its timber, as the boles reach large dimensions and the wood is of good quality, with a density of about 950 kg/m^3 at 15% moisture content.

Selected sources 318, 748.

Vatica umbonata (Hook.f.) Burck

Ann. Jard. Bot. Buitenzorg 6: 232 (1887).

Vernacular names Brunei: resak ayer. Indonesia: damar tingkis (Kalimantan). Malaysia: resak labuan (Sabah), resak ayer (Sarawak). Philippines: Blanco narig (general), lutab, tampusok (Sulu).

Distribution Peninsular Malaysia, Borneo and the southern Philippines (Palawan).

Uses The timber is used as resak for construction of houses, bridges and wharfs and other purposes requiring strength and durability.

Observations A small to medium-sized tree, up to 30 m tall, but often much less, with often crooked, low-branching bole up to 30(–45) cm in diameter and small buttresses; leaves elliptical, 8–16 cm × 3–6.5 cm, with 7–8 pairs of secondary veins, glabrescent, petiole 7–15 mm long; inflorescences brittle, up to 12 cm long; flower buds up to 10 mm long; nut ovoid or globose, up to 30 mm long, with 5 equal, corky fruit calyx lobes fused with the verrucose pericarp. Subsp. *acrocarpa* (v. Slooten) P. Ashton (synonym: *Vatica acrocarpa* v. Slooten) differs from subsp. *umbonata* (synonyms: *Pachynocarpus umbonatus* Hook.f., *Vatica blancoana* Elmer, *Vatica cupularis* v. Slooten) in the more ovoid and acute nut, and in the reflexed fruit calyx lobes united at the basal half of the nut only; it is apparently confined to river banks in eastern Borneo. Subsp. *umbonata* is locally abundant on river banks, and it occurs more scattered on hillsides and mountains up to 1300 m altitude. The density of the wood is 735–1220 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 175, 318, 425, 484, 579, 748.

Vatica venulosa Blume

Mus. Bot. Lugd.-Bat. 2: 32 (1852).

Vernacular names Indonesia: resak seluang, siloki (Sumatra), resak puteh (Bangka). Malaysia: resak letop (Peninsular), resak banka (Sabah).

Distribution Peninsular Malaysia, Sumatra, Bangka, Belitung, western Java and Borneo.

Uses The timber is used as resak and suitable for constructional work in contact with the ground or weather.

Observations A small to medium-sized tree, up to 25 m tall with straight or slightly bent cylindrical bole up to 40 cm diameter and small buttresses; leaves elliptical to ovate-lanceolate, 4–12 cm × 1.5–5 cm, with 7–12 pairs of secondary veins, glabrescent, petiole 5–9 mm long; inflorescences up to 3(–7) cm long; flower buds up to 13 mm long; nut globose, up to 10 mm long, completely hidden by 5 subequal fruit calyx lobes revolute at base. Two subspecies are distinguished: subsp. *venulosa* (synonym: *Vatica bancana* R. Scheffer) occurring very local on river banks and in freshwater swamps; subsp. *simalurensis* (v. Slooten) P. Ashton (synonym: *Vatica simalurensis* v. Slooten) differing in larger leaves with more secondary veins and longer petioles, and longer inflorescences, confined to western Sumatra. The wood is heavy with a density of 660–970 kg/m^3 at 15% moisture content.

Selected sources 30, 89, 100, 183, 253, 318, 425, 461, 677, 748.

Vatica vinosa P. Ashton

Gard. Bull. Sing. 19: 318 (1962).

Vernacular names Brunei: resak tangkai unggu.

Distribution Northern Borneo (Sarawak, Brunei, Sabah, north-eastern Kalimantan).

Uses The timber is used as resak.

Observations A small to medium-sized tree, up to 30 m tall with straight, cylindrical bole up to 40 cm in diameter and small buttresses; leaves elliptical to lanceolate, 6–15 cm × 1.5–4.5 cm, with 12–20 pairs of secondary veins, pubescent on veins beneath, petiole 6–13 mm long; inflorescences up to 7 cm long; flower buds up to 6 mm long; nut globose, up to 8 mm long, densely wine-red pubescent, with 5 equal, revolute fruit calyx lobes reflexed at base but curving outwards and more or less rotate apically. *V. vinosa* is found in mixed dipterocarp forest on fertile clayey soil below 300 m altitude. The wood is reported to be hard, with a density of about 915 kg/m^3 at 15% moisture content.

Selected sources 30, 748.

R.H.M.J. Lemmens (general part, selection of species),
I. Soerianegara (general part),
W.G. Keating (properties),
W.C. Wong (properties),
J. Ilic (wood anatomy)

Table on wood properties of selected species

This table lists the wood properties of species for which information was available in the literature. For much-tested species, a selection has been made which reflects the variability of the wood properties over the area of distribution of the species.

Explanation of abbreviations

gr = green condition
AFR = Africa
AND = the Andaman Islands
AUS = Australia
BUR = Burma
FIJ = Fiji
IJA = Irian Jaya
IND = Indonesia
JAV = Java
MAL = Malaysia
PHI = the Philippines
PMA = Peninsular Malaysia
PNG = Papua New Guinea
SAB = Sabah
SAM = Samoa
SAR = Sarawak
THA = Thailand
VIE = Vietnam

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density (kg/m³)	at moisture content of (%)	specific gravity (moisture content 0%)	shrinkage: green to moisture content (m.c.): m.c. (%)	rad. (%)	tang. (%)	green to oven-dry: rad. (%)	tang. (%)	Mechanical properties: source	number of trees tested	origin of trees	density when tested (kg/m³)	moisture content when tested (%)	modulus of rupture (N/mm²)	modulus of elasticity (N/mm²)	compression: parallel to grain (N/mm²)	perpendicular to grain (N/mm²)	shear (N/mm²)	cleavage: rad. (N/mm)	tang. (N/mm)	Janka hardness: rad. (N)	tang. (N)	side (N)	end (N)
Afzelia afzelia *A. rhomboidea*	579	.	PHI	1140	50	0.77	.	.	.	.	.	579	.	PHI	1140	50	84	10975	33	12	12	.	.	.	.	7635	7135
Agathis kauri *A. borneensis*	461	.	.	360–640	15	.	.	.	.	3.8	6.2	461	.	IND	.	gr	36	8720	22.5	.	4–5	38	32	.	.	1470	2040
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	.	15	49	10975	32	.	2.5	26	31	.	.	1450	2205
	791	.	MAL	380–550	15	.	15	1.2	2.5	.	.	791	.	MAL	.	15	65	12000	34	.	7	.	.	.	.	.	.
A. dammara	.	.	.	.	.	.	.	.	.	.	.	762	5	IND	450	15.5	47.5	5350	29	.	6–6.5	30	42	.	.	2380	3000
Alstonia pulai *A. angustiloba*	461	.	.	240–490	15	.	.	.	.	.	.	461	.	IND	.	gr	27.5	6075	13	.	2	27.5	34	.	.	900	1215
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	.	15	32.5	7150	21.5	.	1.5	25.5	29.5	.	.	725	1315
	619	3	PMA	400	15	.	19	2.3	2.8	.	.	619	3	PMA	.	19	43	7100	25	.	6	.	.	.	.	.	.
A. pneumatophora	274	.	IND	.	.	.	.	.	.	3.4	4.9	274	.	IND	340	15.5	49.5	6175	25.5	.	5.5–6.5	29	33	.	.	1815	2910
A. scholaris	481	.	PHI	380–410	12	.	.	.	.	3.4	6.1	481	.	PHI	.	gr	40	6605	21.5	3	6	.	.	.	.	2020	2235
	67	.	PNG	.	.	0.34	.	.	.	.	.	67	5	PNG	.	gr	36	7800	20	.	5	.	44	1890	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	4	PNG	385	12	60	9110	29	3	5–6	35	44	1735	1735	.	3050
	461	.	.	270–490	15	.	.	.	.	3.1	4.9	461	.	.	.	gr	35	3530	17.5	.	5	30.5	33.5	.	.	1285	2040
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	52	8820	31.5	.	5–7	45	51	.	.	1990	3235

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density (kg/m³)	at moisture content of (%)	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c. (%)	rad. (%)	tang. (%)	shrinkage green to oven-dry: rad. (%)	tang. (%)	Mechanical properties: source	number of trees tested	origin of trees	density when tested (kg/m³)	moisture content when tested (%)	modulus of rupture (N/mm²)	modulus of elasticity (N/mm²)	compression parallel to grain (N/mm²)	compression perpendicular to grain (N/mm²)	shear (N/mm²)	cleavage rad. (N/mm)	cleavage tang. (N/mm)	Janka hardness rad. (N)	tang. (N)	side (N)	end (N)
Altingia rasamala *A. excelsa*	462	.	IND	610–900	15	.	.	.	.	5.6	11.6	462	5	IND	.	gr	75.5	7060	39	.	5.5	62	72.5	.	.	4185	4320
	.	.	.	.	.	.	.	.	.	.	.	462	5	IND	.	15	102	9015	59	.	5–6	65	90	.	.	6195	6195
Anisoptera mersawa *A. costata*	461	.	.	490–710	15	.	.	.	.	.	.	461	.	.	.	gr	75.5	12640	33	.	7	65	60	.	.	.	3600
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	79.5	12150	45	.	8	65.5	72.5	.	.	3520	3310
A. laevis	417	3	PMA	640	15	0.52	.	.	.	.	.	417	3	PMA	1105	112	49	9200	26	6	7	55	69	.	.	3910	.
	297	5	PMA	.	.	.	15	1.4	3.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
A. marginata	417	2	PMA	675	15	0.55	.	.	.	.	.	417	2	PMA	1090	97	54	12800	29	5.5	7	51	66	.	.	4180	.
	497	5	PMA	.	.	.	15	1.4	3.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	461	.	.	520–740	15	.	.	.	.	3.7	7.6	461	.	.	.	gr	58	11170	28.5	.	5.5	63	54	.	.	2185	2870
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	67	9600	36	.	6	56	61	.	.	2215	2450
A. thurifera	579	.	PHI	615–820	15	0.50	.	.	.	.	.	579	.	PHI	900	74	57	10290	25	5	7.5	.	.	.	.	3215	3175
	67	.	PNG	.	.	0.52	.	.	.	.	.	67	22	PNG	.	gr	59	11450	27	4.5	6	50	59	4720	2780	.	2740
	.	.	.	.	.	.	.	.	.	.	.	67	21	PNG	645	12	79	13320	44	7.5	12	42	47	5785	3025	.	2940
Anthocephalus kadam *A. chinensis*	448	.	MAL	370–465	15	.	15	0.8	2.1	.	.	448	.	MAL	.	15	50–73	7700–9300	28–44	.	6.5–8	.	.	.	.	.	.
	578	3	PHI	.	.	0.34	.	.	.	.	.	578	3	PHI	400	12	54	5040–5860	23–25	3.5–4	6–6.5	.	.	.	.	1950–2140	3030–3330
	310	.	SAM	310	12	.	12	0.8	3.1	.	.	310	.	SAM	645	gr	39	5600	18	.	4.5	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	310	.	SAM	310	12	58	6800	25	.	6	.	.	.	.	.	.

Botanical name Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
A. chinensis	462	.	.	290–560	15	.	12	3.0	6.9	.	.	462	.	.	.	gr	51	4205	27.5	.	4–5	45	54	.	.	2340	2695
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	68	6665	36.5	.	5–6	35	54	.	.	2625	4010
	145	.	.	.	.	.	.	.	.	2.5	5.9	145	.	.	.	gr	47	8070	23	.	.	.	.	.	2090	.	.
	.	.	.	.	.	.	.	.	.	.	.	145	.	.	.	12	76	8490	40	.	.	.	.	.	2670	.	.
Araucaria araucaria																											
A. cunninghamii	362	.	.	.	.	.	12	2.5	3.8	.	.	66	42	AUS	.	12	90	12970	49	.	9	39	56	3490	3200	.	5430
A. hunsteinii	362	.	.	.	.	0.39	12	2.2	4.0	.	.	67	20	PNG	.	gr	42	10000	22	2.5	4.5	25	28	2000	1980	.	2310
	.	.	.	.	.	.	.	.	.	.	.	67	20	PNG	450	12	77	11940	44	4.5	9.5	38	54	2400	2380	.	3940
Calophyllum bintangor																											
C. inophyllum	578	1	PHI	.	.	0.56	.	.	.	.	.	578	1	PHI	670	12	97–106	7940–8560	36–39	10.5–12	15	.	.	.	.	5890–6470	7180–7890
	461	.	.	560–790	15	.	.	.	.	4.2	5.3	461	.	.	.	gr	45	6570	32.5	.	6	61	56	.	.	5065	4810
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	48	7545	42	.	6	60	72	.	.	4820	6045
C. papuanum	67	5	PNG	.	.	0.49	.	.	.	.	.	67	5	PNG	.	gr	59	11320	34	.	9	.	63	3600	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	5	PNG	590	12	102	13730	58	.	14	.	78	4580	.	.	.
C. pulcherrimum	461	.	.	590–900	15	.	.	.	.	.	.	461	.	.	.	gr	76.5	13620	40	.	6–7	38	41	.	.	.	4360
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	94	15290	55	.	5–6	52	66	.	.	4175	5585
C. rigidum	100	.	PMA	.	.	.	15	1.5	2.9	.	.	100	3	PMA	970	75	.	.	33	3.5	6.5–8.5	.	.	3470	3600	.	4360

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c.	rad.	tang.	shrinkage green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	perpendicular to grain	shear	cleavage: rad.	tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
Campnosperma terentang																											
C. auriculatum	578	5	MAL	.	.	0.30	.	.	.	.	.	578	5	MAL	370	17	42–51	6500–7000	22–26	2–2.5	7.5–9	38	39	.	.	1470–1540	.
C. brevipetiolatum	67	6	PNG	.	.	0.33	.	.	.	.	.	67	6	PNG	.	gr	34	6970	19	1–1.5	5	19	30	1400	1420	.	1820
	.	.	.	.	.	.	.	.	.	.	.	67	6	PNG	410	12	59	9660	34	.	8	.	32	1760	.	.	.
	241	2	.	310–390	15	0.29–0.37	15	1.6–1.9	4.6–5.5	.	.	241	2	.	.	15	40–52	.	20–24	.	6–8	18–23	18–26	.	.	.	.
Cotylelobium resak																											
C. melanoxylon	.	.	.	.	.	.	.	.	.	.	.	578	.	IND	1100	14	133–135	17730–18630	68–69	.	7–8	.	.	.	.	.	.
	462	.	.	830–1150	15	.	.	.	.	6.1	10.4	462	.	.	.	gr	105	18030	66	.	8–9	37	66.5	.	.	.	7695
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	135	18620	68.5	.	7–7.5	76.5	82	.	.	8860	10190
Cratoxylum geronggang																											
C. arborescens	461	.	.	360–710	15	.	15	2.6	4.7	.	.	461	.	IND	.	gr	47	8920	20.5	.	3	33	44	.	.	.	1910
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	460	16.5	59.5	10065	29.5	.	4.5–6	44	51	.	.	1745	2400
	100	.	PMA	350–710	15	0.38	15	2.6	4.7	.	.	100	5	PMA	800	106	40	8000	18	2	5–5.5	32	41	1910	1825	.	2180
	24	.	PMA	350–610	15	.	15	2.2	4.2	.	.	24	.	PMA	.	gr	40	8000	18	2	5	.	.	.	.	.	.
derum																											
C. formosum	430	.	PMA	705–945	15	.	15	2.3	4.6	.	.	430	.	PMA	.	gr	.	.	38	5	11	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	430	.	PMA	.	15	.	.	48	9.5	14.5	.	.	.	.	.	.

Botanical name Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m^3	%		%	%	%	%	%				kg/m^3	%	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm	N/mm	N	N	N	N
Cynometra kekatong																											
C. malaccensis	100	.	.	910–1065	15	.	.	.	.	.	.	100	1	PMA	1032	17	135	18840	68	.	.	.	.	11925	11925	.	12595
	578	5	MAL	.	.	0.84	.	.	.	.	.	578	5	MAL	1010	19	135–163	18400–18900	67–87	11.5–13.5	15.5–20	61	74	.	.	12370–13820	.
C. ramiflora	100	.	.	720–1155	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dalbergia sonokeling																											
D. latifolia	762	3	IND	.	.	.	.	.	.	2.9	6.4	762	1	IND	790	12.5	114	11270	61	.	8–9	85	91	.	.	6970	8015
Dialium keranji																											
D. cochin-chinense	.	.	.	.	.	.	.	.	.	.	.	578	.	THA	1100	13	166	19410	91	.	23	.	.	.	.	.	.
D. indum	100	.	.	795–1250	15	.	15	3.7	6.6	.	.	100	1	PMA	1265	31	157	19250	89	.	.	.	.	.	.	16655	16375
D. platy-sepalum	578	3	MAL	.	.	0.79	.	.	.	.	.	578	3	MAL	915	17	134–151	20100	72–87	.	16–19	56	67	.	.	10640–11310	.
Dipterocarpus keruing																											
D. baudii	417	5	PMA	785	15	0.68	.	.	.	.	.	417	5	PMA	1025	65	71	15000	39.5	4	7.5	56	68	.	.	4230	.
	297	.	.	.	.	.	15	2.3	5.6	5.5	13.0	417	5	PMA	785	15	96	17100	53	5	9	70	68	.	.	4890	.
D. caudatus	497	1	PHI	.	.	.	12	2.8	6.9	5.0	10.9	497	1	PHI	.	gr	68.5	12150	32	5.5	7	.	.	.	.	3675	3820
D. caudiferus	461	.	.	610–820	15	.	.	.	.	.	.	461	.	.	.	gr	70.5	12840	35	.	7.5	.	.	.	.	3205	.
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	117	13620	60	.	12	.	.	.	.	4575	.
D. cornutus	417	5	PMA	815	15	0.71	.	.	.	.	.	417	5	PMA	975	51	76	16700	39	4	8	42	46	.	.	4140	.

Botanical name Trade name	Physical properties						shrinkage					Mechanical properties							compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
D. cornutus	297	8	PMA	.	.	.	15	3.1	5.5	6.4	11.3	417	5	PMA	815	15	109	20200	60	4.5	9	54	56	.	.	5430	.
	461	.	.	690–910	15	.	.	.	.	.	.	461	.	.	.	gr	76	16660	39	.	7.5–8.5	42	45	.	.	4125	4360
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	109	20190	60	.	8–9	54	56	.	.	5440	6135
D. crinitus	417	1	PMA	925	15	0.81	.	.	.	.	.	417	1	PMA	1090	41	96	20000	51	6	9	64	70	.	.	6050	.
	297	1	PMA	.	.	.	15	2.1	3.5	5.8	9.6	417	1	PMA	925	16	128	22300	63	9	12	57	64	.	.	7830	.
	461	.	IND	740–1010	15	.	15	2.8	4.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. elongatus	461	.	.	610–740	15	.	.	.	.	.	.	461	.	.	.	gr	67	12250	29.5	.	6–8	51	68.5	.	.	.	2815
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	82	14310	47	.	6.5–8.5	59	71.5	.	.	3575	4255
D. gracilis	497	14	PHI	.	.	.	12	3.3	7.2	5.9	11.3	497	14	PHI	.	gr	68.5	13230	33	5	7.5	.	.	.	.	3810	3800
	472	15	PHI	.	.	.	12	3.0–3.9	6.7–7.9	5.4–6.8	10.7–12.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. grandiflorus	417	1	PMA	800	15	0.69	.	.	.	.	.	417	1	PMA	1010	54	84	16300	45	6	8	56	69	.	.	5380	.
	297	2	PMA	.	.	.	15	1.6	4.0	4.1	10.6	417	1	PMA	800	15	98	17600	52	5.5	10	53	57	.	.	5160	.
	501	.	PMA	720	15	0.68	15	2.8	6.6	5.7	11.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	497	15	PHI	.	.	.	12	4.3	8.9	7.0	12.9	497	15	PHI	.	gr	66	13425	31	5	7.5	.	.	.	.	4165	3990
	461	.	.	730–880	15	.	15	4.7	5.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. hasseltii	461	.	.	600–980	15	.	15	.	.	3.5	8.5	461	.	.	.	gr	64	10780	35	.	5.5–7	62	70	.	.	2940	3330
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	82	12935	46	.	6–7.5	60	73.5	.	.	4185	5125
D. kerrii	417	1	PMA	735	15	0.64	.	.	.	.	.	417	1	PMA	1075	89	46	10200	24	.	6.5	47	66	.	.	2850	.
	297	1	PMA	.	.	.	15	2.6	6.6	.	.	417	1	PMA	735	16.5	76	12900	43	.	11	76	93	.	.	4720	.
	497	10	PHI	.	.	.	12	3.0	6.7	5.3	10.4	497	10	PHI	.	gr	67.5	12150	31	4	8	.	.	.	.	3695	3615
D. kunstleri	417	1	PMA	755	15	0.58	.	.	.	.	.	417	1	PMA	995	70	65	14500	32	3	7	53	56	.	.	3030	.
	297	2	PMA	.	.	.	15	2.6	5.4	5.4	11.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. lowii	417	1	PMA	840	15	0.73	.	.	.	.	.	417	1	PMA	1010	45	84	18400	47	5	9	57	61	.	.	5030	.

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c.	rad.	tang.	shrinkage green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	compression: perpendicular to grain	shear	cleavage: rad.	cleavage: tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
D. lowii	297	1	PMA	.	.	.	15	2.7	4.5	5.7	10.1	417	1	PMA	840	15	133	20000	68	7.5	11	60	66	.	.	7290	.
	501	.	PMA	840	15	0.81	15	3.7	7.0	6.9	12.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	461	.	.	770–930	15	.	.	.	.	6.6	10.2	461	.	.	.	gr	85	18130	42	.	6–7	45	46	.	.	3235	4585
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	112	20480	65	.	6–7	63	66.5	.	.	4085	5105
D. sublamel-	417	1	PMA	770	15	0.67	.	.	.	.	.	417	1	PMA	945	56	60	15400	33	3	7	47	56	.	.	3200	.
latus	297	2	PMA	.	.	.	15	2.0	5.5	4.0	10.8	417	1	PMA	770	16	95	18200	50	5	11	65	68	.	.	5160	.
D. verrucosus	417	1	PMA	800	15	0.69	.	.	.	.	.	417	1	PMA	975	61	62	14100	33	4	6.5	53	62	.	.	3290	.
	297	1	PMA	.	.	.	15	3.1	7.4	5.7	13.5	417	1	PMA	800	16.5	91	17000	50	5	9	68	71	.	.	5780	.
Dryobalanops kapur																											
D. beccarii	461	.	.	600–710	15	.	.	.	.	.	.	461	.	.	.	gr	55	9995	30	.	3–4	49	54	.	.	1990	3225
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	62	10880	38	.	4–5	39	51	.	.	2360	2265
D. lanceolata	461	.	.	610–1010	15	.	12	3.5	8.0	.	.	461	.	.	.	gr	77.5	15975	40	.	5–7	47	56	.	.	.	3625
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	68.5	12350	41	.	5–5.5	53	63	.	.	2330	3030
D. oblongifolia	417	5	PMA	720	15	0.59	.	.	.	.	.	417	5	PMA	1010	70	73	13200	39	5	8	65	86	.	.	4810	.
	297	1	PMA	.	.	.	15	1.7	3.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. sumatrensis	417	5	PMA	800	15	0.69	.	.	.	.	.	417	5	PMA	1010	55	84	15900	47	4	8.5	47	50	.	.	4890	.
	297	7	PMA	.	.	.	15	2.1	4.6	4.4	9.6	417	5	PMA	800	16	114	18700	62	6	10.5	56	56	.	.	5560	.
	461	.	.	630–940	15	.	12	2.1	3.8	.	.	461	.	.	.	gr	81.5	15100	45	.	6.5–7.5	48	61.5	.	.	4020	4100
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	108	16860	61	.	7–8	52	64.5	.	.	5910	7320
Endospermum sesendok																											
E. diadenum	492	.	PMA	400	15	.	15	1.2	1.3	.	.	492	.	PMA	575	76	39	8500	21	2	5.5	.	.	.	.	.	.
	100	70	.	300–650	15	.	15	1.4	2.1	.	.	100	3	PMA	.	60	.	.	23	.	.	.	.	.	.	.	.

Botanical name Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
E. medullosum	67	8	PNG	.	.	0.33	.	.	.	.	.	67	8	PNG	.	gr	40	8695	18	2.5	2–4	18	29	1335	1135	.	1535
	.	.	.	.	.	.	.	.	.	.	.	67	7	PNG	392	12	61	9590	36	4–6	5–6	.	31	1600	1825	.	2670
E. peltatum	683	2	PHI	.	.	0.30	.	.	.	.	.	683	2	PHI	.	gr	36	5080	17	2.5	5.5	.	.	.	.	1390	1820
Eucalyptus eucalypt																											
E. alba	64	.	PNG	1010	12	.	12	2.9	4.6	.	.	359	.	PNG	.	gr	86	14200	43	.	11	.	.	.	.	.	.
E. camal-dulensis	362	.	AUS	913	12	.	12	4.4	8.9	.	.	66	32	AUS	.	12	101	11180	55	.	15	89	98	9745	9525	.	10415
E. citriodora	97	.	.	785	12	.	12	3.0	6.3	.	.	66	21	AUS	992	12	142	18840	76	.	17	84	89	10060	10100	.	8410
E. deglupta	462	.	.	390–810	15	.	.	.	.	4.8	5.7	462	.	.	.	gr	32.5	6565	18.5	.	3–3.5	26.5	30.5	.	.	1010	1635
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	45	8720	27.5	.	3–3.5	23.5	29.5	.	.	490	1325
	97	.	.	400	12	.	12	2.4	7.0	.	.	69	.	PNG	685	12	106	14075	70	.	11	59	56	5030	5650	.	5875
	310	.	SAM	.	.	.	12	1.8	3.4	.	.	310	.	SAM	885	150	56	7600	21	.	5	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	310	.	SAM	419	12	67	8000	39	.	7	.	.	.	.	.	.
Eusideroxylon ulin																											
E. zwageri	762	3	IND	.	.	.	.	.	.	4.2	8.3	762	3	IND	1040	15	140	18030	71.5	.	11.5	53	85.5	.	.	.	.
	448	.	MAL	835–1185	15	.	15	2.0	4.5	.	.	448	.	MAL	.	15	178	18300	94	17	20	.	.	.	.	.	.
	100	.	.	830–1185	15	0.92	15	2.4	4.5	4.3	7.5	100	2	SAB	1295	38	135	18080	80	17.5	14	61	122	12150	11570	.	10725
Gmelina yemane																											
G. arborea	578	5	MAL	480	17	0.41	.	.	.	.	.	578	5	MAL	480	17	61–75	8900–9600	33–39	3	8–9	49	53	.	.	2580–2725	.
	392	.	AFR	.	.	.	12	1.2–1.5	2.4–3.5	.	.	392	5	MAL	480	12	.	9620	33	.	8	50	55	.	.	2665	.

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c.	rad.	tang.	shrinkage green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	perpendicular to grain	shear	cleavage: rad.	tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
G. arborea	.	.	.	.	.	.	.	.	.	.	.	392	5	BUR	495	12	.	8625	23	.	.	.	.	.	.	3380	.
	144	.	.	480	12	.	.	.	.	2.4	4.9	144	.	.	480	12	65	8900	33	.	.	.	.	.	.	.	.
white beech																											
G. moluccana	67	5	PNG	465	12	0.40	.	.	.	.	.	67	5	PNG	.	gr	47	8695	26	.	6	.	22	2135	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	5	PNG	465	12	61	8830	36	.	7–8	.	45	2000	.	.	.
Gonystylus																											
ramin																											
G. bancanus	639	.	IND	.	.	.	12	2.6	5.8	4.4	9.6	639	.	IND	.	14	84	13620	47	.	6	50	58	.	.	2970	3725
	100	.	MAL	540–750	15	.	15	1.3–1.9	3.7–5.2	.	.	100	9	SAR	785	37	71	10145	39	.	8	.	.	.	.	2850	.
	.	.	.	.	.	.	.	.	.	.	.	100	9	SAR	655	12	134	14000	72	.	12	.	.	.	.	5785	.
	620	.	PMA	.	.	.	15	1.6	3.4	.	.	620	.	PMA	.	gr	62	14200	35	.	7	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	620	.	PMA	.	15	88	15900	49	.	8.5	.	.	.	.	.	.
Heritiera																											
mengkulang																											
H. javanica	443	.	PMA	.	.	.	15	1.3	3.0	.	.	443	.	PMA	.	gr	68	10600	32	4	10	.	.	.	.	.	.
	579	.	PHI	.	.	0.56	.	.	.	.	.	579	.	PHI	700	37	60	9410	21.5	5.5	7	.	.	.	.	2880	3065
	461	.	.	660–840	15	.	15	1.3	3.0	.	.	461	.	.	.	gr	.	9410	31	.	7	.	.	.	.	.	2880
H. simplicifolia	443	.	PMA	.	.	.	15	1.7	3.8	.	.	443	.	PMA	.	gr	75	13700	38	4	8	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	443	.	PMA	.	15	91	15990	52	5.5	11	.	.	.	.	.	.
	461	.	.	520–990	15	.	15	1.6	3.1	.	.	461	.	.	.	gr	73.5	12840	34	.	6	45	50	.	.	4310	3755
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	98	13820	50	.	7	52	48	.	.	4010	6430
dungun																											
H. littoralis	67	5	PNG	795	12	0.65	.	.	.	.	.	67	5	PNG	.	gr	86	15460	38	.	9.5	49	.	.	6410	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	5	PNG	795	12	132	17940	72	.	14	62	.	.	7565	.	.
H. sylvatica	579	.	PHI	.	.	0.77	.	.	.	.	.	579	.	PHI	1130	46	73.5	9410	23.5	10	10	.	.	.	.	8485	7515

Botanical name / Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
Hopea																											
merawan																											
H. acuminata	579	.	PHI	.	.	0.62	.	.	.	.	.	579	.	PHI	880	40	108	14700	51	9	11	.	.	.	.	5525	5990
H. dasyrrachis	461	.	IND	590–960	15	.	.	.	.	.	.	461	.	IND	.	gr	76.5	12640	42	.	8	47	60.5	.	.	4745	5585
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	.	15	105	13330	53	.	10	33	36	.	.	.	5145
H. mengarawan	461	.	.	520–910	15	.	.	.	.	2.7	6.1	461	.	.	.	gr	75.5	12055	42	.	5–6	35	44	.	.	3010	3910
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	94	13915	51	.	4–5	26	31	.	.	3820	5075
H. nervosa	417	5	PMA	785	15	0.57	.	.	.	.	.	417	5	PMA	930	64	92	15500	51	5.5	9	65	84	.	.	5070	.
	297	1	PMA	.	.	.	15	1.3	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H. papuana	67	8	PNG	715	12	0.58	.	.	.	.	.	67	8	PNG	.	gr	97	15320	45	5–7	9	52	80	.	4670	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	8	PNG	715	12	110	16150	64	.	.	.	.	.	.	4495	.
H. sangal	462	.	.	510–890	15	.	.	.	.	3.6	7.5	462	.	.	.	gr	95	14015	45	.	8–9	35	42	.	.	4810	5350
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	116.5	12935	58	.	11–12	42	65.5	.	.	4775	6055
H. sulcata	417	5	PMA	655	15	0.53	.	.	.	.	.	417	5	PMA	850	61	90	15000	46	.	9	63	72	.	.	4630	.
	297	3	PMA	.	.	.	15	0.9	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
giam																											
H. basilanica	579	.	PHI	.	.	0.86	.	.	.	.	.	579	.	PHI	1090	35	123.5	17445	42	13	13	.	.	.	.	8700	8105
H. helferi	417	3	PMA	945	15	0.81	.	.	.	.	.	417	3	PMA	1170	54	103	14600	54	10	14	89	111	.	.	9750	.
	297	3	PMA	.	.	.	15	2.0	4.4	4.3	9.6	417	3	PMA	945	17	122	16500	59	11	16	81	75	.	.	9830	.
H. iriana	67	11	PNG	985	12	0.82	.	.	.	.	.	67	11	PNG	.	gr	119	22010	70	15–17	14	58	75	9525	8945	.	8410
	.	.	.	.	.	.	.	.	.	.	.	67	11	PNG	985	12	169	24220	95	14–15	15–18	76	76	10415	10010	.	9790
H. nutans	417	5	PMA	1025	15	0.84	.	.	.	.	.	417	5	PMA	1200	42	109	17900	67	13.5	13.5	98	116	.	.	9660	.
	297	1	PMA	.	.	.	15	1.4	2.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Intsia																											
merbau																											
I. bijuga	579	.	PHI	880	15	0.75	.	.	.	.	.	579	.	PHI	1100	46	103	14010	51	11	12	.	.	.	.	7410	6625
	97	5	.	860	12	0.74	12	1.2	2.5	.	.	408	1	PHI	.	gr	90	12445	.	11	.	.	.	.	.	.	5900

Botanical name / Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
I. bijuga	362	10	AUS	825	12	0.70	12	1.2	2.6	.	.	408	1	PHI	.	12	105	13915	.	14	.	.	.	.	.	.	7750
	395	3	.	805	12	0.68	12	1.1	1.9	3.8	6.2	67	14	PNG	.	gr	104	14835	55	18	13	68	82	7520	7610	.	7430
	.	.	.	.	.	.	.	.	.	.	.	67	14	PNG	825	12	147	18010	81	27	18	70	83	8455	8680	.	8545
	462	.	.	630–1040	15	.	.	.	.	3.3	4.1	462	.	.	.	gr	105	15485	53	.	6–7	63.5	74.5	.	.	.	7840
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	145	15485	76.5	.	10	68.5	73.5	.	.	8250	8625
I. palembanica	.	.	.	.	.	.	.	.	.	.	.	417	5	PMA	1135	67	89	13900	47	6.5	11	68	65	.	.	6140	.
	395	9	.	815	11	0.70	12	1.3	2.4	3.2	5.4	417	5	PMA	800	15	116	15400	58	9	12.5	75	82	.	.	6680	.
	448	.	MAL	515–1040	15	.	15	0.9	1.6	.	.	448	.	MAL	.	15	116	15400	58	9	12.5	.	.	.	.	.	.
	462	.	.	520–970	15	.	15	0.6	0.7	.	.	462	.	.	.	gr	111	16955	57	.	7.5–8.5	77.5	82.5	.	.	.	5145
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	130	16365	68.5	.	9–10	53	58	.	.	5755	5820
Koompassia kempas *K. malaccensis*	100	.	.	670–1280	15	.	15	2.5	2.6	.	.	100	.	PMA	1025	41	100	16630	55	6	10	61	63	.	.	6585	6985
	611	.	PMA	890	15	.	18	2.0	3.0	.	.	611	.	PMA	.	gr	100	16600	55	6	10	.	.	.	.	.	.
	611	.	PMA	1020	40	.	.	.	.	.	.	611	.	PMA	.	18	122	18600	66	8	12	.	.	.	.	.	.
	578	5	MAL	.	.	0.71	.	.	.	.	.	578	5	PMA	850	15	122–127	18100–18600	66–72	7.5	12–14	60	67	.	.	7610–7630	.
	462	.	.	680–1290	15	.	15	2.5	2.6	.	.	462	.	.	.	gr	116	19210	58	.	9–10	60	64.5	.	.	5780	6490
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	133	20875	72.5	.	8	54	61.5	.	.	5980	7695
tualang *K. excelsa*	448	.	MAL	800–865	15	.	15	1.5	1.7	.	.	448	.	MAL	.	15	121	17800	62	8	16	.	.	.	.	.	.
	100	.	.	570–1115	15	0.73	15	1.4	1.9	.	.	100	5	PMA	1095	50	102	16440	54	7	12	73	78	8320	8200	.	8320
	578	1	PHI	.	.	0.70	.	.	.	.	.	578	1	PHI	865	12	146	18100	76	12	13	.	.	.	.	9410	10400

Botanical name Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
Lophopetalum																											
perupok																											
L. floribundum	794	.	PMA	.	.	.	16.5	2.3	2.7	.	.	794	.	PMA	.	gr	62	11300	32	3.5	7.5	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	794	.	PMA	.	16.5	79	12600	35	5.5	9	.	.	.	.	.	.
L. javanicum	462	.	.	300–560	15	.	15	1.3	2.7	.	.	462	.	.	.	gr	54	7740	25.5	.	5.5–7	36	40	.	.	2145	3095
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	62.5	8625	30	.	7–9	34	42	.	.	2930	4470
L. subovatum	794	.	PMA	.	.	.	15	2.4	3.0	.	.	794	.	PMA	.	gr	64	11700	33	3.5	7	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	794	.	PMA	.	15	76	12200	43	5.5	7.5	.	.	.	.	.	.
Madhuca																											
nyatoh																											
M. motleyana	792	.	PMA	545	15	.	14.5	2.4	3.0	.	.	792	.	PMA	.	gr	50	9800	25	.	.	.	.	.	.	.	.
bitis																											
M. betis	.	.	.	.	.	.	.	.	.	.	.	578	.	IND	1015	16	105–113	9830–10000	54–61	.	10–12	.	.	.	.	.	.
M. utilis	100	.	PMA	1100	15	.	15	3.0	3.4	.	.	100	.	PMA	1295	38	123	21940	74	12	.	.	.	.	.	10460	10100
	432	.	PMA	1120	15	.	15	2.8	4.0	.	.	432	.	PMA	1120	15	171	23800	90	12.5	15.5	.	.	.	.	.	.
	578	5	MAL	.	.	0.92	.	.	.	.	.	578	5	MAL	1120	14	171	22700–23800	90–93	12–12.5	15.5–17	86	67	.	.	14415–14860	.
Manilkara																											
manilkara																											
M. fasciculata	814	.	IJA	1010–1090	15	1.00–1.06	15	2.5	8.7	4.8	12.2	814	.	IJA	.	15	174–198	.	76.5–86	.	19.5–24	39–58.5	48–65.5	.	.	.	.
M. hexandra	.	.	.	.	.	.	.	.	.	.	.	641	.	THA	1315	33	113	11170	57.5	24	17	.	.	9660	10080	.	.
M. kanosiensis	67	4	PNG	.	.	0.82	.	.	.	.	.	67	4	PNG	.	gr	104	17180	54	.	14	.	81	8900	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	67	4	PNG	1030	12	164	21185	83	.	19.5	.	109	12640	.	.	.

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density (kg/m³)	at moisture content of (%)	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c. (%)	rad. (%)	tang. (%)	shrinkage green to oven-dry: rad. (%)	tang. (%)	Mechanical properties: source	number of trees tested	origin of trees	density when tested (kg/m³)	moisture content when tested (%)	modulus of rupture (N/mm²)	modulus of elasticity (N/mm²)	compression parallel to grain (N/mm²)	compression perpendicular to grain (N/mm²)	shear (N/mm²)	cleavage rad. (N/mm)	cleavage tang. (N/mm)	Janka hardness rad. (N)	Janka hardness tang. (N)	Janka hardness side (N)	Janka hardness end (N)
Neobalanocarpus chengal																											
N. heimii	417	5	PMA	.	.	0.82	.	.	.	.	.	417	5	PMA	1170	78	122	18100	69	12	14	67	1	.	.	9260	.
	297	7	PMA	.	.	.	15	1.1	2.6	3.0	7.4	417	5	PMA	945	15.5	149	19600	75	12	14	55	9	.	.	9480	.
Palaquium nyatoh																											
P. burckii	461	.	.	520–760	15	.	.	.	.	.	.	461	.	.	.	gr	68.5	11760	36	.	6–7	45	9	.	.	.	3715
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	79.5	12840	44	.	4.5–5.5	38	8	.	.	2960	3785
P. gutta	792	.	PMA	760	19.5	.	19.5	1.0	1.9	.	.	792	.	PMA	.	gr	64	11300	34	.	9	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	792	.	PMA	.	19.5	79	12200	45	.	11	.	.	.	.	.	.
	461	.	.	610–910	15	.	.	.	.	.	.	461	.	.	.	gr	62	8920	33	.	7.5	59.5	67.5	.	.	3205	4085
P. hispidum	792	.	PMA	670	17	.	17	1.3	2.8	.	.	792	.	PMA	.	gr	60	10600	30	3	7.5	.	.	.	.	.	.
P. luzoniense	480	.	PHI	440–600	12	.	12	1.6	3.4	3.0	5.8	480	.	PHI	.	12	90–98	11465–12250	26–32	8	10	.	.	.	.	4360–4430	5370–5695
	579	.	PHI	.	.	0.56	.	.	.	.	.	579	.	PHI	690	17	69	10190	27.5	7	9	.	.	.	.	3725	4105
P. maingayi	792	.	PMA	735	15	.	15	2.3	4.3	.	.	792	.	PMA	.	gr	63	11700	34	4	8	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	792	.	PMA	.	15	.	.	44	4.5	11	.	.	.	.	.	.
	419	.	PMA	.	.	.	15	2.5	4.0	.	.	419	.	PMA	1010	79	65	12370	34	4.5	8	.	.	4415	4690	.	4470
	.	.	.	.	.	.	.	.	.	.	.	419	.	PMA	690	16.5	.	.	44	4.5	.	.	.	4165	3945	.	4805
P. obovatum	643	.	THA	572	14	.	14	0.5	0.9	.	.	642	.	THA	650	14	82	6520	30	9	17	.	.	5645	4810	.	.
	.	.	.	.	.	.	.	.	.	.	.	578	.	THA	650	14	82	6570	30	.	17	.	.	.	.	.	.
bitis																											
P. impressinervium	792	.	PMA	.	.	.	16.5	3.0	3.6	.	.	792	.	PMA	.	gr	97	17000	54	6	12	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	792	.	PMA	945	15	129	18300	65	9	12	.	.	.	.	.	.
P. ridleyi	578	.	IND	.	.	0.85	.	.	.	.	.	578	.	IND	1043	35	94–158	17840–21000	49–87.5	.	5–10	.	.	.	.	.	.

Botanical name Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
Paraserianthes batai *P. falcataria*	537	.	MAL	360–415	12	.	12	1.2–2.0	2.6–3.7	2.5–3.4	5.2–6.5	537	5	MAL	.	gr	31	6190	17	.	4.5	.	.	2275	2500	.	2725
	.	.	.	.	.	.	.	.	.	.	.	537	4	MAL	.	12	48	6895	26.5	.	6.5	.	.	.	.	.	.
	363	.	AUS	410–450	12	.	.	.	.	3–4	5–6.5	363	.	AUS	.	gr	.	.	19.5–24.5	.	5–6	.	.	.	.	2270–2805	.
	462	.	.	240–490	15	.	.	.	.	2.5	5.2	462	.	.	.	gr	45.5	3235	21	.	3–3.5	24	27.5	.	.	1100	1570
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	51.5	4360	27.5	.	4.5–5	33	35.5	.	.	1165	2175
	.	.	.	.	.	.	.	.	.	.	.	145	.	.	.	gr	36.5	7450	36.5	.	.	.	.	.	.	1600	.
	.	.	.	.	.	.	.	.	.	.	.	145	.	.	.	12	58	8830	58	.	.	.	.	.	.	2000	.
Parashorea white seraya *P. malaanonan*	100	.	.	440–660	15	0.44	15	1.4	4.3	3.4	7.8	100	2	SAB	760	73	55.5	9865	30.5	.	6	43	52	.	.	2690	2935
	100	.	.	.	.	.	12	1.6–2.5	4.2–5.0	.	.	100	5	SAB	530	12	81.5	12350	49.5	.	7	50.5	52	.	.	2935	2760
	408	.	PHI	.	.	0.46–0.56	.	.	.	.	.	408	.	PHI	.	gr	55.5–68	9805–11765	29–33	3–4.5	7	.	.	.	.	2620–3500	2620–3620
	.	.	.	.	.	.	.	.	.	.	.	408	14	PHI	.	12	83.5–97	11570–13925	42.5–51	5–7	8.5–10.5	.	.	.	.	3065–4145	2870–3885
P. tomentella	100	31	.	390–670	15	.	12	2.5	5.5	.	.	100	5	SAB	.	70	56.5	7730	29.5	.	6.5	25	31	.	.	2580	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	480	12	75	8900	45.5	.	8.5	26	31.5	.	.	2625	.
gerutu *P. densiflora*	138	.	PMA	650–875	15	.	15	2.0	3.6	.	.	138	.	PMA	.	gr	94	19700	50	7	8.5	.	.	.	.	.	.

Botanical name Trade name	Physical properties						shrinkage					Mechanical properties							compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
P. stellata	138	.	PMA	695–745	15	.	18	1.6	3.3	.	.	138	.	PMA	.	gr	74	13205	41.5	4.5	8	.	.	.	.	.	.
Payena nyatoh *P. spec.*	.	.	.	.	.	.	.	.	.	.	.	641	.	THA	675	13	107	9900	51.5	8	16	.	.	5790	5810	.	.
Pericopsis pericopsis *P. mooniana*	371	.	IJA	.	.	0.69	.	.	.	4.3	7.5	371	.	IJA	.	65	127	14765	67	8.5–10	12–13	.	.	7565	7610	.	8635
	.	.	.	.	.	.	.	.	.	.	.	371	.	IJA	825	12	151	16075	90	10.5–12	14–15	.	.	8990	8900	.	10635
Peronema sungkai *P. canescens*	578	.	IND	.	.	0.63	.	.	.	.	.	578	.	IND	725	15	67	8235	31	.	6–7	.	.	.	.	.	.
	461	.	.	520–730	15	.	.	.	.	.	.	461	.	.	.	gr	67	9900	25	.	6–7	49.5	52	.	.	3195	4330
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	55.5	8230	31	.	4.5–6	61	64	.	.	2530	2960
Pinus pine *P. caribaea*	.	.	.	.	.	.	.	.	.	.	.	417	14	MAL	1075	188	26	3400	13.5	.	5.5	29	32	.	.	1960	.
	.	.	.	.	.	.	.	.	.	.	.	417	14	MAL	435	18	36	3700	19.5	.	8.5	40	44	.	.	2220	.
	156	15	FIJ	.	.	.	15	2.5	3.9	4.5	6.4	68	12	FIJ	.	gr	34	4550	16	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	68	12	FIJ	503	12	64	6280	33.5	.	.	.	.	.	.	.	.
P. kesiya	.	.	.	.	.	.	.	.	.	.	.	417	10	MAL	1040	132	39	8300	18.5	.	6	35	39	.	.	2400	.
	.	.	.	.	.	.	.	.	.	.	.	417	10	MAL	530	15	61	9300	29	.	9	41	48	.	.	2760	.
	548	.	PHI	.	.	0.55	.	.	.	3.9	7.7	548	.	PHI	.	12	104	14900	51	7.5	11	.	.	.	.	.	.
P. merkusii	462	.	IND	400–750	15	.	.	.	.	4.9	8.3	462	.	IND	.	gr	53	10290	26	.	6–7	39	38	.	.	2450	2705
	.	.	.	.	.	.	.	.	.	.	.	462	.	IND	.	15	83	12445	44	.	8–9	42	55	.	.	3800	4790

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage: green to moisture content (m.c.): m.c.	green to moisture content: rad.	green to moisture content: tang.	green to oven-dry: rad.	green to oven-dry: tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	compression: perpendicular to grain	shear	cleavage: rad.	cleavage: tang.	Janka hardness: rad.	Janka hardness: tang.	Janka hardness: side	Janka hardness: end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
P. merkusii	.	.	.	.	.	.	.	.	.	.	.	417	15	MAL	1090	159	32	4600	15	.	7	35	36	.	.	2310	.
	.	.	.	.	.	.	.	.	.	.	.	417	15	MAL	515	15	41	4600	24	.	10	38	46	.	.	3200	.
Pometia kasai																											
P. pinnata	408	.	PHI	.	.	0.49	12.5	2.5	4.3	5.2	7.7	408	2	PHI	.	gr	58	10485	30.5	8	9	.	.	.	.	5800	5270
	.	.	.	.	.	.	.	.	.	.	.	408	6	PHI	.	12	104–112	12740–13330	50–57	11	12–14	.	.	.	.	5155–9005	6890–9340
	67	12	PNG	.	.	0.57	.	.	.	.	.	67	12	PNG	.	gr	62–66.5	11180–11730	29–31.5	4	7.5–9	45–58.5	50.5–61.5	3715–4160	3740–4140	.	3405–4340
	.	.	.	.	.	.	.	.	.	.	.	67	13	PNG	700	12	96–106	14350–14420	53–60	8.5–10	12.5–17	78.5–83	70.5–89	5430–6855	5830–6230	.	7920
	462	.	.	500–990	15	.	15	3.0–4.5	5.5–7.8	3.4–5.9	5.6–9.4	462	.	.	.	gr	62	8625–10780	35	.	3–7.5	51	56	.	.	3115–3360	3480–3820
	.	.	.	.	.	.	.	.	.	.	.	462	.	.	.	15	76.5–100	8920–14015	37–56.5	.	7–10.5	50–64	53–69	.	.	3870–4320	4910–6350
P. ridleyi	.	.	.	.	.	.	.	.	.	.	.	417	2	PMA	1040	52	81	15700	41	6.5	13	57	68	.	.	5830	.
	.	.	.	.	.	.	.	.	.	.	.	417	2	PMA	835	20.5	106	17000	53.5	9.5	14.5	79	86	.	.	7030	.
Pouteria nyatoh																											
P. kaern-	67	5	PNG	.	.	0.44	.	.	.	.	.	67	5	PNG	.	gr	51	10625	26	.	7	.	63	2470	2000	.	.
bachiana	.	.	.	.	.	.	.	.	.	.	.	67	5	PNG	540	12	83.5	12625	46.5	.	11	.	59	2960	.	.	.
P. torricel-	67	5	PNG	.	.	0.49	.	.	.	.	.	67	5	PNG	.	gr	59.5	10765	29	.	8	.	49.5	3425	2960	.	.
lensis	.	.	.	.	.	.	.	.	.	.	.	67	5	PNG	600	12	88.5	12350	51.5	.	14	.	48	3870	.	.	.
P. villamilii	480	.	PHI	.	.	0.50	12	2.3	4.0	4.3	7.1	480	.	PHI	.	gr	58	9700	26.5	5	8.5	.	.	.	.	4055	3705
	.	.	.	.	.	.	.	.	.	.	.	480	.	PHI	530	12	92	11465	42.5	8	11	.	.	.	.	6360	4420

Botanical name Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c.	rad.	tang.	shrinkage green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression parallel to grain	compression perpendicular to grain	shear	cleavage rad.	cleavage tang.	Janka hardness rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
Pterocarpus																											
narra																											
P. dalber-	145	.	AND	775	12	0.63	.	.	.	3.3	4.4	145	.	AND	.	gr	84	11040	47	.	.	.	.	.	.	5650	.
gioides	.	.	.	.	.	.	.	.	.	.	.	145	.	AND	.	8	105	12280	63	.	.	.	.	.	.	7255	.
P. indicus	407	4	PHI	.	.	0.52	12	3.2	5.4	.	.	407	4	PHI	.	gr	68.5	9865	.	4.5	7	.	.	.	.	3560	4005
	.	.	.	.	.	.	.	.	.	.	.	407	4	PHI	.	12	96	12075	.	8	10.5	.	.	.	.	3870	4540
	67	15	PNG	.	.	0.54	.	.	.	.	.	67	15	PNG	.	gr	74	10145	38.5	6	8–9	54.5	44.5	4295	4115	.	4450
	.	.	.	.	.	.	.	.	.	.	.	67	14	PNG	620	12	95	12215	58.5	8.5	10–13	55.5	46	4715	4675	.	5205
	461	.	.	390–940	15	.	.	.	.	3.0	5.9	461	.	.	.	gr	68.5	10190	34	.	8.5–10	58.5	58.5	.	.	.	4585
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	89.5	13130	51	.	9	47	44	.	.	4310	4705
Scaphium																											
kembang semangkok																											
S. macropo-dum	431	.	PMA	515–755	15	.	18.5	1.2	3.0	.	.	431	.	PMA	.	gr	76	15500	37	.	8.5	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	431	.	PMA	.	15	92	17000	50	.	10	.	.	.	.	.	.
	578	3	MAL	.	.	0.59	.	.	.	.	.	578	3	MAL	705	17	92–103	17000	50–60	.	10–12	34	52	.	.	4940–5205	.
Shorea																											
red meranti																											
S. acuminata	417	6	PMA	560	15	0.46	.	.	.	.	.	417	6	PMA	755	64	54	10500	27.5	2.5	6.5	46	58	.	.	2760	.
S. balangeran	462	.	IND	730–980	15	.	.	.	.	.	.	462	.	IND	.	gr	77	14110	36.5	.	4.5	57	59.5	.	.	5585	4880
	.	.	.	.	.	.	.	.	.	.	.	462	.	IND	.	15	94	15975	52.5	.	6.5	52	57	.	.	5205	5575
S. contorta	579	.	PHI	.	.	0.50	.	.	.	.	.	579	.	PHI	590	17	70	11465	30.5	5	8	.	.	.	.	2980	3795
S. curtisii	417	5	PMA	.	.	0.55	.	.	.	.	.	417	5	PMA	770	47	69	12800	36.5	4	7	42	46	.	.	3340	.
	297	5	PMA	.	.	.	15	2.0	4.1	4.0	8.1	417	5	PMA	625	15	90	13900	45.5	5	8	54	61	.	.	3920	.

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c.	rad.	tang.	green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression parallel to grain	compression perpendicular to grain	shear	cleavage rad.	cleavage tang.	Janka hardness rad.	Janka hardness tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
S. dasyphylla	100	5	.	345–690	15	.	10	3.1	5.2	.	.	100	2	PMA	.	56	59.5	10280	31	.	.	47	54	.	.	2490	2805
	.	.	.	.	.	.	.	.	.	.	.	100	2	PMA	485	12	83.5	11180	48	.	.	63	66.5	.	.	2805	4185
S. hemsleyana	417	3	PMA	.	.	0.60	.	.	.	.	.	417	3	PMA	1075	82	68	13200	37	.	7.5	60	64	.	.	3870	.
	297	3	PMA	.	.	.	15	1.9	5.4	.	.	417	3	PMA	690	19	77	13400	42.5	.	11	54	59	.	.	3520	.
S. johorensis	100	76	.	320–695	15	.	12	2.5	6.5	.	.	100	5	SAB	.	73	50.5	6970	27	.	6	20.5	33.5	.	.	2000	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	435	12	69	7865	42.5	.	7.5	27	36.5	.	.	2045	.
S. leprosula	417	5	PMA	.	.	0.50	.	.	.	.	.	417	5	PMA	755	63	53	11400	29	2.5	6.5	32	40	.	.	2540	.
	297	3	PMA	.	.	.	15	2.6	5.3	.	.	417	5	PMA	575	14	75	13600	41.5	2.5	7	42	44	.	.	2940	.
	461	.	.	300–860	15	.	.	.	.	2.1	3.5	461	.	.	.	gr	30	6075	17.5	.	5	31.5	35	.	.	490	1335
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	35	6470	23	.	2.5	27.5	30.5	.	.	625	1275
S. macroptera	100	31	.	360–640	15	.	15	1.2	3.3	.	.	100	5	PMA	720	62	59.5	11315	30	.	6.5	41.5	56	.	.	2535	3160
S. negrosensis	579	.	PHI	505–805	15	0.40	.	.	.	.	.	579	.	PHI	600	48	50.5	8820	19.5	3.5	3	.	.	.	.	2285	2135
S. ovalis	579	.	PHI	480–650	15	0.50	.	.	.	.	.	579	.	PHI	590	17	71	12445	35	5.5	8	.	.	.	.	3195	2890
	461	.	.	320–860	15	.	.	.	.	.	.	461	.	.	.	gr	47	11560	28.5	.	4–5	28.5	39	.	.	1370	2235
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	60.5	11170	34	.	4.5	38	44.5	.	.	1765	2820
S. palosapis	579	.	PHI	365–680	15	0.38	.	.	.	.	.	579	.	PHI	460	38	46.5	8525	15	2.5	4.5	.	.	.	.	1775	1960
S. parvifolia	417	5	PMA	.	.	0.41	.	.	.	.	.	417	5	PMA	640	68	50	9300	25.5	2	6	35	42	.	.	2140	.
	297	5	PMA	.	.	.	15	1.5	4.8	2.7	8.5	417	5	PMA	465	15	63	10200	34.5	2.5	6.5	40	53	.	.	2360	.
	461	.	.	290–830	15	.	12	2.0	6.0	.	.	461	.	.	.	gr	49	11170	26.5	.	3.5–4.5	31.5	37	.	.	.	2115
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	66.5	10780	33.5	.	5	51.5	57	.	.	1570	2570
S. pauciflora	417	5	PMA	675	15	0.54	.	.	.	.	.	417	5	PMA	880	62	71	12700	37.5	3.5	7.5	56	74	.	.	3960	.
	297	3	PMA	.	.	.	15	1.7	2.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Botanical name Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage: green to moisture content (m.c.): m.c.	rad.	tang.	green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	perpendicular to grain	shear	cleavage: rad.	tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
S. pauciflora	100	.	.	500–695	15	.	15	1.8–2.2	2.9–4.5	.	.	100	5	SAB	.	69	68.5	9660	34	.	8.5	29.5	38.5	.	.	3115	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	565	12	92	11385	53	.	11.5	31.5	40.5	.	.	3470	.
	578	2	PHI	.	.	0.32	.	.	.	.	.	578	2	PHI	400	12	68	9460–11000	31.5–34.5	3–3.5	5.5–6	.	.	.	.	1500–1650	2575–2830
	461	.	.	540–780	15	.	.	.	.	.	.	461	.	.	.	gr	79	14600	37.5	.	5.5–6.5	54	53.5	.	.	.	3320
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	91.5	14210	30.5	.	5.5–6	60.5	66.5	.	.	3115	3380
S. pinanga	100	27	IND	310–575	15	.	.	.	.	.	.	100	3	SAB	630	53	54.5	10840	27.5	.	6.5	36.5	43	.	.	1960	2945
S. platyclados	417	5	PMA	.	.	0.53	.	.	.	.	.	417	5	PMA	815	66	58	11300	30	2.5	6.5	40	53	.	.	2980	.
	297	5	PMA	.	.	.	15	2.1	4.4	3.8	7.9	417	5	PMA	610	16.5	77	12100	39.5	4	8.5	58	75	.	.	3650	.
	461	.	.	340–860	15	.	.	.	.	.	.	461	.	.	.	gr	65	11760	34	.	5–6.5	49.5	71.5	.	.	3480	3460
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	83	12450	42.5	.	8–9	60	66.5	.	.	3910	4480
S. polysperma	579	.	PHI	490–815	15	0.53	.	.	.	.	.	579	.	PHI	690	37	59	10190	20	4	7	.	.	.	.	3020	2960
S. singkawang	417	1	PMA	.	.	0.47	.	.	.	.	.	417	1	PMA	770	71	55	10100	32	3	7.5	49	61	.	.	2940	.
	297	1	PMA	.	.	.	15	1.1	3.4	.	.	417	1	PMA	560	19.5	74	11200	39	3	8.5	53	63	.	.	3290	.
S. smithiana	100	49	.	300–725	15	.	12	3.5	7.0	.	.	100	5	SAB	.	64	49.5	7245	25.5	.	5	18.5	26.5	.	.	1960	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	455	12	74.5	9110	45.5	.	7.5	26.5	34	.	.	2405	.
	461	.	.	300–720	15	.	12	3.5	7.0	.	.	461	.	.	.	gr	46.5	4410	21.5	.	4.5	25	27	.	.	1695	2215
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	52.5	8430	27	.	6	33.5	37	.	.	1550	2510
S. stenoptera	461	.	.	430–520	15	.	.	.	.	1.5	4.5	461	.	.	.	gr	29	6270	45.5	.	3.5	21.5	25	.	.	465	1165
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	32	6565	21	.	2.5	23	19	.	.	510	1050

Botanical name Trade name	Physical properties: source	number of trees tested	origin of trees	density (kg/m³)	at moisture content of (%)	specific gravity (moisture content 0%)	shrinkage green to moisture content (m.c.): m.c. (%)	rad. (%)	tang. (%)	shrinkage green to oven-dry: rad. (%)	tang. (%)	Mechanical properties: source	number of trees tested	origin of trees	density when tested (kg/m³)	moisture content when tested (%)	modulus of rupture (N/mm²)	modulus of elasticity (N/mm²)	compression parallel to grain (N/mm²)	compression perpendicular to grain (N/mm²)	shear (N/mm²)	cleavage rad. (N/mm)	cleavage tang. (N/mm)	Janka hardness rad. (N)	tang. (N)	side (N)	end (N)
S. teysmanniana	417	2	PMA	510	15	0.42	.	.	.	.	.	417	2	PMA	765	83	46	10600	23.5	2.5	5.5	31	36	.	.	2580	.
	461	.	.	400–810	15	.	.	.	.	.	.	461	.	.	.	gr	64	12150	29.5	.	5–5.5	41.5	44	.	.	1595	2645
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	58.5	11075	33	.	5	32.5	28.5	.	.	1645	2560
S. uliginosa	461	.	.	420–790	15	.	.	.	.	.	.	461	.	.	.	gr	94.5	15290	31.5	.	6–7	37	53.5	.	.	.	2695
white meranti	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	89.5	17150	45	.	6.5–8	44.5	27	.	.	3010	3275
S. assamica	579	.	PHI	485–590	15	0.44	.	.	.	.	.	579	.	PHI	510	15	57	9505	28.5	4.5	7.5	.	.	.	.	2735	3410
S. bracteolata	417	6	PMA	.	.	0.51	.	.	.	.	.	417	6	PMA	735	52	63	12700	34	2.5	6	37	39	.	.	3070	.
	297	3	PMA	.	.	.	15	1.8	3.0	.	.	417	6	PMA	575	14.5	.	.	44.5	4	9.5	46	53	.	.	3870	.
	461	.	.	510–840	15	.	15	1.7	2.2	.	.	461	.	.	.	gr	63.5	12640	34	.	6	37	38.5	.	.	3420	3065
S. henryana	417	3	PMA	.	.	0.79	.	.	.	.	.	417	3	PMA	1170	52	109	18400	62	9.5	14	66	70	.	.	9120	.
	297	3	PMA	.	.	.	15	1.1	2.6	3.7	8.6	417	3	PMA	915	17	132	19400	67	11	14	58	60	.	.	9210	.
S. hypochra	417	5	PMA	.	.	0.60	.	.	.	.	.	417	5	PMA	915	58	79	14400	42	5	9	61	61	.	.	4720	.
	297	5	PMA	.	.	.	15	1.3	2.7	3.5	7.5	417	5	PMA	690	15.5	97	15700	51.5	6	10	41	44	.	.	5250	.
S. javanica	461	.	IND	470–830	15	.	.	.	.	2.5	5.7	461	.	IND	.	gr	50	4900	25	.	4	40	44	.	.	1860	2080
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	.	15	57.5	9605	31.5	.	5.5	40.5	42.5	.	.	2765	2575
S. polita	578	4	PHI	.	.	0.47	.	.	.	.	.	578	4	PHI	605	12	81.5–89	10300–11100	38.5–42	6–7	9.5–10	.	.	.	.	3485–3830	4660–5120
S. retinodes	461	.	IND	570–890	15	.	.	.	.	.	.	461	.	IND	.	gr	63.5	12445	33.5	.	5	44.5	45	.	.	3330	3205
	.	.	.	.	.	.	.	.	.	.	.	461	.	IND	.	15	84	12055	44.5	.	7	49	54	.	.	3175	3800
S. roxburghii	417	6	PMA	.	.	0.59	.	.	.	.	.	417	6	PMA	960	76	73	10800	40.5	5	9	59	62	.	.	4850	.
	297	3	PMA	.	.	.	15	0.6	1.4	.	.	417	6	PMA	675	15.5	90	11500	47.5	7	10.5	52	56	.	.	5030	.

Botanical name / Trade name	Physical properties											Mechanical properties															
							shrinkage												compression			cleavage		Janka hardness			
							green to moisture content (m.c.)			green to oven-dry																	
	source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	m.c.	rad.	tang.	rad.	tang.	source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	parallel to grain	perpendicular to grain	shear	rad.	tang.	rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
yellow meranti *S. faguetiana*	417	2	PMA	530	15	0.44	.	.	.	.	.	417	2	PMA	880	102	60	10700	33	4	6.5	49	62	.	.	3110	.
	297	3	PMA	.	.	.	15	1.0	3.5	2.3	8.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	100	43	.	400–800	15	.	12	2.5	7.5	.	.	100	5	SAB	.	107	65.5	9730	32	.	8.5	29	40	.	.	3380	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	535	12	88.5	9730	50.5	.	10.5	27.5	41	.	.	3295	.
	461	.	.	400–700	15	.	12	2.5	7.5	.	.	461	.	.	.	gr	65.5	9700	32	.	8.5	.	.	.	.	3380	.
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	88	9995	50.5	.	10.5	.	.	.	.	3295	.
S. longisperma	417	5	PMA	530	15	0.43	.	.	.	.	.	417	5	PMA	755	74	55	10500	29.5	3	6	44	51	.	.	2580	.
	297	3	PMA	.	.	.	15	1.2	3.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S. multiflora	417	3	PMA	560	15	0.48	.	.	.	.	.	417	3	PMA	815	79	57	11000	30	.	6.5	41	49	.	.	2890	.
	297	3	PMA	.	.	.	15	0.9	3.8	.	.	417	3	PMA	560	17.5	67	12100	40	.	8	48	50	.	.	3290	.
	461	.	.	440–860	15	.	.	.	.	.	.	461	.	.	.	gr	87	12935	41	.	5.5–7	55.5	84	.	.	.	4045
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	101.5	12640	49	.	7.5–8	60	65	.	.	3850	4310
balau *S. elliptica*	461	.	.	820–1110	15	.	.	.	.	.	.	461	.	.	.	gr	128.5	20285	67.5	.	6–9	72	75	.	.	.	7215
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	151.5	19500	71.5	.	9–9.5	74	82	.	.	6985	8310
S. glauca	417	5	PMA	960	15	0.79	.	.	.	.	.	417	5	PMA	1105	40	115	19400	60.5	7.5	12	54	58	.	.	8010	.
	297	5	PMA	.	.	.	15	2.1	3.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S. laevis	417	5	PMA	.	.	0.84	.	.	.	.	.	417	5	PMA	1105	38	121	18400	69	9.5	13	65	74	.	.	9300	.
	297	5	PMA	.	.	.	15	1.7	3.7	4.2	9.3	417	5	PMA	960	15.5	142	20100	76	10	15	65	72	.	.	10010	.
	461	.	.	600–1160	15	.	15	1.5	3.1	4.5	8.3	461	.	.	.	gr	113.5–121	18425–18520	61.5–68.5	.	6.5–13.5	48.5–64.5	64.5–73.5	.	.	9290	6840–9645
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	122	18325	66.5	.	9–10	64.5	83	.	.	5960	6075
S. maxwelliana	417	5	PMA	1040	15	0.86	.	.	.	.	.	417	5	PMA	1215	43	125	22100	70.5	12.5	11.5	88	133	.	.	9520	.
	297	5	PMA	.	.	.	15	1.7	3.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Botanical name Trade name	Physical properties: source	number of trees tested	origin of trees	density (kg/m³)	at moisture content of (%)	specific gravity (moisture content 0%)	shrinkage, green to moisture content (m.c.): m.c. (%)	rad. (%)	tang. (%)	shrinkage, green to oven-dry: rad. (%)	tang. (%)	Mechanical properties: source	number of trees tested	origin of trees	density when tested (kg/m³)	moisture content when tested (%)	modulus of rupture (N/mm²)	modulus of elasticity (N/mm²)	compression: parallel to grain (N/mm²)	perpendicular to grain (N/mm²)	shear (N/mm²)	cleavage: rad. (N/mm)	tang. (N/mm)	Janka hardness: rad. (N)	tang. (N)	side (N)	end (N)
S. maxwelliana	461	.	.	880–1150	.	.	15	1.7	3.5	.	.	461	.	.	.	gr	124.5	22150	70.5	.	.	87.5	133	.	.	9535	8625
S. superba	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	.	56	102	12765	53.5	.	11.5	36	49.5	.	.	5830	.
	.	.	.	.	.	.	.	.	.	.	.	100	5	SAB	790	13.5	130	15040	70	.	15.5	29.5	42.5	.	.	6140	.
red balau																											
S. guiso	417	6	PMA	.	.	0.65	.	.	.	.	.	417	6	PMA	915	53	84	13700	43.5	5.5	10	75	82	.	.	5340	.
	297	7	PMA	.	.	.	15	1.6	3.6	3.9	9.0	417	6	PMA	755	17	100	14800	52	5.5	12	65	77	.	.	5920	.
	472	11	PHI	.	.	.	12	1.7–2.5	5.2–7.2	3.3–6.2	9.5–11.5	483	.	PHI	.	gr	86	14110	42	9	10	.	.	.	.	6025	5330
	497	12	PHI	.	.	.	12	2.6	6.3	5.2	10.7	483	.	PHI	760	12	127	17150	66.5	12	14	.	.	.	.	7655	7035
S. kunstleri	417	5	PMA	880	15	0.71	.	.	.	.	.	417	5	PMA	1075	51	105	19000	58	7	9.5	74	93	.	.	6940	.
	297	5	PMA	.	.	.	15	2.2	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S. ochrophloia	417	3	PMA	.	.	0.65	.	.	.	.	.	417	3	PMA	1040	65	85	15900	43.5	.	10	67	77	.	.	4490	.
	297	5	PMA	.	.	.	15	1.4	3.2	.	.	417	3	PMA	755	18.5	99	17000	55.5	.	10	52	53	.	.	5030	.
Sindora sepetir																											
S. coriacea	325	.	PMA	675	15	.	15	1.5	2.9	.	.	417	3	PMA	815	47	71	11700	36.5	4.5	10	56	54	.	.	4090	.
	.	.	.	.	.	.	.	.	.	.	.	417	3	PMA	690	15	92	13600	46.5	6	13.5	57	67	.	.	5210	.
S. siamensis	.	.	.	.	.	.	.	.	.	.	.	578	.	VIE	880	12	123.5	.	69	.	.	.	.	.	.	.	.
S. supa	579	.	PHI	.	.	0.55	.	.	.	.	.	579	.	PHI	730	34	65.5	9700	22.5	8.5	9.5	.	.	.	.	3625	5265
Swietenia mahogany																											
S. macrophylla	310	.	SAM	.	.	.	12	1.4	2.2	.	.	310	.	SAM	815	gr	69	8700	29	.	9	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	310	.	SAM	535	12	90	9300	43	.	13.5	.	.	.	.	.	.
	461	.	.	530–670	15	.	15	0.9	1.3	3.3	5.7	461	.	.	.	gr	50.5	7940	24.5	.	5–6	48	78.5	.	.	2820	3360
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	61	9015	35.5	.	4	51	58	.	.	2655	3695

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage: green to moisture content (m.c.): m.c.	rad.	tang.	green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	perpendicular to grain	shear	cleavage: rad.	tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
S. macrophylla	144	.	.	485–840	12	0.40–0.68	.	.	.	3.0	4.1	144	.	.	.	gr	62	8830	30	.	.	.	.	.	.	3295	.
	.	.	.	.	.	.	.	.	.	.	.	144	.	.	.	12	80	9800	44.5	.	.	.	.	.	.	3560	.
S. mahagoni	461	.	.	560–720	15	.	.	.	.	.	.	461	.	.	.	gr	58	8995	29.5	.	7–7.5	52.5	51.5	.	.	3450	3830
	.	.	.	.	.	.	.	.	.	.	.	461	.	.	.	15	54.5	9555	37	.	7–7.5	55	63.5	.	.	3840	3840
Tectona teak *T. grandis*	461	.	IND	620–750	15	.	.	.	.	2.8	5.2	461	.	IND	670	15	101	12515	54	.	8–9	.	.	.	.	4195	4055
	.	.	.	.	.	.	.	.	.	.	.	58	.	JAV	670	12.5	105	13000	56	.	.	77	87	.	.	4120	.
	.	.	.	.	.	.	.	.	.	.	.	417	9	PMA	975	99	73	9400	35.5	5.5	13	72	91	.	.	5430	.
	.	.	.	.	.	.	.	.	.	.	.	417	9	PMA	625	15	86	10300	46	6	10.5	59	73	.	.	4850	.
	.	.	.	.	.	.	.	.	.	.	.	408	2	PHI	.	gr	67	8320	32.5	6	8.5	.	.	.	.	3785	3820
	.	.	.	.	.	.	.	.	.	.	.	408	2	PHI	.	12	88	13230	42.5	7.5	10	.	.	.	.	3745	4065
	.	.	.	.	.	.	.	.	.	.	.	409	.	BUR	815	50	84	8800	43	.	10	.	.	.	.	4140	.
	.	.	.	.	.	.	.	.	.	.	.	409	.	BUR	640	10.5	106	10000	60.5	.	15	.	.	.	.	4450	.
	395	8	.	640–690	9.5	0.56–0.59	12	0.9	1.9	2.5	5.0	58	.	BUR	765	12.5	106	13400	59	.	.	82	91	.	.	4510	.
	226	.	.	610–690	12	.	12	1.5	2.5	.	.	58	.	THA	615	12.5	89	10800	49	.	.	82	87	.	.	3730	.
	310	.	SAM	700	12	0.58	12	0.7	1.1	.	.	310	.	SAM	.	gr	82	9800	39	.	10.5	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	310	.	SAM	.	12	118	11900	59	.	15.5	.	.	.	.	.	.
Tetramerista punah *T. glabra*	445	.	PMA	720	15	.	15	3.2	4.5	.	.	445	.	PMA	.	gr	86	13500	34.5	4	9	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	445	.	PMA	.	15	87	15400	48.5	5.5	9.5	.	.	.	.	.	.
	578	1	MAL	.	.	0.63	.	.	.	.	.	578	1	MAL	785	19	87–105	15400–15800	49.5–64	5.5–6.5	9.5–12.5	43	80	.	.	4670–5215	.

Botanical name / Trade name	Physical properties: source	number of trees tested	origin of trees	density	at moisture content of	specific gravity (moisture content 0%)	shrinkage: green to moisture content (m.c.): m.c.	rad.	tang.	green to oven-dry: rad.	tang.	Mechanical properties: source	number of trees tested	origin of trees	density when tested	moisture content when tested	modulus of rupture	modulus of elasticity	compression: parallel to grain	perpendicular to grain	shear	cleavage: rad.	tang.	Janka hardness: rad.	tang.	side	end
				kg/m³	%		%	%	%	%	%				kg/m³	%	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm	N/mm	N	N	N	N
T. glabra	144	.	MAL	730	15	0.61	.	.	.	6.1	10.7	144	.	MAL	.	gr	67	12835	31.5	.	.	.	.	.	.	4050	.
Upuna upun *U. borneensis*	448	.	MAL	945–1040	15	.	15	0.5–1.8	2.9–3.2	.	.	448	.	MAL	.	15	156	17800	87	.	18	.	.	.	.	.	.
Vatica resak																											
V. cuspidata	417	5	PMA	1040	15	0.86	.	.	.	.	.	417	5	PMA	1215	41	105	18100	61	11.5	12.5	61	105	.	.	8990	.
	297	5	PMA	.	.	.	15	1.5	3.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
V. manga-	497	8	PHI	.	.	0.66	12	1.8	4.9	3.9	9.0	497	8	PHI	.	gr	81	13230	41.5	8	10	.	.	.	.	5960	6035
chapoi	472	7	PHI	.	.	.	12	1.4–2.2	4.4–5.4	3.4–4.8	8.3–9.6	578	9	PHI	875	12	123–134	16100–17400	60–65	10–11.5	13–13.5	.	.	.	.	6900–7580	8180–8990
V. rassak	461	.	.	490–650	15	.	.	.	.	3.3	5.0	461	.	.	.	gr	56	10190	29	.	4–5	44	51.5	.	.	2570	2880
V. stapfiana	.	.	.	.	.	.	.	.	.	.	.	417	5	PMA	960	54	81	14400	41.5	5	9.5	60	84	.	.	5160	.

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Acronyms of organizations

- BIOTROP: South-East Asian Regional Centre for Tropical Biology (Bogor, Indonesia)
- CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
- CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia)
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy)
- IAWA: International Association of Wood Anatomists
- ICRAF: International Centre for Research in Agroforestry (Nairobi, Kenya)
- ITTO: International Tropical Timber Organization (Yokohama, Japan)
- IUCN: International Union for Conservation of Nature and Natural Resources
- PPHI: Panitia Perancang Hutan Industri [Committee for Planning of Industrial Forests] (Bogor, Indonesia)
- SAFODA: Sabah Forestry Development Authority (Sabah, Malaysia)
- TNO: Technisch en Natuurkundig Onderzoek [Technical and physical science research] (Delft, the Netherlands)
- UNESCO: United Nations Educational, Scientific and Cultural Organization (Paris, France)
- USDA: United States Department of Agriculture (Washington, D.C., United States)

Glossary

abaxial: on the side facing away from the axis or stem (dorsal)

abscission: the natural detachment of leaves, branches, flowers or fruits

achene: a small dry indehiscent one-seeded fruit

acicular: needle-shaped; sharp pointed

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

adaxial: on the side facing the axis or stem (ventral)

adnate: united with another part; with unlike parts fused, e.g. ovary and calyx tube

adpressed (appressed): lying flat for the whole length of the organ

adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems

afforestation: see Introduction

air layering: a form of layering in which soil (rooting medium) is brought to the branch to be layered; the ball of soil in a polyethene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated

albino: in botany, a colourless plant due to the absence of chloroplasts or undeveloped chromoplasts

albumen: the nutritive material stored within the seed, and in many cases surrounding the embryo (endosperm)

aliform: wing-shaped

aliform axial parenchyma: parenchyma surrounding or to one side of the vessel and with lateral extensions

alkaloid: large group of organic bases containing nitrogen and usually oxygen that occur for the most part in the form of salts with acids; usually optically and biologically active

alluvium: soil material deposited by running water in recent geological time

alterative: a drug used empirically to alter favourably the course of an ailment and to restore healthy body functions

alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled

Ambrosia beetle: see pinhole borer

amplexicaul: stem-clasping, when the base of a sessile leaf or a stipule is dilated at the base, and embraces the stem

anastomosis: cross connection of branches or roots; union of one vein with another, the connection forming a reticulation

andosol: a young tropical soil originating from weathering of volcanic ash

androecium: the male element; the stamens as a unit of the flower

androgynophore: a column on which stamens and carpels are borne

androphore: a stalk supporting the androecium or stamens

anthelmintic: a drug or agent that destroys or causes expulsion of intestinal worms

anther: the part of the stamen containing the pollen

anthesis: the time the flower is expanded, or, more strictly, the time when pollination may take place

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*

antiperiodic: prevents periodic returns of paroxysms or exacerbations of disease (as in intermittent fevers)

aperture: gap or mouth

apetalous: without petals or with a single perianth

apex (plural apices): tip or summit of an organ

apical: at the point of any structure

apiculate: ending abruptly in a short point
apomixis: reproduction by seed formed without sexual fusion (apomictic)
apophysis: in conifers, the swollen top of the scales of a female cone
apotracheal: not associated or contiguous with vessels or vascular tracheids
appressed (adpressed): lying flat for the whole length of the organ
arachnoid: like a cobweb
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
areole: irregular squares or angular spaces marked out on a surface, e.g. of a fruit; a small cell or cavity
aril: an expansion of the funicle enveloping the seed, arising from the placenta; sometimes occurring as a pulpy cover (arillus)
arillode: a false aril, any seed-coat not arising from the placenta
arris: a sharp external angle formed by the meeting of two surfaces
ascending: curving or sloping upwards
asthma: a chronic disorder characterized by paroxysms of the bronchi, shortness of breath, wheezing, a suffocating feeling, and laboured coughing to remove tenacious mucus from the air passages
astringent: an agent or substance causing shrinkage of mucous membranes or raw or exposed tissues
attenuate: gradually tapering
auricle: a small lobe or ear
auriculate: eared, having auricles
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
back-sawn: = plain-sawn
barbate: bearded, having long weak hairs in tufts
bark: the tissue external to the vascular cambium collectively, being the secondary phloem, cortex and periderm
basifixed: attached or fixed by the base
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
bending strength: = modulus of rupture, see Introduction
berry: a juicy indehiscent fruit with the seeds immersed in pulp; usually several-seeded without a stony layer surrounding the seeds
bilabiate: two-lipped
biliousness: a situation marked or accompanied by disordered liver function due to or associated with excessive secretion of bile
bisexual: having both sexes present and functional in the same flower
blade: the expanded part of a leaf or petal
blockboard: a plywood in which the core layers are replaced by blocks of wood
blue stain: a common form of bluish discoloration, generally of sapwood, caused by various fungi
bole: the main trunk of a tree, generally from the base up to the first main branch
bordered pit: a fibre pit in which the membrane is overarched by the secondary cell wall
bract: a reduced leaf subtending a flower, flower stalk or the whole or part of an inflorescence
bracteole: a secondary bract on the pedicel or close under the flower
breeding: the propagation of plants or animals to improve certain characteristics
bristle: a stiff hair or a hair-like stiff slender body
brittle heart: the defective core of a log, characterized by abnormal brittleness
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
bullate: surface much blistered or puckered
buttress: the enlargement at the base of trunks of emergent 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 early
callus: small hard outgrowth at the base of spikelets in some grasses; tissue that forms over cut or damaged plant surface
calorific value: = energy value
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 or a

forest

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

carcinostatic: having an inhibitive effect on the growth of cancer tissue

carpel: one of the foliar units of a compound pistil or ovary; a simple pistil has only one carpel

cartilaginous: hard and tough

caruncle: an outgrowth of a seed near the hilum

caudate: with a tail-like appendage

cauliflorous: flowers borne on the stem from the old wood, separate from the leaves

chartaceous: papery

check (in wood): small separation of the wood fibres along the grain forming a crack or fissure not penetrating as far as the opposite or adjoining side of a piece of sawn timber

chipboard: a fibreboard made from depulped wood chips

chlorophyll: green pigment in plants which absorbs light for photosynthesis

ciliate: with a fringe of hairs along the edge

circumscissile: dehiscing or falling off along a circular line

clavate: club-shaped or thickened towards the end

claw: the narrow part of a petal or sepal

cleavage: see Introduction

cleft: cut halfway down

cleft grafting (or wedge grafting): grafting a decapitated rootstock by inserting a scion with a wedge-shaped base in a cleft cut into the cut surface of the rootstock, see also grafting

cleistogamous: pollination and fertilization taking place within the unopened flower

clone: a group of plants originating by vegetative propagation from a single plant and therefore of the same genotype

coccous: referring to the parts of a lobed fruit

collapse (in wood): a defect due to abnormal and irregular shrinkage and resulting in a wrinkled or corrugated appearance of the surface and sometimes also an internal honeycombing

colluvium: a heterogenous soil emplaced primarily by gravitational processes (also creek and slope wash) on or at the foot of slopes

column: a tube of connate stamen filaments

compound: of two or more similar parts in one organ, as in a compound leaf or compound fruit

compression parallel to grain: see Introduction

compression perpendicular to grain: see Introduction

compression wood: darker and denser reaction wood formed on the lower sides of branches and leaning or crooked stems of coniferous trees

concave: hollow

concoction: a combination of crude materials that are prepared (cooked) together

concolourous: similarly coloured on both sides or throughout; of the same colour as a specified structure

conduplicate: folded lengthwise

cone: the fruit of a pine or fir tree (gymnosperms), largely made up of imbricated scales

confluent: blended into one, passing by degrees from one into the other

conical: having the shape of a cone (cone-shaped)

connective (botany): tissue between the pollen sacs of an anther

contorted: twisted or bent

convex: having a more or less rounded surface

coppice: a small wood which is regularly cut at stated intervals (the verb is 'to coppice'), the new growth arising from the stools

cordate: heart-shaped, as seen at the base of a leaf, etc., which is deeply notched

corewood: the often darker inner portion of the heartwood

coriaceous: of leathery texture

corolla: the inner envelope of the flower existing of free or united petals

cortex: the bark or rind

cortical: relating to the cortex

corymb: a flat-topped indeterminate inflorescence in which the branches or pedicels sprout from different points, but attain approximately the same level, with the outer flowers opening first

corymbose: flowers arranged to resemble a corymb

cotyledon: seed-leaf, the primary leaf (dicotylous embryos have two cotyledons and monocotylous embryos have one)

cover crop: a crop planted to prevent soil erosion and to provide humus and/or fodder

crenate: the margin notched with blunt or rounded teeth

cross cut: cut across the grain, cross sectioned

crown: the aerial expanse of a tree, not including the trunk; corona; a short rootstock with leaves; the base of a tufted, herbaceous, perennial grass

crustaceous: of brittle texture

cryptocotylar: of germination, condition in which the cotyledons remain enveloped in the persistent fruit wall and/or testa

cuesta: a hill or ridge with a steep face on one side and a gentle slope on the other

cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals
cupping: the curvature of a piece of sawn timber across its width
cusp: a sharp, rigid but small point
cuspidate: abruptly tipped with a sharp rigid point
cutting: the severed portion of a plant, used for propagation
cyme: a determinate inflorescence, often flat-topped, in which each growing point ends in a flower and the central flowers open first
cymose: bearing cymes or inflorescences related to cymes
dammar (damar): a soft, clear to yellow resin used largely in varnishes and printing inks
damping-off: a disease of seedlings or cuttings caused by fungi who cause various affects, from germination failure to die off
deciduous: shedding or prone to shedding, applied to leaves, petals, etc.
decoction: a preparation made by boiling a medicinal 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
degrade: of timber, any effect that lowers the grade or quality
dehiscent: opening spontaneously when ripe, e.g., capsules, anthers
dentate: margin prominently toothed with the pointed teeth directed outwards
denticulate: minutely toothed
depulping: removing the outer, soft, fleshy part of a fruit
dermatitis: inflammation of the skin typically marked by reddening, swelling, oozing, crusting or scaling
dichasium (plural dichasia): a cymose inflorescence with 2 equal or nearly equal lateral branches arising below the terminal flower, this pattern being repeated or not (compound and simple dichasium respectively)
dichogamy: prevention of natural self-pollination in an individual flower by separation of pollen dehiscence and stigma receptivity in time
didynamous: with the stamens in two pairs, two long and two short ones
dieback: the dying off of parts of the above-ground structure of the plant, generally from the top downward
dioecious: with unisexual flowers and with the staminate and pistillate flowers on different plants (dioecy)
discolourous: dissimilarly coloured on both sides or throughout; of a different colour to a specified structure
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: an agent increasing the urinary discharge
domatium (plural domatia): a modified projection that provides shelter for other organisms
dormancy: a term used to denote the inability of a resting plant or plant part (e.g. the seed, or in tree crops usually the buds) to grow or to leaf out, even under favourable environmental conditions
dorsal: back; referring to the back or outer surface of a part or organ (abaxial)
dorsifixed: attached by the back, as in the case of the attachment of anthers to a filament
dropsy: an abnormal accumulation of serous fluid in connective tissue, causing puffy swelling
drupe: a fleshy one-seeded indehiscent fruit with the seed enclosed in a strong endocarp
druse (anatomy): a globular cluster of crystals
earlywood: the less dense wood formed during the early stage of annual growth
ecto-: prefix, referring to the outside or the outer surface or part
ectomycorrhiza: see mycorrhiza
edaphic: pertaining to or influenced by conditions of the soil
elfin forest: a low type of montane forest with trees of about 15 m tall or less
elliptic(al): 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
endemic: exclusively native to a specified or comparatively small region; also used as a noun for a taxon thus distributed
endo-: prefix, referring to the inside or the inner

surface or part

endocarp: the innermost layer of the pericarp or fruit wall

endogenous: originating from within the organism

endosperm: the starchy or oily nutritive material stored within some seeds, sometimes referred to as albumen; it is triploid, having arisen from the triple fusion of a sperm nucleus and the two polar nuclei of the embryo sac

energy value: the heat produced by the combustion of a unit weight of a fuel

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.

entomophilous: applied to flowers which are pollinated by insects

epicalyx: an involucre of bracts below the flower, resembling an extra calyx

epicotyl: the young stem above the cotyledons

epiderm: 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)

epipetalous: borne upon or placed in front of the petals

episepalous: borne upon or placed in front of the sepals

epithelium: the layer of secretory parenchymatous cells that surrounds an intercellular canal or cavity

eutrophic: providing adequate nutrients or with a large supply of nutrients

evergreen: bearing foliage all year long; a plant that changes its leaves gradually

exocarp: the outer layer of the pericarp or fruit wall

exsert, exserted: protrude beyond, as stamens beyond the tube of the corolla

ex situ: in an artificial environment or unnatural habitat

extrorse: directed outward, as the dehiscence of an anther

falcate: sickle-shaped

fascicle: a cluster of flowers, leaves, etc., arising from the same point

febrifuge: an agent serving to reduce fever

ferruginous: rust coloured

fertile (botany): bearing pollen which fecundates the ovules; said of pollen-bearing anthers or of seed-bearing fruits

fibre: any long, narrow cell of wood or bast other than vessel or parenchym elements

fibre pit: a pit in the cell wall of a fibre (see also pits)

fibreboard: = hardboard

fiddleback: resembling the shape of a fiddle; in wood anatomy: a wavy grain giving an undulating appearance to a smooth surface

filament: thread; the stalk supporting the anther

filiform: slender; threadlike

filler: a composition (as of powdered silica and oil) used to fill the pores and grain of wood

flabellate: fan-shaped, dilated in a wedge-shape, sometimes plaited (folded)

flat-sawn: = plain-sawn

floccose: covered with dense hairs that fall away in tufts, locks or flocci

flush: a brief period of rapid shoot growth, with unfolding of the leaf primordia which had accumulated during the previous quiescent period

foliaceous: leaf-like

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

foveolate: with small pits

free: neither adhering nor united

fugaceous: withering or falling off rapidly or early

full-cell process: a process to leave the maximum concentration of preservative in a piece of wood by the subsequent application of vacuum, pressure and again vacuum

fulvous: yellow, tawny

fusiform: spindle-shaped; tapering towards each end from a swollen centre

gamelan: a percussion instrument related to the xylophone

gamopetalous: with united petals either throughout their length or at the base

gamosepalous: with united sepals either throughout their length or at the base

genetic erosion: the decline or loss of genetic variability

geniculate: abruptly bent so as to resemble the knee-joint

genus (plural genera): the smallest natural group containing distinct species

geotropism: a growth movement related to gravitational attraction

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

gonorrhoea: a venereal disease characterized by inflammation of the mucous membrane of the genitourinary tract and a discharge of mucus

and pus
graft: a union of different individuals by apposition, the rooted plant being termed the stock, the portion inserted the scion
grafting: the process of inserting a scion, which consists of a piece of stem and two or more buds of the plant to be propagated, into another plant (rootstock) with the intention that it will unite and grow
grain (wood anatomy): the general direction or arrangement of the fibres; texture
granodiorite: granular intrusive igneous rock intermediate between granite and quartz diorite
granulose (granular): composed of or covered with grain-like minute particles
graveyard test: see Introduction
gregarious: growing in associated herds or clusters but not matted; at the same time
grumosol: = vertisol
gum: a colloidal polysaccharide substance that is gelatinous when moist but hardens on drying; gum is exuded by plants or extracted from them
gum up: of a saw, when wood resin gets stuck between the sawteeth which hinders the sawing
gutta-percha: a latex with a high percentage of polyisoprene originating from certain trees of the family *Sapotaceae*, especially those of the species *Palaquium gutta*
habit: external appearance or way of growth of a plant
habitat: the kind of locality in which a plant grows
hardboard: board manufactured from fibres of ligno-cellulosic material
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, half
herbaceous: with the texture, colour and properties of a herb; not woody
hermaphrodite: bisexual; in flowers, with stamens and pistil in the same flower
heterogamous: with two or more kinds or forms of flowers
heteromorphic: varying in number or form
heterophyllous: bearing leaves of different shape
heterostylous: having styles of two or more distinct forms or of different lengths
hilum: the scar left on a seed indicating its point of attachment
hirsute: with rather coarse stiff hairs
hispid: covered with long rigid hairs or bristles
holocellulose: the total polysaccharide cellulose and hemicellulose fraction of wood
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 differing in one or more genes
hybridization: the crossing of individuals of unlike genetic constitution
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)
ichthyotoxic: poisonous to fishes
idioblast: a cell differing markedly in form and contents from other constituents of the same tissue, like crystalliferous cells, oil and mucilage cells
igneous rock: rock formed by solidification of a molten magma
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
inbreeding: breeding through a succession of parents belonging to the same stock
incrassate: thickened
indehiscent: not opening when ripe
indigenous: native to a particular area or region
indumentum: a covering, as of hairs, scales, etc
induplicate: with the margins bent inwards and the external face of these edges applied to each other without twisting
inferior: beneath, lower, below (an inferior ovary is one which is below the sepals, petals and stamens)
inflammation: a diseased condition of some part of the body, resulting from injury, infection, irritation, etc. and characterized by redness, pain, heat, and swelling
inflorescence: the arrangement and mode of development of the flowers on the floral axis
infrageneric: within a genus, e.g. a subdivision
infraspecific: within a species, e.g. variation
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

in situ: in the natural environment

interlocked grain: a wood grain in which the fibres incline in one direction in a number of annual rings and in a reverse direction in succeeding rings

internode: the portion of the stem between two nodes

interpetiolar: of stipules placed between the petioles of opposite leaves

intervessel pit: see pits

intramarginal: of a vein, running near and parallel with the margin

intrapetiolar: of stipules, positioned within the petiole axil

introrse: turned inward, towards the axis, as the dehiscence of an anther

irregular flower: in which parts of the calyx or corolla are dissimilar in size and shape; asymmetrical or zygomorphic

Janka hardness: see Introduction

kaolin: a fine, usually white clay resulting from extreme weathering of aluminous minerals

keel (carina): a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla; the principal vein of a sepal or glume

kerangas: heath forest, a type of tropical forest generally consisting of comparatively small trees with thin trunks (pole forest), often overlying a podzol

kernel: the nucellus of an ovule or of a seed, that is, the whole body within the coats

kiln drying: see seasoning

kiln schedule: see Introduction

kino: gum of various trees, resembling catechu, and used in medicine and tanning as an astringent

knee root: a tree root with an outgrowth

Koriba's architectural model: habit of growth determined by the production of initially equivalent branches on top of a primary axis one of which becomes erect and dominant and constitutes a unit of a sympodially formed trunk

kraft pulp: = sulphate pulp

Kribs type heterogeneous I: of wood rays, with the ray cells of the central or multiseriate part dissimilar to the vertically elongated ones (in tangential section) of the marginal or uniseriate part and the latter part as long as or longer than the first part

Kribs type heterogeneous II: see type I but the marginal or uniseriate part shorter than the central or multiseriate part

Kribs type heterogeneous III: of wood rays, with the ray cells of the central or multiseriate part dissimilar to the square and generally single marginal cell (in tangential section)

Kribs type homogeneous: of wood rays, with all ray cells similar and with their largest dimension radial as seen in radial section

laminate(d): consisting of plates or layers

lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex

lateral: on or at the side

laterite: a red soil that shows intensive weathering and chemical change and leaching away of bases and silica, leaving aluminium and iron oxides

latewood: the denser wood formed during the later stages of annual growth

latex: a juice, usually white and sometimes sticky, exuding from broken surfaces of some plants

laticiferous: latex-bearing

latosol: a leached red or yellow tropical soil

latrorse: directed towards the sides, as the dehiscence of an anther

lax: loose, distant

laxative: having a tendency to loosen or relax; producing bowel movements and relieving constipation; a drug making the bowels loose and relieving constipation

leaching: of a soil, the removal of soluble and nutritive elements by a vertical, downward movement of water

leaflet: one part of a compound leaf

lenticel: lenticular masses of loose cells protruding through fissures in the periderm on stems, fruits and roots; they usually arise beneath individual stomata and their main function is gaseous exchange

lenticular: shaped like a double-convex lens

lepidote: covered with small scales

libriform (wood anatomy): of a fibre, a cell with thick walls (which is normal)

lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres

limb: the expanded part of a tubular corolla, as distinct from the tube or throat; the lamina of a leaf or of a petal *line planting*: setting trees in parallel rows, generally at regularly spaced intervals, on land wholly or partially cleared, also used to denote enrichment planting by means of setting trees in lines

linear: long and narrow with parallel sides

lobed: of leaves: 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 a tree 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

loop root: branch root given off above the ground and curving towards the soil

lorate: strap-shaped

lozenge-aliform axial parenchyma: parenchyma surrounding or to one side of the vessel with lateral extensions forming a diamond-shaped outline

lumen (plural lumina): the space enclosed by the walls of a cell

Lyctus: see powder-post beetle

macronutrients: chemical elements of which comparatively large quantities are essential for the growth of a plant (such as N, P, Ca, Mg)

Malesia: the bio-geographical 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

marine borer: a salt or brackish water mollusc (teredo), commonly called shipworm, damaging wood by producing tunnels with calcareous lining increasing rapidly in diameter from the surface inwards, or certain crustacea causing surface erosion

masticatory: used for chewing

maximum crushing strength: = compression parallel to grain, see Introduction

meiosis: nuclear divisions in which the diploid chromosome number is reduced to half that of the parent cell to give the haploid number, as in gametes

membranous: thin and semi-transparant, 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.

mesocarp: the middle layer of the pericarp or fruit wall which is often fleshy or succulent

midrib: the main vein of a leaf which is a continuation of the petiole

modulus of elasticity: see Introduction

modulus of rupture: see Introduction

monadelphous: of stamens, united into one group by their filaments

monochasium: a cymose inflorescence where a pattern of a single lateral branch arising below the terminal flower is repeated

monocotyledon: angiosperm having a single cotyledon or seed-leaf

monoecious: with unisexual flowers, but male and female flowers borne on the same plant

monophyletic: of a group of taxa, a natural one including the known or hypothesized common ancestor and all of its descendants

monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches

monotypic: consisting of a single element, e.g. of a genus consisting of only one species

mortice: a hole or slot to receive a tenon of corresponding size

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

mucous: secreting or containing a viscous or slimy matter

mucro: a sharp terminal point

mucronate: ending abruptly in a short stiff point

multiple (anatomy): a vessel arrangement where clusters of adjacent vessels are aligned parallel to the rays (radial multiple) or in a line oblique to the rays (oblique multiple)

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)

naturalized: introduced into a new area and established there, giving the impression of wild growth

necrosis: death of a portion of tissue often characterized by a brown or black discoloration

nectar: a sweet fluid extruded from various parts of the plant (e.g. by the flower to attract pollinators)

nectary: a group of modified subepidermal cells in flowers or leaves (extrafloral) secreting nectar *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-seeded indehiscent fruit with a hard dry pericarp or shell

nutlet: a little nut

ob-: prefix, indicating inverse or opposite condition (obtriangular, obcordate, etc.)

oblanceolate: reverse of lanceolate

oblique: slanting; of unequal sides

oblique multiple: see multiple

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

open tank method: having timber absorb a preservative without applying any vacuum or pressure

operculum: a lid or cover which separates by a transverse line of division

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

orthotropic: having a more or less vertical direction of growth

outer bark: the periderm or rhytidome; the non-living layer of fibrous or corky tissue outside the cambium in woody plants which is 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: solid and egg-shaped

ovule: the immature seeds in the ovary before fertilization

palmate: of leaflets, leaf-lobes or veins, with the different elements arising from the same point

panicle: an indeterminate branched racemose inflorescence

paniculate: resembling a panicle

pantropical: distributed throughout the tropics

papilionaceous flower: butterfly-like, pea-like flower, with standard, wings and keel

papillose: covered with minute nipple-like protuberances

parasitic: deriving nourishment from some other organism

paratracheal: applied to wood-elements arranged about the vessels

parenchyma: tissue composed of more or less isodiametric cells, e.g. the pith and mesophyll

parietal: when ovules are attached to the inner surface of the walls of a one-celled syncarpous ovary

paripinnate: a pinnate leaf with all leaflets in pairs

particle board: board made from bonded particles of wood and/or other ligno-cellulosic material

pedicel: stalk of each individual flower of an inflorescence

pedicellate: borne on a pedicel

peduncle: the stalk of an inflorescence or partial inflorescence

peeling: of a log, producing a continuous sheet of veneer by feeding a knife mounted parallel to the axis into a rotating log

peltate: of a leaf with the stalk attached to the lower surface, not at the edge

pendent, pendulous: drooping; hanging down from its support

perforation plate: the originally imperforate wall involved in the coalescence of two elements of a vessel

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

petal: a member of the inner series of perianth segments which are often brightly coloured

petiolate: having a petiole

petiole: the stalk of a leaf

phanerocotylar: of germination, condition in which the cotyledons or paracotyledons become entirely exposed, free from the fruit wall and/or testa

phenology: the complex annual course of flushing, quiescence, flowering, fruiting and leaf fall in a given environment

phenotype: the physical or external appearance of an organism as distinguished from its genetic constitution (genotype); a group of organisms with similar physical or external make-up

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

phyllotaxis: the arrangement of leaves or floral parts on an axis or stem

phylogenetic: based on natural evolutionary and genealogical relationships

pickle: steep or soak in a solution for preservation, conditioning etc.

picking up: of wood, the release of fibres, generally during and due to sawing, giving the surface a more of less woolly appearance

pilose: hairy with rather long soft hairs

pinhole borer: generally an *Ambrosia* beetle damaging wood by a wormhole of up to about 1.5 mm across which is generally darkly stained and without bore-dust

pinna (plural pinnae): a primary division or leaflet of a pinnate leaf

pinnate: arranged in pairs along each side of a common axis

pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of one or more ovaries, styles and stigmas

pith: the soft core occurring in the structural centre of a log; the tissue, sometimes soft, in the centre of the stem of a non-woody dicotyledon

pits: recesses in the secondary wall of a cell, often in walls connecting two elements of a vessel (intervessel pits)

placenta: the part of the ovary to which the ovules are attached

placentation: the way in which the placentae are arranged in the ovary

plagiotropic: having an oblique or horizontal direction of growth

plain-sawn: of timber, converted so that the growth rings meet the face in any part at an angle of less than 45°

planing: smoothing the timber surface

plano-convex: flat on one side and convex on the other

plasmin: a certain enzyme in blood plasma

plicate: folded to and fro, like a fan

plumule: the primary bud of an embryo or germinating seed

plywood: a structural material consisting of sheets of wood glued or cemented together with the grains of adjacent layers arranged at right angles or at a wide angle

pneumatophore: used of air vessels of any description; a root often functioning as a respiratory organ in a marsh plant

pod: 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

pole forest: forest with small trees with boles of 10–20 cm in diameter

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

polyembryony: the production of two or more embryos within a single ovule

polygamous: with unisexual and bisexual flowers in the same plant

polymorphic: polymorphous, with several or various forms; variable as to habit

polyphyletic: of a group of taxa, a non-natural one in which the most recent common ancestor is assigned to another group, the characterization of the group being based on convergent similarity

poultice: a soft, usually heated and sometimes medicated mass spread on cloth and applied to sores or other lesions

powder-post beetle: 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

preservative: a liquid absorbed by timber to increase its durability

Prévost's architectural model: habit of growth determined by the development of two types of modules: branches originating in a restricted subapical region of the trunk and successive trunks produced subdistally, i.e. below the branch tier producing a sympodial trunk

pro-embryo: an embryonic structure preceding the true embryo

proliferous: multiplying quickly; bearing progeny as offshoot

propagule: a part of a plant that becomes detached and grows into a new plant

protandrous: stamens shedding pollen before the stigma is receptive

protogynous: the stigma being receptive before the pollen is shed

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 shaped 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

pulverulent: powdered, as if dusted over

punctiform: in the form of a point or dot
pungent: bearing a sharp point; causing a sharp or irritating sensation
pyriform: resembling a pear in shape
quadrangular: four-cornered or four-edged
quarter-sawn: of timber, converted so that the growth rings meet the face in any part at an angle of not less than 45°
raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards
racemose: raceme-like
rachis (plural rachides): the principal axis of an inflorescence or a compound leaf
radial: lengthwise, in a plane that passes through the pit; radiating, as from a centre
radial multiple: see multiple
radicle: the first root of an embryo or germinating seed
rays (in wood): ribbons of parenchymatous tissue which are seen on a cross-section of timber as paler lines radiating from the pith outwards, and extending right up to the bark
receptacle: the flat, concave or convex part of the axis from which the parts of the flower arise
recurved: bent or curved downward or backward
reflexed: abruptly bent or turned downward or backward
reforestation: see Introduction
regosol: an azonal soil consisting chiefly of soft and imperfectly consolidated parent material
regular: of a radially symmetrical flower; actinomorphic
rendzina: a dark greyish-brown soil generally developed in grassy tropical regions from calcareous marl or chalk
reniform: kidney-shaped
resin: solid to soft semisolid amorphous fusible flammable substance obtained as exudate or as an extract of plants
resistance to splitting: = cleavage, see Introduction
reticulate: netted, as when the smallest veins of a leaf are connected together like the meshes of a net
retrorse: turned or directed backward or downward (opposed to antrorse)
retuse: with a shallow notch at a rounded apex
revolute: of leaf margins, rolled downwards towards the midrib
rheumatism: any of various painful conditions of the joints and muscles
rhinitis: inflammation of the mucous membrane of the nose
rhizobia: bacteria of the genus *Rhizobium* capable of forming symbiotic nodules on the roots of leguminous plants and able to fix atmospheric nitrogen
rhombic: shaped like a rhomb, an equilateral oblique-angled figure
rhomboid (botany): quadrangular, diamond-shaped with the lateral angles obtuse
ring-porous: of wood, with vessels of the earlywood distinctly larger than those of the latewood and forming a well-defined zone or ring
rip-sawn: of timber, sawn lengthwise, parallel to the edges
riparian: frequently growing on the banks of streams or rivers
ripple mark: fine horizontal striations visible on tangential longitudinal surfaces of wood, due to the storied arrangement of rays or of axial elements or both
root-nodules: small dwellings on roots of leguminous and other plants, containing nitrogen-fixing bacteria (rhizobia)
rostrate: beaked
rotary-cut: = peeled, see peeling
rotate: wheel-shaped; circular and flat
rudimentary: of organs which are imperfectly developed and nonfunctional
rufous: reddish
rugose: wrinkled
rugulose: somewhat wrinkled
saccate: pouched
sagittate: shaped like an arrowhead; of a leaf base with two acute straight lobes directed downwards
samara: an indehiscent winged fruit
sambal: a condiment made typically from hot peppers and various other ingredients
sanding: of wood, producing a smooth surface by means of an abrasive sheet, belt or drum
sapling: a young tree of more than 1.5 m tall and with a bole of less than 10 cm in diameter
saponin: a glycoside with soap properties
sapwood: the outer layers of wood adjacent to the bark which in the living tree contain living cells and reserve materials
scabrid, scabrous: rough to the touch
scalariform: having markings suggestive of a ladder
scale: a thin scarious body, often a degenerate leaf or a trichome of epidermal origin
scantling: timber converted to an agreed specified size
schizocarp: a pericarp which splits into one-seeded portions, mericarps or 'split fruits'
sclerenchymatous: of tissue, composed of thick-

walled cells
season (of timber): to reduce the moisture content of timber either by air drying (air season) or kiln drying (kiln season). Timber is fully seasoned when the moisture content has dropped to the equilibrium moisture content of the ambient climate
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
section (botany): a taxonomic rank between the genus and the species accommodating a single or several related species
secund: arranged on one side
seed: the reproductive unit formed from a fertilized ovule, consisting of embryo and seed-coat, and, in some cases, also endosperm
seed orchard: a plantation of selected trees, isolated to reduce pollination from outside, cultivated for the production of seed
seedling: the juvenile plant, grown from a seed, up to 1.5 m tall
selective logging: a system with which only certain *a priori* selected timber groups are harvested from a forest
self-compatible: = self-fertile
self-fertile: capable of fertilization and setting seed after self-pollination
self-pollination: pollination with pollen from the same flower or from other flowers of plants of the same clone
semi-: prefix, half; incompletely, e.g. semi-inferior
senescence: advancing in age
sepal: a member of the outer series of perianth segments
sepaloid: sepal-like
septate: divided by one or more partitions
septum (plural septa): a partition or cross-wall
seriate: serial, disposed in series of rows
sericeous: silky
serrate: toothed like a saw, with regular pointed teeth pointing forwards
serrulate: serrate with minute teeth
sessile: without a stalk
setose: set with bristles or bristle-like elements
setulose: set with small bristles or bristle-like elements
shake: in wood, a seperation of fibres along the grain due to stresses developing in the standing tree, in felling, or in seasoning
shale: sedimentary rock formed by the consolidation of unaltered clay or silt
shear: see Introduction
sheath cell: a ray cell located along the side of a broad ray (> 3-seriate) as viewed in tangential section and which is larger than the central cells
shrub: a woody plant branching from the base, all branches being equivalent
silica body: globular or amorphous conglomerate of siliceous material, generally included in parenchymatous cells
siliceous: containing silica
silique: a dry and many-seeded dehiscent fruit splitting into 2 valves with a false partition
simple (botany): not compound, as in leaves with a single blade
slash: a cut or stroke along the stem of a tree to reveal exudates and colours of bark and sapwood
sliced veneer: a thin sheet of wood cut from a stationary block of wood by a knife mounted approximately parallel with and moving to and fro across the longitudinal axis of the block
soda pulp: a chemical woodpulp obtained through application of a solution of sodium hydroxyde
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
spherical: globular
spike: a simple indeterminate inflorescence with sessile flowers along a single axis
spine: a short stiff straight sharp-pointed hard structure arising from the wood of a stem
spinescent: ending in a spine or sharp point
spiral: as though wound round an axis
spongy heart: situation where the wood of the pith of a bole is softened by saturation with water
sporophyll: a leaf or leaf-like structure bearing or subtending a sporangium
spur (botany): a hollow and slender extension of some part of the flower, usually nectariferous; a small reproductive shoot
spur root: a root projecting from the base of the trunk
stain: discoloration or variation from natural colour due to fungi, chemical action or other causes
stake test: = graveyard test, see Introduction
stamen: one of the male reproductive organs of a flower; a unit of the androecium
staminate: of a flower, bearing stamens but no pistil
staminode: an abortive or rudimentary stamen

without a perfect anther

staminophore: an often thickened structure on which the stamens are inserted

standard (flower part): the fifth, posterior or upper petal of a papilionaceous corolla

stellate: star-shaped, as of hairs with radiating branches

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)

stickering: using a stick or strip of wood (sticker) to separate the layers in a stack of wood to improve air circulation during seasoning

stigma: the portion of the pistil which receives the pollen

stilt roots: the oblique adventitious roots of the mangrove and similar forms

stipe: the stalk supporting a carpel or gynoecium

stipel: small secondary stipule at the base of a leaflet

stipitate: borne on a stipe or short stalk

stipulate: with or bearing stipules

stipule: a scale-like or leaf-like appendage at the base of a petiole

stone: the hard endocarp of a drupe containing the seed(s)

storied (anatomy): of cells, arranged in horizontal series as viewed on the tangential surface

stress at limit proportionality: = compression perpendicular to grain, see Introduction

strigillose: covered with minute stiff hairs

strigose: with short stiff hairs lying close along the surface

strip planting: setting trees in two or more parallel lines in a long narrow area that has been wholly or partially cleared

strobile (plural strobili): cone, an assemblage of imbricate sporophylls arranged in a cone-shaped structure in horsetails, club mosses and conifers

strophiole: = caruncle

style: the part of the pistil connecting the ovary with the stigma

stylopodium: enlargement or swelling at the base of the style

sub-: prefix, underneath (e.g. subterranean) or less than, imperfectly, e.g. subacute

subfamily: a taxonomic rank between the family and the tribe denoting a part of a family

subspecies: a subdivision of a species, in rank between a variety and a species

subulate: awl-shaped

succulent: juicy, fleshy

sulphate pulp: a chemical woodpulp obtained through application of a solution of sodium hydroxyde and sodium sulphate

superior (ovary): 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

sympetalous: with united petals

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 (see radial)

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)

tenon: a projection at the end of a piece of timber intended to fit into a mortice to which it is thereby joined

tension wood: reaction wood formed typically on the upper sides of branches and leaning or crooked stems with an abnormally high longitudinal shrinkage tending to cause distortion and splitting

tepal: a segment of a perianth, applied when no distinction between sepal and petals can be made

teredo: see marine borer

terete: cylindrical; circular in transverse section

terminal: borne at the end or apex

termite: ant-like organism damaging wood by characteristic irregular honeycombing or wide channels with dry bore-dust or dust cemented together

termiticide: agent to exterminate termites

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

theca (plural thecae): a spore- or pollen-case

thinning: removing trees from immature stands in order to stimulate the growth of the remaining trees

thyrse: a compound inflorescence composed of a panicle (indeterminate axis) with the secondary and ultimate axes cymose (determinate)

tissue culture: a body of tissue growing in a culture medium outside the organism

tomentose: densely covered with short soft hairs

tonic: medicinal preparation believed to have the power of restoring normal activity

tortuous: bent or twisted in different directions

tracheid: an imperforate wood cell with bordered pits to congeneric elements

transverse: of tertiary veins, connecting the secondary veins, not necessarily in a perpendicular way

trapezoid: like a trapezium, a figure of four unequal sides

traumatic duct: canal formed in response to injury, generally irregular in outline

tree: a perennial woody plant with a single evident trunk

tribe (plural tribae): a taxonomic rank between the family and the genus

trichome: any hair, bristle or scale-like outgrowth of the epidermis

trifoliate: three-leaved

trifoliolate: with three leaflets

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

tungsten carbide: a heavy and very hard type of metal

turbinate: top-shaped

tylosis (plural tyloses): an outgrowth of a parenchyma cell through a pit cavity in a vessel wall

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 umbel

umbo: a protuberance on the swollen top of the scale of a coniferous female cone

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

unifoliolate: with one leaflet only, but in origin a compound leaf

unisexual: of one sex, having stamens or pistils only

urceolate: urn-shaped

vacuum-pressure method (or system): = full-cell process

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; in grasses the glume next to the flower

variety: botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar

vasicentric: with parenchyma round the vessel

vein: a strand of vascular tissue in a flat organ, such as a leaf

velutinous: = velvety

velvety: with a coating of fine soft hairs; the same as tomentose but denser so that the surface resembles (and feels like) velvet

venation: the arrangement of the veins in a leaf

veneer: a thin sheet of wood

ventral: faces central axis (adaxial), opposed to dorsal

ventricose: with a swelling or inflation on one side

vermifuge: a drug serving to destroy or expel parasitic worms of the intestine

verrucose: warty

versatile (botany): turning freely on its support, as many anthers on their filaments

verticil: whorl

verticillate: in a whorl with several elements arising at the same node

vertisol: dark and heavy clay-rich soil type (40–80% montmorillonite) with well-developed horizons and a pH of 6–7.5 which generally occurs in areas with a pronounced dry season

vessel-parenchyma pit: pit in the wall connecting a parenchyma cell and a vessel element

vessel-ray pit: pit in the wall connecting a ray cell and a vessel element

vestigial: small and imperfectly developed

vestured pit: an intervessel pit with the pit cavity and/or aperture wholly or partially lined with projections from the secondary cell wall

viability: ability to live, grow and develop

villous: shaggy; with long weak hairs

viscid: sticky

warp: distortion of a piece of sawn timber usually occurring during seasoning

warty: covered with firm roundish excrescences

water-logged: flooded with water, generally for a period of at least a few weeks

water shoot: a sucker emerging higher up in the tree on a trunk or branch, often following injury (e.g. pruning) and recognized by juvenile traits and vigorous growth

whorl: more than two organs of the same kind arising at the same level

wildling: a seedling that germinated and developed in a natural environment

wing: any membraneous expansion attached to an organ; a lateral petal of a papilionaceous corolla

winged-aliform axial parenchyma: parenchyma surrounding or to one side of the vessel with the lateral extensions being elongated and narrow

wood-cement board: = wood-wool board

wood-wool board: a panel material in which wood shavings or shredded waste paper is bonded with inorganic cement

woolly: referring to an indumentum, clothed with long and tortuous or matted hairs

xerophytic: relating to a plant structurally adapted for life and growth with a limited water supply

zygomorphic: irregular flowers divisible into equal halves in one plane only

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Campnosperma coriaceum: Whitmore, T.C., 1984. Tropical rain forests of the Far East. 2nd Edition. Clarendon Press, Oxford. p. 156, Fig. 11.15 (habit). Ding Hou, 1978. Anacardiaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 8. Sijthoff & Noordhoff International Publishers, Alphen aan den Rijn. p. 525, Fig. 59 (fruiting twig, female flower, male flower). Redrawn and adapted by Achmad Satiri Nurhaman and P. Verheij-Hayes.

Cotylelobium melanoxylon: Meijer, W. & Wood, G.H.S., 1964. Dipterocarps of Sabah. Sabah Forest Records No 5. Forest Department, Sandakan. p. 325, Pl. 59 (fruiting twig); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 340, Fig. 37 (flowerbud, ovary, stamens). Redrawn and adapted by Achmad Satiri Nurhaman.

Cratoxylum arborescens: Robson, N.K.B., 1974. Hypericaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 8. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 12, Fig. 8. Redrawn and adapted by P. Verheij-Hayes.

Cratoxylum formosum: Koorders, S.H. & Valeton, Th., 1913. Atlas der Baumarten von Java. Vol. 1. P.W.M. Trap, Leiden. Fig. 83 (habit); Cockburn, P.F., 1976. Trees of Sabah. Vol. 1. Forest Department, Sabah. p. 143, Fig. 30 (fruiting twig); Robson, N.K.B., 1974. Hypericaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 8. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 10,

Fig. 6 (flower, styles and two staminodial fascicles, pistil). Redrawn and adapted by P. Verheij-Hayes.

Cynometra malaccensis: Photograph taken by R.H.M.J. Lemmens (habit); Knaap-van Meeuwen, M.S., 1970. A revision of four genera of the tribe Leguminosae - Caesalpinioideae - Cynometrae in Indomalesia and the Pacific. Blumea 18: 18, Fig. 2 (flowering twig, sectioned flower, fruits). Redrawn and adapted by L. Gozali.

Cynometra ramiflora: Koorders, S.H. & Valeton, Th., 1913. Atlas der Baumarten von Java. Vol. 1. P.W.M. Trap, Leiden. Fig. 18 (flowering twig, flower, ovary); Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae. p. 84, Fig. 19 (fruit). Redrawn and adapted by L. Gozali.

Dalbergia latifolia: Troup, R.S., 1921. The silviculture of Indian trees. Vol. 1. Clarendon Press, Oxford. Fig. 131 (habit); Koorders, S.H. & Valeton, Th., 1913. Atlas der Baumarten von Java. Vol. 1. P.W.M. Trap, Leiden. Fig. 16 (flowering twig, leaf, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Dialium indum: Cockburn, P.F., 1976. Trees of Sabah. Vol. 1. Forest Department Sabah. p. 166, Fig. 9 (habit); Rojo, J.P., 1982. Studies in the genus Dialium (Cassieae - Caesalpinioideae). Thesis. University of Oxford. p. 225, Fig. 7.4 (flowering twig, flower bud, flower with sepals removed, ovary, fruits). Redrawn and adapted by L. Gozali.

Dialium procerum: Rojo, J.P., 1982. Studies in the genus Dialium (Cassieae - Caesalpinioideae). Thesis. University of Oxford. p. 245, Fig. 7.7. Redrawn and adapted by L. Gozali.

Dipterocarpus costulatus: Photograph taken by R.H.M.J. Lemmens (habit); Whitmore, T.C. & Tantra, I.G.M., 1986. Tree flora of Indonesia. Checklist for Sumatra. Forest Research and Development Centre, Bogor. p. 352 (flowering twig, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Dipterocarpus crinitus: Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Pl. 10 (habit); Whitmore, T.C., Tantra, I.G.M. & Sutisna, U., 1990. Tree flora of Indonesia. Checklist for Kalimantan. Part II.2. Agency for Forestry Research and Development, Forest Research and Development Centre, Bogor. p. 492 (fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Dipterocarpus geniculatus: Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Pl. 11 (habit); van Slooten, D.F., 1941. Sertulum Dipterocarpacearum Malayensium 2. Bulletin of the Botanic Gardens, Buitenzorg, ser. III, 17: 99, Fig. 11 (fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Dipterocarpus lowii: Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Pl. 14 (habit); van Slooten, D.F., 1927. The Dipterocarpaceae of the Dutch East Indies. Bulletin du Jardin Botanique de Buitenzorg, sér. III, 8: 343, Fig. 14 (leafy twig, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Dryobalanops lanceolata: Photograph taken by R.H.M.J. Lemmens (habit); van Slooten, D.F., 1932. The Dipterocarpaceae of the Dutch East Indies VI. The genus Dryobalanops. Bulletin du Jardin Botanique de Buitenzorg, sér. III, 12: 29, Fig. 3 (fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Dryobalanops sumatrensis: Photograph taken by R.H.M.J. Lemmens (habit); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 372, 374, Fig. 48, 50 (leafy twig, flowering twig, flower bud, fruit, nut). Redrawn and adapted by Achmad Satiri Nurhaman.

Endospermum diadenum: Photograph taken by R.H.M.J. Lemmens (habit); Whitmore, T.C., 1983. Euphorbiaceae. In: Whitmore, T.C. (Editor): Tree flora of Malaya. 2nd edition. Vol. 2. Malayan Forest Records No 26. Longman Malaysia SDN Berhad, Kuala Lumpur. p. 94, Fig. 7 (flowering twig, fruits). Redrawn and adapted by Achmad Satiri Nurhaman.

Eucalyptus deglupta: Davidson, J., 1973. A description of Eucalyptus deglupta. Tropical Forest Research Notes No 7. Department of Forests, Port Moresby. p. 13, Fig. 4 (habit); Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen. p. 124 (flowering branch). Redrawn and adapted by Achmad Satiri Nurhaman.

Eucalyptus robusta: Lizardo, L., 1960. Results of trial planting of eucalypts in the Philippines. Philippine Journal of Forestry 16: Pl. 3.1 (habit); Chippendale, G.M., 1990. Eucalyptus L'Hér. In: Wagner, W.L., Herbst, D.R. & Sohmer, S.H.

(Editors): Manual of the flowering plants of Hawai. Bishop Museum Special Publications 83. Vol. 1. Bishop Museum Press, Honolulu. p. 955, Pl. 134 (flowering twig); Chippendale, G.M., 1988. Eucalyptus. In: George, A.S. (Editor): Flora of Australia. Vol. 19. Australian Government Publishing Service, Canberra. p. 199, Fig. 64K, L (flower buds, fruits). Redrawn and adapted by Achmad Satiri Nurhaman.

Eusideroxylon zwageri: Witkamp, H., 1925. De ijzerhoutboom als geologische indicator. De Tropische Natuur 14, 7: 98, Fig. 1 (habit); Teijsman, J. & Binnendijk, S., 1863. Bijdrage tot de kennis van het echte ijzerhout, Eusideroxylon zwageri T. et B. Natuurkundig Tijdschrift van Nederlands Indië 25: pl. 1, 2 (inflorescence, flower, leaf, fruit, seed). Redrawn and adapted by P. Verheij-Hayes.

Gmelina arborea: Freezaillah bin Che Yeom & Sandrasegaran, K., 1966. Growth and yield of yemane (Gmelina arborea Roxb.). Malayan Forester 29: 149, Fig. 5 (habit); Sastri, S.B.N., 1972 (Editor): The wealth of India. Vol. 4. Publications & Information Directorate, New Dehli. p. 154, Fig. 71 (flowering twig and fruits); Briquet, J., 1894. Verbenaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien. Vol. 4, 3a. Wilhelm Engelmann, Leipzig. p. 165, Fig. 62H (flower). Redrawn and adapted by Iskak Syamsudin.

Gmelina moluccana: Henderson, C.P. & Hancock, I.R., 1988. A guide to the useful plants of the Solomon Islands. Ministry of Agriculture and Lands, Honaira. p. 219. Redrawn and adapted by Achmad Satiri Nurhaman.

Gonystylus bancanus: Photograph provided by I. Soerianegara (habit); Airy Shaw, H.K., 1953. Thymelaeaceae - Gonystyloideae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 4. Noordhoff-Kolff n.v., Djakarta. p. 360, Fig. 4 (leafy twig, flower, sectioned flower, dehisced fruit). Redrawn and adapted by Iskak Syamsudin.

Gonystylus velutinus: Airy Shaw, H.K., 1953. Thymelaeaceae – Gonystyloideae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 4. Noordhoff-Kolff n.v., Djakarta. p. 358, Fig. 3 (flowering twig, flower, sectioned flower, dehisced fruit, seed). Redrawn and adapted by Iskak Syamsudin.

Heritiera javanica: Koorders, S.H. & Valeton, Th., 1914. Atlas der Baumarten von Java. Vol. 3. P.W.M. Trap, Leiden. Fig. 419. Redrawn and adapted by Achmad Satiri Nurhaman.

Heritiera littoralis: Kostermans, A.J.G.H., 1959. A monograph of the genus Heritiera Dry. (Sterculiaceae). Madjelis Ilmu Pengetahuan Indonesia [Council for Sciences of Indonesia]. Penerbitan [Publication] 1. Djakarta. p. 80, Fig. 1 (flowering twig); Baillon, H., 1872. Histoire des plantes. Vol. 4. L. Hachette et Cie, Paris, London, Leipzig. p. 62, Fig. 89, 92 (male and female flower); Schumann, K., 1893. Sterculiaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien. Vol. 3, 6. Wilhelm Engelmann, Leipzig. p. 99, Fig. 51A (fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Heritiera simplicifolia: Kostermans, A.J.G.H., 1959. A monograph of the genus Heritiera Dry. (Sterculiaceae). Madjelis Ilmu Pengetahuan Indonesia [Council for Sciences of Indonesia]. Penerbitan [Publication] 1. Djakarta. p. 97, Fig. 18. (flowering branch, fruit). Redrawn and adapted by P. Verheij-Hayes.

Hopea beccariana: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 390, Fig. 62 (flowering branch), p. 392, Fig. 63.C3, 63.C4 (pistil and stamens), p. 406, Fig. 69 (trunk base); Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. p. 95, Fig. 12 (fruit). Redrawn and adapted by Iskak Syamsudin.

Hopea gregaria: Whitmore, T.C., Tantra, I.G.M. & Sutisna, U., 1989. Tree flora of Indonesia. Checklist for Sulawesi. Forest Research and Development Centre, Bogor. p. 189 (flowering and fruiting twig); van Slooten, D.F., 1952. Sertulum Dipterocarpacearum Malayensium. Reinwardtia 2: 22, Fig. 7d (fruit). Redrawn and adapted by L. Gozali.

Hopea mengarawan: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 400, Fig. 66 (habit); Prawira, S.A., 1975. Pengenalan jenis-jenis pohon ekspor. Laporan 214. Lembaga Penelitian Hutan, Bogor. p. 10 (flowering and fruiting twig). Redrawn and adapted by Iskak Syamsudin.

Hopea odorata: Photograph taken by R.H.M.J. Lemmens (habit); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 422, Fig. 73a, c, d (flowering twig, fruit, nut); Smitinand, T., Vidal, J.E. & Pham Hoang Hô, 1990. Dipterocarpacées. In: Lescot, M. (Editor): Flore du Cambodge, du Laos et du Vietnam. Vol. 25. Muséum National d'Histoire Naturelle, Paris. p. 71, Pl. 12, 3 (flower). Redrawn and adapted by Achmad Satiri Nurhaman.

Hopea pentanervia: Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Fig. 12.13 (leaf, fruit), Pl. 31 (trunk base); Whitmore, T.C., Tantra, I.G.M. & Sutisna, U., 1990. Tree flora of Indonesia. Checklist for Kalimantan. Part. II.2. Forest Research and Development Centre, Bogor. p. 525 (fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Intsia palembanica: Photograph taken by R.H.M.J. Lemmens (habit); Prawira, S.A., 1975. Pengenalan jenis-jenis pohon ekspor, ser. ke: VI. Laporan 212. Lembaga Penelitian Hutan, Bogor. p. 19 (flowering branch, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Koompassia malaccensis: Foxworthy, F.W., 1927. Commercial timber trees of the Malay Peninsula. Malayan Forest Records No 3. Forest Department, Federated Malay States, Kuala Lumpur. photo opposite p. 82 (habit); Prawira, S.A. & Tantra, I.G.M., 1973. Pengenalan jenis-jenis pohon ekspor. Laporan 161. Lembaga Penelitian Hutan, Bogor. p. 14–15 (flowering branch and fruits). Redrawn and adapted by Achmad Satiri Nurhaman.

Lophopetalum javanicum: Loher, A., 1897. Lophopetalum toxicum Loher. Icones Bogorienses. Vol. 1. E.J. Brill, Leiden. Tab. XVI (flowering twig, flowers, fruit); Valeton, Th., 1901. Lophopetalum javanicum Turcz. Icones Bogoriensis. Vol. 1. E.J. Brill, Leiden. Tab. XC (seed). Redrawn and adapted by Iskak Syamsudin.

Lophopetalum wightianum: Ding Hou, 1962. Celastraceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 6. Wolters-Noordhoff, Groningen. p. 269, Fig. 12 (habit); Wight, R., 1839. Icones Plantarum Indiae orientalis. Vol. 1. J. Cramer, Weinheim. Pl. 162 (flowering twig, flower). Redrawn and adapted by Iskak Syamsudin.

Madhuca betis: Whitford, H.N., 1911. The forests of the Philippines. Part 2: the principal forest trees. Bulletin No 10. Department of the Interior, Bureau of Forestry. Bureau of Printing, Manila. Pl. 94 (flowering and fruiting twig). Redrawn and adapted by Achmad Satiri Nurhaman.

Madhuca korthalsii: Photograph taken by R.H.M.J. Lemmens (habit); Ng, F.S.P., 1983. Sapotaceae. In: Whitmore, T.C. (Editor): Tree flora of Malaya. 2nd edition. Vol. 1. Longman Malaysia SDN Berhad, Kuala Lumpur. p. 402, Fig. 7 (leaf, fruit). Redrawn and adapted by Iskak Syamsudin.

Madhuca utilis: Foxworthy, F.W., 1927. Commercial timber trees of the Malay Peninsula. Malayan Forest Records No 3. Forest Department, Federated Malay States, Kuala Lumpur. photo opposite p. 116 (habit); Lam, H.J., 1925. The Sapotaceae of the Dutch East Indies. Bulletin du Jardin Botanique de Buitenzorg, sér. III, 7: 179, Fig. 50 (leafy twig, seed); Ng, F.S.P., 1983. Sapotaceae. In: Whitmore, T.C. (Editor): Tree flora of Malaya. 2nd edition. Vol. 1. Longman Malaysia SDN Berhad, Kuala Lumpur. p. 403, Fig. 7 (fruit). Redrawn and adapted by Iskak Syamsudin.

Manilkara kauki: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 619 (habit); Laporan 175. Lembaga Penelitian Hutan, Bogor (leafy twig); Lam, H.J., 1941. Note on the Sapotaceae – Mimusopsoideae in general and on the far-eastern Manilkara-allies in particular. Blumea 4: 3, Fig. 3 (flower); Aubréville, A., 1963. Sapotacées. In: Aubréville, A. (Editor): Flore du Cambodge, du Laos et du Vietnam. Vol. 3. Muséum Nationale d'Histoire Naturelle, Paris. p. 13, Pl. 1.9, 1.10 (twig with fruit, seed in side and front view). Redrawn and adapted by Iskak Syamsudin.

Neobalanocarpus heimii: Photograph taken by R.H.M.J. Lemmens (habit); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 388, Fig. 60a (flowering twig), p. 389, Fig. 61d (stamens); Symington, C.F., 1943. Foresters' manual of dipterocarps. Malayan Forest Records No 16. Forest Department, Kuala Lumpur. p. 148, Fig. 80 (inflorescence and fruit). Redrawn and adapted by Iskak Syamsudin.

Palaquium amboinense: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 610. Redrawn and adapted by Achmad Satiri Nurhaman.

Palaquium ottolanderi: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol.

4. P.W.M. Trap, Leiden. Fig. 611, 612. Redrawn and adapted by Achmad Satiri Nurhaman.

Palaquium philippense: van Royen, P., 1960. Revision of the Sapotaceae of the Malaysian area in a wider sense 23. Palaquium Blanco. Blumea 10: 469, Fig. 3. Redrawn and adapted by Iskak Syamsudin.

Paraserianthes falcataria: Corner, E.J.H., 1988. Wayside trees of Malaya. 3rd edition. Vol. 1. The Malayan Nature Society, Kuala Lumpur. Pl. 118 (habit); Whitmore, T.C., Tantra, I.G.M. & Sutisna, U., 1989. Tree flora of Indonesia. Checklist for Bali, Nusa Tenggara and Timor. Agency for Forestry Research and Development, Forest Research and Development Centre, Bogor. p. 116 (flowering twig, fruit); Cockburn, P.F., 1976. Trees of Sabah. Vol. 1. Forest Department, Sabah, Kuching. p. 186, Fig. 41 (flower). Redrawn and adapted by Iskak Syamsudin.

Parashorea densiflora: Photograph taken by R.H.M.J. Lemmens (habit); van Slooten, D.F. & Symington, C.F., 1939. Notes on Malayan Dipterocarpaceae V. The Gardens' Bulletin Straits Settlements 10: 373, Pl. 24 (flowering twig, fruit); Symington, C.F., 1941. Foresters' manual of dipterocarps. Malayan Forest Records No 16. Forest Department, Kuala Lumpur. p. 98, Fig. 59A (flowers). Redrawn and adapted by Iskak Syamsudin.

Parashorea malaanonan: Symington, C.F., 1938. Notes on Malayan Dipterocarpaceae IV. The Gardens' Bulletin Straits Settlements 9: 334, pl. 21 (flowering branch); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 381, Fig. 54A, C (flower bud and stamens), p. 384, Fig. 57C (fruit). Redrawn and adapted by Iskak Syamsudin.

Payena acuminata: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 608 (habit and flowering twig); Lam, H.J., 1925. The Sapotaceae of the Dutch East Indies. Bulletin du Jardin Botanique de Buitenzorg sér. III, 7: 141, Fig. 38 (flower); Ng, F.S.P., 1983. Sapotaceae. In: Whitmore, T.C. (Editor): Tree flora of Malaya. 2nd edition. Vol. 1. Longman Malaysia SDN Berhad, Kuala Lumpur. p. 430, Fig. 11 (fruit). Redrawn and adapted by Iskak Syamsudin.

Payena leerii: Photograph taken by R.H.M.J. Lemmens (habit); Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 615 (fruiting twig, flower opened, seed). Redrawn and adapted by Achmad Satiri Nurhaman.

Payena maingayi: van Bruggen, A.C., 1958. Sapotaceae of the Malaysian area 15. Payena DC. Blumea 9: 105, Fig. 3 (flowering twig, fruiting twig and detail of leaf venation); Engler, A., 1890. Sapotaceae. In: Engler, A. & Prantl, K. (Editors): Die natürlichen Pflanzenfamilien. Vol. 4, 1. Wilhelm Engelmann, Leipzig. p. 132, Fig. 69 (flower). Redrawn and adapted by Achmad Satiri Nurhaman.

Pericopsis mooniana: Verdcourt, B., 1979. A manual of New Guinea Legumes. Botany Bulletin 11. Office of Forests, Division of Botany, Lae. p. 286, Fig. 62. Redrawn and adapted by Achmad Satiri Nurhaman.

Peronema canescens: Photograph taken by Beekman at Kediri, 1919, from the files of J.W. Hildebrand (habit); Koorders, S.H. & Valeton, Th., 1914. Atlas der Baumarten von Java. Vol. 2. P.W.M. Trap, Leiden. Fig. 280 (leaf, flower, fruit). Redrawn and adapted by P. Verheij–Hayes.

Pinus kesiya: Farjon, A., 1984. Pines: drawings and descriptions of the genus Pinus. E.J. Brill, Leiden. p. 92. Redrawn and adapted by Achmad Satiri Nurhaman.

Pinus merkusii: Farjon, A., 1984. Pines: drawings and descriptions of the genus Pinus. E.J. Brill, Leiden. p. 112 (habit, needles and female cone); files of J.W. Hildebrand (cone-bearing twig). Redrawn and adapted by Iskak Syamsudin.

Pometia pinnata: Henderson, C.P. & Hancock I.R., 1989. A guide to the useful plants of the Solomon Islands. Research Department, Ministry of Agriculture and Lands, Honaira. p. 50, Fig. 12 (habit); van Royen, P., 1964. Manual of the forest trees of Papua and New Guinea. Part 2 – Sapindaceae. Department of Forests, Administration of Papua and New Guinea, Port Moresby. p. 38, Fig. 17 (flowering twig); Prawira, S.A., 1970. Pengenalan djenis-djenis pohon ekspor, serie ke: III. Laporan 116. Lembaga Penelitian Hutan, Bogor. p. 28 (fruiting twig). Redrawn and adapted by Iskak Syamsudin.

Pouteria doonsaf: Herrmann-Erlee, M.P.M. & van Royen, P., 1957. Revision of the Sapotaceae of the Malaysian area in a wider sense 9. Pouteria Aublet. Blumea 8: 487, Fig. 8. Redrawn and adapted by Achmad Satiri Nurhaman.

Pouteria duclitan: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4.

P.W.M. Trap, Leiden. Fig. 607. Redrawn and adapted by Iskak Syamsudin.

Pouteria obovata: Koorders, S.H. & Valeton, Th., 1916. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 604 (flowering twig, flower), Fig. 605 (habit), Fig. 606 (fruiting twig). Redrawn and adapted by Iskak Syamsudin.

Pterocarpus indicus: Corner, E.J.H., 1988. Wayside trees of Malaya, 3rd edition. Vol. 1. The Malayan Nature Society, Kuala Lumpur. Pl. 90 (habit); Greshoff, M., 1894. Nuttige Indische planten. Aflevering 3. Extra Bulletin van het Koloniaal Museum. J.H. De Bussy, Amsterdam. Pl. 26 (flowering branch); Koorders S.H. & Valeton, Th., 1913. Atlas der Baumarten von Java. Vol. 1. P.W.M. Trap, Leiden. Fig. 17 (fruit). Redrawn and adapted by Iskak Syamsudin.

Scaphium macropodum: Photograph taken by R.H.M.J. Lemmens (habit); Kostermans, A.J.G.H., 1953. The genera Scaphium Schott & Endl. and Hildegardia Schott & Endl. (Sterculiaceae). Journal of Scientific Research Indonesia 2: 16, Fig. 2 (leafy twig, flowering twig, fruits). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea albida: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 254, Fig. 8, p. 502, Fig. 97 (habit); Symington, C.F., 1935. Notes on Malayan Dipterocarpaceae – 3. The Gardens' Bulletin Straits Settlements 8: 282a, Pl. 26 (flowering twig, flower bud, fruit). Redrawn and adapted by Iskak Syamsudin.

Shorea assamica: Photograph taken by R.H.M.J. Lemmens (habit); Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 490, Fig. 93 (flowering twig, leaf, fruit and nut). Redrawn and adapted by Iskak Syamsudin.

Shorea bracteolata: Prawira, S.A. & Tantra, I.G.M., 1969. Pengenalan djenis-djenis pohon ekspor, serie ke: I. Laporan 103. Lembaga Penelitian Hutan, Bogor. p. 3 (flowering twig); Symington, C.F., 1941. Foresters' manual of dipterocarps. Malayan Forest Records No 16. Forest Department, Kuala Lumpur. p. 29, Fig. 18 (flowers), p. 32, Fig. 19 (fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea curtisii: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 542, 543, Fig. 112, 113 (habit); Foxworthy, F.W., 1927. Commercial timber trees of the Malay Peninsula. Malayan Forest Records No 3. Forest Department, Federated Malay States, Kuala Lumpur. photo between p. 38 and 39 (leafy twig); Symington, C.F., 1941. Foresters' manual of dipterocarps. Malayan Forest Records No 16. Forest Department, Kuala Lumpur. p. 66, 69, Fig. 38, 41 (leaf, fruit, nut and flower). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea guiso: Symington, C.F., 1935. Notes on Malayan Dipterocarpaceae – 3. The Gardens' Bulletin Straits Settlements 8: 266a, Pl. 16 (flowering twig, fruiting twig, fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea laevis: Photograph taken by R.H.M.J. Lemmens (habit); Prawira, S.A. & Tantra, I.G.M., 1969. Pengenalan djenis-djenis pohon ekspor, serie ke: I. Laporan 103. Lembaga Penelitaian Hutan, Bogor. p. 12 (flowering twig, fruits and nut). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea laxa: Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Fig. 14.6, Pl. 38. Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea leprosula: Photograph taken by R.H.M.J. Lemmens (habit); Prawira, S.A. & Tantra, I.G.M., 1969. Pengenalan djenis-djenis pohon ekspor, serie ke: I. Laporan 103. Lembaga Penelitaian Hutan, Bogor. p. 13 (fruiting twig); Ashton, P.S., 1964. Manual of the dipterocarp trees of Brunei State. Oxford University Press, London. Fig. 16.17 (fruit). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea ovalis: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 548, Fig. 116 (flowering twig, fruit and nut), p. 550 Fig. 118 (habit). Redrawn and adapted by Achmad Satiri Nurhaman.

Shorea polyandra: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 470, 471, Fig. 87, 88. Redrawn and adapted by Iskak Syamsudin.

Sindora coriacea: Foxworthy, F.W., 1927. Commercial timber trees of the Malay Peninsula.

Malayan Forest Records No 3. Forest Department, Federated Malay States, Kuala Lumpur. Photo opposite p. 92 (habit); de Wit, H.C.D., 1949. Revision of the genus Sindora Miquel (Legum.). Bulletin of the Botanic Gardens Buitenzorg, ser. III, 18: 31, Fig. 5 (leaf, flower, fruits). Redrawn and adapted by Achmad Satiri Nurhaman.

Sindora irpicina: Cockburn, P.F., 1976. Trees of Sabah. Vol. 1. Forest Department Sabah. p. 180, Pl. 11 (habit); de Wit, H.C.D., 1949. Revision of the genus Sindora Miquel (Legum.). Bulletin of the Botanic Gardens Buitenzorg, ser. III, 18: 51, Fig. 10 (flowering twig, flower, fruit). Redrawn and adapted by Iskak Syamsudin.

Swietenia macrophylla: Lamb, F.B., 1966. Mahogany of tropical America: its ecology and management. The University of Michigan Press, Michigan. p. 82, Fig. 11 (habit); Pennington, T.D., 1981. Meliaceae. In: Luteyn, J.L. & Mori, S.A. (Editors): Flora Neotropica. Monograph Number 28. The New York Botanical Garden, New York. p. 397, Fig. 80 (flowering twig, male flower, female flower, capsule, seed). Redrawn and adapted by Achmad Satiri Nurhaman.

Tectona grandis: Koorders, S.H. & Valeton, Th., 1914. Atlas der Baumarten von Java. Vol. 4. P.W.M. Trap, Leiden. Fig. 256 (fruiting twig, flower), Fig. 257 (fruits, fruit with opened calyx), Fig. 272 (habit). Redrawn and adapted by Iskak Syamsudin.

Tetramerista glabra: Photograph taken by R.H.M.J. Lemmens (habit); Kneg, H., 1989. Tetrameristaceae. In: Ng, F.S.P. (Editor): Tree flora of Malaya. 2nd edition. Vol. 4. Longman Malaysia SDN Berhad, Kuala Lumpur. p. 471, Fig. 1 (flowering twig, fruit). Redrawn and adapted by Iskak Syamsudin.

Upuna borneensis: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 336, 337, Fig. 32, 33 (habit, fruit, nut); Symington, C.F., 1941. Upuna, a new genus of the Dipterocarpaceae. Bulletin of the Botanic Gardens Buitenzorg, ser. III, 17: 89, Fig. 1 (flowering twig, flower, stamens). Redrawn and adapted by Achmad Satiri Nurhaman.

Vatica dulitensis: Drawn from a tree in the Botanic Gardens, Bogor (habit); Symington, C.F., 1934. Notes on Malayan Dipterocarpaceae 2. The Gardens' Bulletin Staits Settlements 8: Pl. 10 (flowering twig, fruiting twig, fruit). Redrawn and adapted by Iskak Syamsudin.

Vatica maingayi: Ashton, P.S., 1982. Dipterocarpaceae. In: van Steenis, C.G.G.J. (Editor): Flora Malesiana. Ser. I, Vol. 9. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/London. p. 368, Fig. 47. Redrawn and adapted by Iskak Syamsudin.

Vatica nitens: Photograph taken by R.H.M.J. Lemmens (habit); Whitmore, T.C., Tantra, I.G.M. & Sutisna, U. (Editors), 1990. Tree flora of Indonesia. Checklist for Kalimantan. Part II.2. Agency for Forestry Research and Development, Forest Research and Development Centre, Bogor. p. 602 (fruiting twig); Symington, C.F., 1941. Foresters' manual of dipterocarps. Malayan Forest Records No 16. Forest Department, Kuala Lumpur. p. 215a, Fig. 107 (leaf, fruit, fruit with part of calyx removed). Redrawn and adapted by Iskak Syamsudin.

Map of South-East Asia for Prosea: original design of R. Boekelman.

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Transcriptions of Vietnamese names:

[aa] = â
[aaf] = ầ
[aaj] = ậ
[aar] = ẩ
[aas] = ấ
[aax] = ẫ
[af] = à
[aj] = ạ
[ar] = ả
[as] = á
[aw] = ă
[awf] = ằ
[awj] = ặ
[awr] = ẳ
[aws] = ắ
[awx] = ẵ
[ax] = ã
[ee] = ê
[eef] = ề
[eej] = ệ
[eer] = ể
[ees] = ế
[eex] = ễ
[ef] = è
[ej] = ẹ
[er] = ẻ
[es] = é
[ex] = ẽ
[if] = ì
[is] = í
[of] = ò
[oj] = ọ
[oo] = ô
[oof] = ồ
[ooj] = ộ
[oor] = ổ
[oos] = ố
[oox] = ỗ
[or] = ỏ
[os] = ó
[ow] = ơ
[owf] = ờ
[owj] = ợ
[owr] = ở
[ows] = ớ
[owx] = ỡ
[ox] = õ
[uf] = ù
[uj] = ụ
[ur] = ủ
[us] = ú
[uw] = ư
[uwf] = ừ
[uwj] = ự
[uwr] = ử
[uws] = ứ
[uwx] = ữ
[ux] = ũ

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 at 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 FRI Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Widya Graha, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology & Biological Resources (NCSR), Nghia do, Tu Liem, Hanoi, Vietnam;
- Papua New Guinea University of Technology (UNITECH), Private Mail Bag, Lae, Papua New Guinea;
- Philippine Council for Agriculture, Forestry and Natural Resources Research & Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific and Technological Research (TISTR), 196 Phahonyothin Road, Bang Khen, Bangkok 10900, Thailand;
- Wageningen Agricultural University (WAU), Costerweg 50, 6701 BH Wageningen, the Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and disseminaton of reports and the research results.

Implementation

The programme period has been tentatively divided into 3 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–1995): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.

Documentation

A documentation system has been developed for information storage and retrieval called SAPRIS (South-East Asian Plant Resources Information System). It consists of 6 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.

Publication

The handbook in blue cover (hardbound) is distributed by Pudoc, the low-price edition in green cover (paperback) by Prosea only in developing countries of South-East Asia and the Pacific, the bibliographies by Prosea and the miscellaneous publications by Pudoc and Prosea.

The handbook

- No 1. Pulses. L.J.G. van der Maesen and Sadikin Somaatmadja (Editors). Pudoc, Wageningen. 1989/ESCAP CGPRT Centre, Bogor. 1990 (out of print)/Prosea, Bogor. 1992.
- No 2. Edible fruits and nuts. E.W.M. Verheij and R.E. Coronel (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992.
- No 3. Dye and tannin-producing plants. R.H.M.J. Lemmens and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992.
- No 4. Forages. L. 't Mannetje and R.M. Jones (Editors). Pudoc, Wageningen. 1992/Prosea, Bogor. 1992.
- No 5(1). Timber trees. Major commercial timbers. I. Soerianegara and R.H.M.J. Lemmens (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor, 1994.
- No 5(2). Timber trees. Minor commercial timbers. R.H.M.J. Lemmens, I. Soerianegara and W.C. Wong (Editors). (expected publication date 1994/1995).
- No 6. Rattans. J. Dransfield and N. Manokaran (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor, 1994.
- No 7. Bamboos. S. Dransfield and E.A. Widjaja (Editors). (expected publication date 1994).
- No 8. Vegetables. J.S. Siemonsma and Kasem Piluek (Editors). Pudoc, Wageningen. 1993/Prosea, Bogor, 1994.
- No 9. Plants mainly producing carbohydrates. F. Rumawas and M. Flach (Editors). (expected publication date 1994).
- No 10. Cereals.
- No 11. Auxiliary plants in agriculture and forestry. F.H. Ibrahim and L.J.G. van der Maesen (Editors). (expected publication date 1994).

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- Bibliography 1: Pulses. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor. 1990.
- Bibliography 2: Edible fruits and nuts. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor/Pudoc, Wageningen. 1993.
- Bibliography 3: Dye and tannin-producing plants. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor/Pudoc, Wageningen. 1991.

Miscellaneous

- A Selection. E. Westphal and P.C.M. Jansen (Editors). Pudoc, Wageningen. 1989/Prosea, Bogor, 1993.
- Basic list of species and commodity grouping. Version 1. R.H.M.J. Lemmens, P.C.M. Jansen, J.S. Siemonsma, F.M. Stavast (Editors). Prosea Project, Wageningen. 1989. (out of print).
- Basic list of species and commodity grouping. Final version. P.C.M. Jansen, R.H.M.J. Lemmens, L.P.A. Oyen, J.S. Siemonsma, F.M. Stavast and J.L.C.H. van Valkenburg (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor, 1993.
- Proceedings of the First Prosea International Symposium, May 22–25, 1989. Jakarta, Indonesia. J.S. Siemonsma and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1989. (out of print).

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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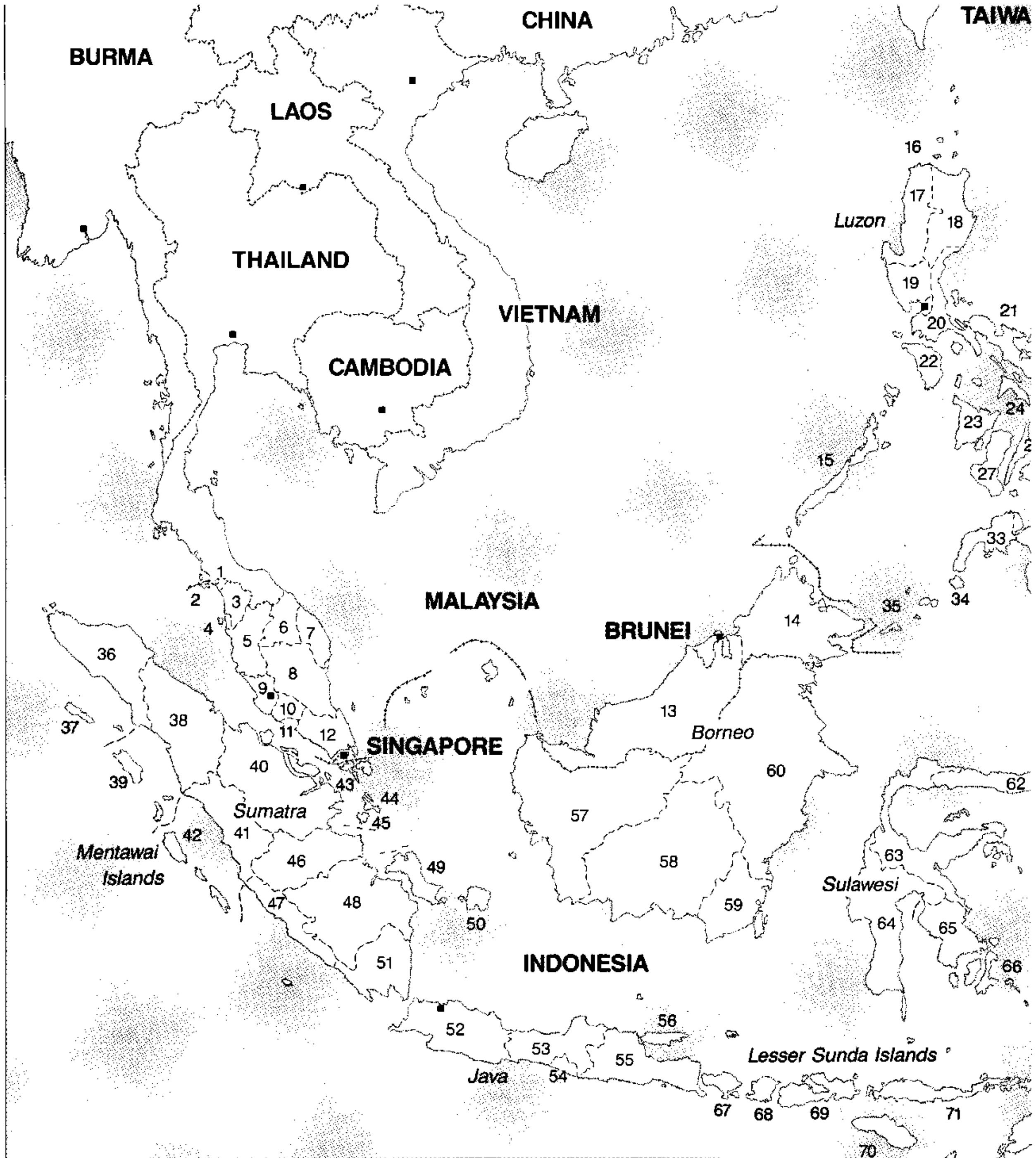
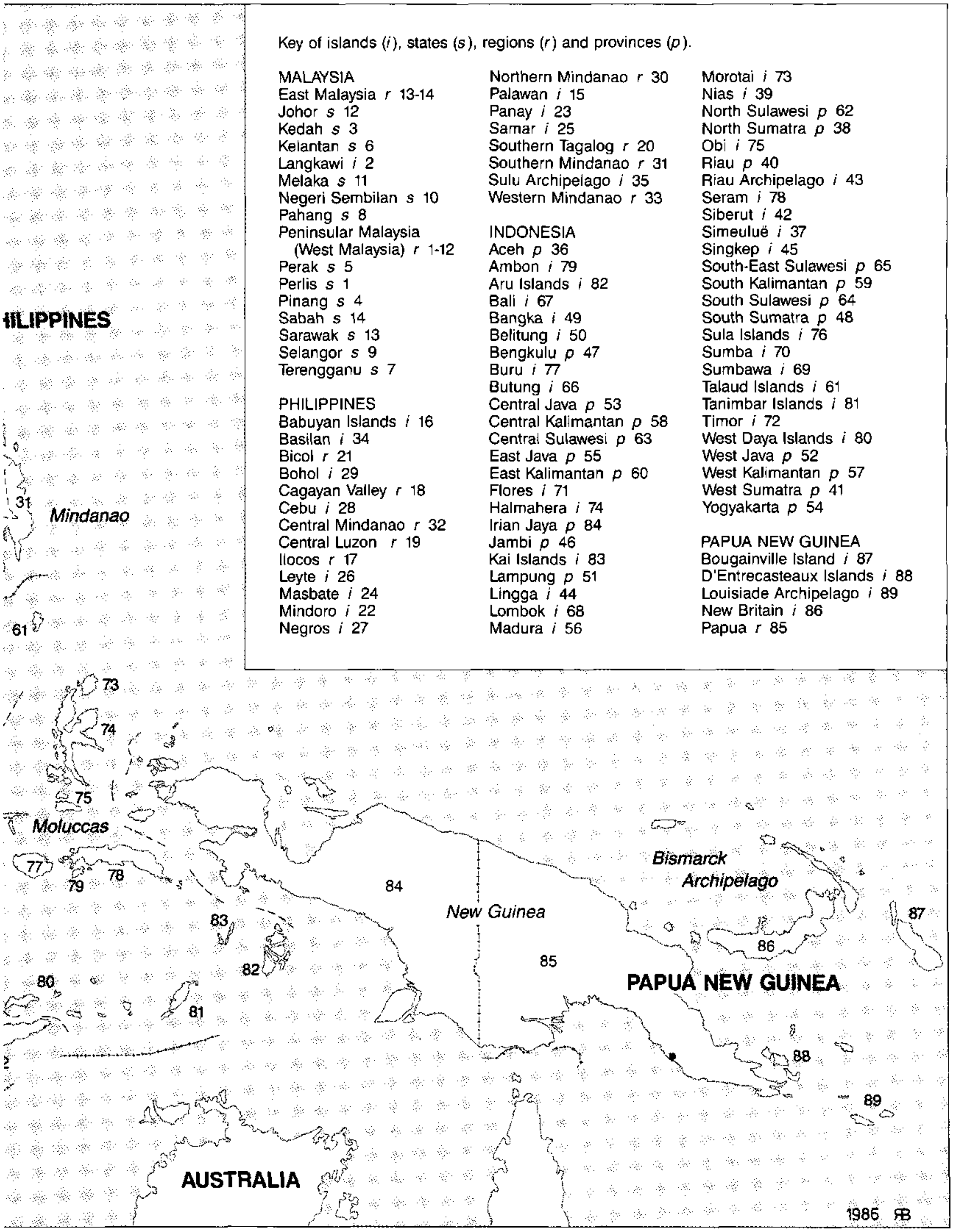


MAP OF SOUTH-EAST ASIA FOR PROSEA
Names of countries in capital letters and islands in lower case; numbers refer to the key.



Key of islands (*i*), states (*s*), regions (*r*) and provinces (*p*).

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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
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Terengganu *s* 7

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