Plant Resources of South-East Asia

No 11

Auxiliary plants

I. Faridah Hanum and L.J.G. van der Maesen (Editors)

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Foreword

This volume in the Prosea handbook series is dedicated to auxiliary plants in agriculture and forestry. Any plant that forms part of a land-use system and provides a service and/or a product that is secondary to the main outputs of that system can be classified as an auxiliary plant.
One of the major service functions of this group of plants in agriculture and forestry, including agroforestry, is the maintenance and improvement of soil fertility such as by mulching, shading, shelter, green manuring and cover crops for erosion control. Production roles, on the other hand, may include fuelwood, domestic timber, forage, food, fibres, staking and support material.
In many farmers' practices the cultivation of herbaceous crops is combined with trees. In these land-use systems, trees or shrubs are grown in association with agricultural crops or pastures in a spatial arrangement or a rotation, in which both ecological and economic interactions exist between the trees and other components of the system. Appropriate agroforestry systems can control erosion, maintain soil organic matter and physical properties, and promote efficient nutrient cycling.
At the beginning of this century the use of auxiliary plants in South and South-East Asia was mainly restricted to plantation agriculture. Since then, however, interest in the service and/or production roles of auxiliary plants has intensified significantly over the last decades resulting in the establishment of international research centres in this field of science.
From this volume of the Prosea handbook it appears that a fairly large number of auxiliary plants is not yet commonly used in South-East Asia on a large scale, but their performance outside the region is well-known and initial trials in South-East Asia have shown promise. In this sense this publication is not only a witness of well-used, or earlier-used and since then forgotten plants, but also of future promising ones. This publication also shows that there is a great discrepancy in data available. The amount of interest, research efforts, hence output of data, vary considerably. Some plants are little studied and are merely condoned to grow as weeds to be ploughed in for the purpose of green manure. Others play a more prominent role and have been researched in more detail.
The information presented here is very much the result of a collective effort of an international group of scientists. It is gratifying that the approach of Prosea could muster so much cooperation. The Board and personnel of the Prosea Foundation are to be congratulated on this excellent comprehensive overview of auxiliary plants.
Finally, I sincerely hope that this book will be instrumental in focusing attention to the important issue of how to combine agriculture and forestry in order to raise the production of food, forage, fibre, fuel and timber, and how

to improve income and living standards for the rural population of South-East Asia.

Nairobi, February 1997

Dr. Pedro A. Sanchez
Director General
International Centre for Research in Agroforestry (ICRAF)

1 Introduction

1.1 Definition of auxiliary plants

Any plant that forms part of a land-use system and provides a service and/or a product that is secondary to the main outputs of a system, can be classified as an auxiliary plant. The plants covered in this volume are an odd array; what they have in common is their role in agriculture and forestry. Auxiliary plants do not deliver primary products, but assist the farmer or forester to better produce such products. They have a service role. In the terminology of the International Centre for Research in Agroforestry (ICRAF) 'service functions' are the production of mulch, shade, shelter, atmospheric nitrogen fixation and erosion control, whereas 'production functions' include supply of firewood, stakes, fruits, vegetables and fodder. Fuelwoods as a primary product are included here, since many fuelwoods are planted on farmland and often have a service function as well. They are the main source of energy for many households. On the other hand, the poles produced for building and fencing, such as from *Gmelina arborea* Roxb., are covered in the volume on Timber Trees, as timber also covers non-sawn wood.

Plants with other primary uses may also have a secondary role as auxiliary crop. However, all the species dealt with in this volume (except fuelwood) have a primary role as a service crop. Multiple uses and dual roles are often difficult to separate quantitatively, and the decision to assign a particular species to a particular commodity group is sometimes arbitrary ('t Mannetje & Jones, 1992).

The commodity subgroupings made for the auxiliary plants are: shade and nurse trees, cover crops, green manures, mulches, fallow crops, live fences, wind-breaks and shelter-belts, erosion-controlling plants, land reclamation species, live supports and stakes, and fuelwood (both firewood and the woody species used for charcoal). Of course, many timber species have a secondary use as fuel. Also, many cover crops are good forage. It should be noted that some plants important as water-clearing agents are also dealt with in this volume. Furthermore, in certain production systems a species may have an auxiliary function, whereas in another it may supply primary products. Sometimes, both functions are combined, e.g. grazed cover crops in coconut plantations. Moreover, some important auxiliary plants are also among the most important forages; therefore, a few of the species dealt with in the volume on Forages are highlighted as well.

An early standard reference work on auxiliary plants in South-East Asia was published in the late 1940s (Ossewaarde & Wellensiek, 1946).

1.2 Role of auxiliary plants in agriculture and forestry

1.2.1 Major groups and uses

Auxiliary plants can be grouped in several ways. How the species concerned is used provides a practical way of subdivision. Auxiliary plants may also be grouped according to their habit: plants in all major habit groups – erect herbs, herbaceous and woody creepers, or climbers, shrubs and trees – may play a service role. The plant's habit is clearly of prime importance for certain service roles. Not all groups are mutually exclusive, and some plants play many roles. Table 1 gives an indication of the various functions of auxiliary plants. The 12 auxiliary functions discerned are described below.

Shade and nurse trees

Shade trees are primarily used to manipulate the levels of incoming light to the light requirements of associated crops such as cocoa, coffee or lowland tea.
The shade requirements of these perennial crops depend on environmental factors, on cultivars and management practices and, in case of lowland tea, on leaf-quality criteria. More shade is required when crops are still in a single-leaf-layer stage than when a multi-layer canopy has been formed and self-shading occurs.
Shade is sometimes also needed to protect full-grown leaves and branches against sun scorch. As a management tool shade can be used to reduce the photosynthesis-driven growth to levels which can be met by the nutrient supply from the soil. Shade trees are multifunctional. Apart from creating a favourable microclimate, they can increase the organic matter supply through leaf litter and prunings, thereby reinforcing the nutrient cycle of the crop and the cropping system. Ideally, shade trees should form a wide-spreading, horizontal, light-filtering leaf layer, well above the canopy of the crops (National Research Council, 1993). They should be deep-rooting to avoid root competition with the main crop and for uptake of nutrients from the deeper soil layers. Fast-growing and luxuriant trees should tolerate pruning and pollarding.
Commonly used shade trees include well-known agroforestry plants such as various *Acacia* and *Albizia* species, *Derris microphylla* (Miq.) Jackson, *Erythrina* spp. (*E. poeppigiana* (Walp.) O.F. Cook., *E. subumbrans* (Hassk.) Merrill), *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Grevillea robusta* A. Cunn. ex R. Br., *Leucaena* spp. (*L. diversifolia* (Schlecht.) Benth., *L. leucocephala* (Lamk) de Wit), and *Paraserianthes falcataria* (L.) Nielsen.
During establishment, crops like cocoa and coffee may need lateral shade, also referred to as temporary shade. For this purpose shrubs (*Flemingia macrophylla* (Willd.) Merrill and *Tephrosia* spp.) and trees (*Leucaena leucocephala*) are planted in hedges along single or double rows of crop plants. These hedges have a secondary function: the provision of mulch. This practice, originating from plantation agriculture, has been further developed in the alley-cropping model, in which annual food crops are grown in between nutrient-cycling hedges which are pruned frequently to provide mulch for the inter-row crops. Here the emphasis is on the transfer (recycling) of nutrients from the auxiliary plants to the main crop plants, and not on lateral protection. Hedges of *Gliricidia sepium*

Table 1. Major auxiliary plants, their functions and occurrence in different ecological zones.

Name	Auxiliary functions												Ecological zones
	shade and nurse tree	cover crop	green manure	mulch	fallow crop	live fence	wind-break and shelter-belt	erosion-controlling plant	land reclamation species	live support and stake	fuelwood	water-clearing agent	
Acacia aulacocarpa	x								x		x		(semi-arid–)sub-humid–humid(–per-humid) tropics, subtropics, 0–1000 m
Acacia auriculiformis				x			x		x		x		(semi-arid–) sub-humid–humid(–per-humid) tropics, 0–400(–1000) m
Acacia crassicarpa	x			x					x		x		(semi-arid–) sub-humid–humid(–per-humid) tropics, 0–200(–450) m
Acacia glauca								x	x		x		(arid–)semi-arid–sub-humid tropics, 0–1200 m
Aeschynomene afraspera			x										humid tropics, 0–900 m
Albizia chinensis	x							x	x		x		sub-humid–per-humid tropics, subtropics, 0–1800 m
Albizia procera	x						x		x		x		(semi-arid–)humid(–per-humid) tropics, subtropics, 0–1500 m
Alnus	x							x	x	x	x		semi-arid–per-humid tropics, subtropics, (300–)1000–1800(–3000) m
Azadirachta indica	x						x	x			x		semi-arid–sub-humid(–per-humid) tropics, 0–700(–1500) m
Bruguiera cylindrica											x		humid tropics, about 20 m
Bruguiera sexangula											x		humid tropics, about sea-level
Calliandra calothyrsus	x		x		x			x	x		x		semi-arid–per-humid tropics, (0–)250–800(–1850) m
Calopogonium mucunoides		x	x										sub-humid–humid tropics, (0–)300–1500(–2000) m
Casuarina equisetifolia							x	x	x		x		semi-arid–per-humid tropics, 0–100(–1200) m
Casuarina junghuhniana				x		x	x		x		x		semi-arid–sub-humid tropics, (0–)1500–3100 m
Centrosema pubescens		x	x										sub-humid–humid tropics, 0–600(–900) m
Chromolaena odorata			x	x	x			x					(semi-arid–)sub-humid–humid tropics, 0–1000(–1500) m
Cordia alliodora	x										x		semi-arid–per-humid tropics, 0–1000(–2000) m
Crotalaria micans		x	x					x					tropics, 0–1600(–2600) m
Crotalaria pallida		x	x					x					semi-arid–per-humid tropics, 0–1000(–1800) m
Crotalaria spectabilis			x					x					semi-arid–per-humid tropics, subtropics, 0–1500 m
Crotalaria trichotoma		x	x										humid tropics, 0–1800 m
Cyamopsis tetragonoloba	x	x	x										semi-arid–sub-humid tropics, 0–900 m
Dactyladenia barteri				x	x	x				x			sub-humid tropics, 0–300 m
Derris microphylla	x		x								x		humid tropics, 200–1200 m
Desmodium adscendens		x	x										(per-humid–)humid tropics, subtropics, 200–1000 m
Eichhornia crassipes			x	x								x	tropics, subtropics

Table 1. Continued

Name	Auxiliary functions: shade and nurse tree	cover crop	green manure	mulch	fallow crop	live fence	wind-break and shelter-belt	erosion-controlling plant	land reclamation species	live support and stake	fuelwood	water-clearing agent	Ecological zones
Erythrina fusca	x					x				x			sub-humid–per-humid tropics, 0–2000 m
Erythrina poeppigiana	x		x	x		x					x		sub-humid–per-humid tropics, (0–)500–1500(–2000) m
Erythrina subumbrans	x		x							x			humid tropics, (0–)300–1500 m
Erythrina variegata	x		x			x	x			x			humid tropics, 0–1200 m
Eucalyptus camaldulensis	x						x				x		arid–per-humid tropics, subtropics, temperate regions, 20–700 m
Eucalyptus tereticornis	x						x				x		semi-arid–per-humid tropics, subtropics, 0–1800 m
Eucalyptus urophylla											x		(semi-arid–)sub-humid–humid(–per-humid) tropics, (70–)1000–1500(–3000) m
Flemingia macrophylla	x	x	x	x	x		x	x			x		sub-humid–per-humid tropics, 0–2000 m
Gliricidia sepium	x		x	x		x		x	x	x	x		semi-arid–per-humid tropics, 0–1500 m
Grevillea robusta	x			x		x					x		semi-arid–humid tropics, 130–2300 m
Homonoia riparia								x			x		(per-humid–)humid tropics, 50–500 m
Indigofera hendecaphylla		x	x										semi-arid–sub-humid(–per-humid) tropics, 0–700(–2500) m
Indigofera hirsuta		x	x					x					semi-arid–per-humid tropics, 0–1500 m
Indigofera suffruticosa		x	x										tropics, 0–1800 m
Ipomoea								x	x				tropics, 0–800 m
Kleinhovia hospita				x						x	x		humid tropics, 0–200(–500) m
Kummerowia		x											highland tropics, subtropics, warm temperate regions
Lespedeza cuneata		x						x	x				highland tropics, subtropics, warm temperate regions, 1200–2200(–3100) m
Leucaena diversifolia	x		x								x		semi-arid–per-humid highland tropics, (700–)1000–2500 m
Leucaena leucocephala	x		x	x		x	x			x	x		semi-arid–humid tropics, subtropics, 0–1000 m or higher
Lupinus			x					x	x				at least (250–)350 mm rainfall, tropical highlands, subtropics, temperate regions
Maesopsis eminii	x								x		x		sub-humid tropics, (0–)600–900(–1800) m
Melia azedarach	x								x		x		semi-arid–humid tropics, subtropics, temperate regions, 0–1200(–2200) m
Melilotus		x	x										highland tropics, subtropics, temperate regions, 0–2000 m
Mikania		x											humid–per-humid tropics, 0–1500(–3000) m
Mimosa diplotricha		x	x		x			x					humid tropics, 0–2000 m

Table 1. Continued

Name	Auxiliary functions: shade and nurse tree	cover crop	green manure	mulch	fallow crop	live fence	wind-break and shelter-belt	erosion-controlling plant	land reclamation species	live support and stake	fuelwood	water-clearing agent	Ecological zones
Mucuna pruriens cv group Utilis		x	x		x				x				(semi-arid–)sub-humid–per-humid tropics, subtropics, warm temperate regions
Paraserianthes falcataria	x							x			x		per-humid tropics, 0–2300 m
Peltophorum dasyrhachis	x				x				x		x		humid–per-humid tropics, 0–800 m
Pongamia pinnata			x				x	x			x		semi-arid–per-humid tropics, subtropics, 0–1200 m
Prosopis juliflora							x	x	x		x		semi-arid–sub-humid tropics, subtropics, 0–1500 m
Psophocarpus scandens		x	x										sub-humid–humid tropics, 0–950 m
Pueraria phaseoloides		x	x					x					humid(–per-humid) tropics, 0–1000 m
Rhizophora apiculata											x		(per-)humid tropics, sea-level
Samanea saman	x										x		sub-humid–per-humid tropics, 0–1000 m
Schleichera oleosa											x		semi-arid–per-humid tropics, 0–900(–1200) m
Senna didymobotrya	x	x	x										tropics, 900–2400 m
Senna hirsuta	x		x										tropics, 0–700 m
Senna siamea	x			x			x		x		x		(semi-arid–)humid–per-humid tropics, 0–1300 m
Sesbania	x		x	x			x				x		semi-arid–humid tropics, subtropics, 0–850(–1250) m
Sesbania rostrata			x								x		tropics, 0–1600 m
Sonneratia ovata								x			x		tropics, sea-level
Tephrosia candida	x		x			x		x			x		semi-arid–per-humid tropics, 0–1600 m
Tephrosia purpurea	x		x								x		tropics, 0–400(–1300) m
Tephrosia vogelii	x		x				x						semi-arid–per-humid tropics, 0–2100 m
Thespesia populnea							x	x					tropics, sea-level
Trema orientalis	x				x				x		x		sub-humid–humid tropics, 0–2000(–2500) m
Vigna hosei		x	x										per-humid tropics, 0–1100 m
Vigna marina		x						x					at least semi-arid tropics, sea-level
Vigna trilobata			x										at least semi-arid tropics, 0–2100 m
Vigna vexillata		x	x				x						sub-humid tropics, ?–1200(–1500) m

and *Leucaena leucocephala* are often used for this purpose. On-farm trials are essential to test the shade and alley trees, and to convince farmers of the advantages of the system, especially if rewards are not immediate (IITA, 1995).
In forestry, nurse trees are often planted between the main trees providing timber. Nurse trees are fast-growing and their shade not only improves the microclimate but also the shape of the timber trees and reduces weed growth.
Roadside plants include trees planted along roads, railway lines, canals, rivers and power lines. They provide shade, play a protective role in the landscape and improve comfort during travel; they are dealt with in the volume on Ornamental Plants.

Cover crops

Tree and plantation crops are usually planted directly at final spacing, and therefore the inter-row soil surface needs to be protected while they are establishing. Intercropping with a mixture of cover crops is a common practice to protect the soil against erosion and to prevent soil nutrients from leaching. Cover crops help to maintain the physical properties of the soil by protecting it by lowering the soil temperature and promoting life of microorganisms in the soil, which benefits soil structure. The growth of cover crops usually declines when the tree canopy closes. Sun-loving species disappear first, shade-tolerant species last. Mature oil-palm plantations contain few or no cover crops or weeds on the ground. Rubber plantation canopies allow more light to reach the soil surface (at least periodically), but a luxuriant ground cover is a disadvantage, as it interferes with the daily latex harvest. Unlike green manure crops, cover crops are not ploughed or dug in. Important cover crop species include *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth.
Velvet bean (*Mucuna pruriens* (L.) DC. cv. group Utilis) has become a popular cover crop with farmers in West Africa. Its advantage is that it enriches exhausted soil with nitrogen in only one or two seasons, and takes up whatever phosphate is available (IITA, 1995). The presence of suitable strains of *Bradyrhizobium* bacteria or of vesicular-arbuscular mycorrhizae (VAM) should be verified if initial growth is slow in a particular area, as successful growth depends on atmospheric nitrogen fixation and efficient nutrient uptake. A good *Mucuna* crop smothers *Imperata* grass and shades out unwanted weeds (IITA, 1995; Versteeg & Koudokpon, 1990).
Low-growing cover crops can be grown as live mulch (IITA, 1995). Ideally, they do not compete substantially with the main crop where soil moisture is adequate during the growing season.

Green manures

Green manure and cover crops are both sown or planted in situ, but the former are ploughed in at an appropriate time. All plants, whether leguminous or not, that enrich the soil with organic matter and nutrients when incorporated in the soil, provide green manure if their residues contain no allelophatic substances. Certain species are particularly useful. These include herbaceous plants which can be worked into the soil before they complete their life cycle, decompose rapidly and release nutrients which become available for the associated crops. Their ability to fix atmospheric nitrogen and their high content of this element make most legumes important green manures. Other desirable characteristics of suitable green manure crops are easy establishment and rapid production of large quantities of green biomass, and a well-developed, deep root system. They should not be host plants for diseases and pests affecting the main crops.

The main function of green manures is chemical improvement of the soil, but beneficial effects on soil biology and soil physical properties are also well documented. Because green manures consist of readily decomposable material, their effects on lowering soil temperature and conserving soil moisture, are of short duration (Tian, 1992).

Green manures include cultivated and wild annual and perennial legumes. *Calopogonium mucunoides*, *Pueraria phaseoloides* and *Vigna hosei* (Craib) Backer are among the most widely used green manures. Other examples of tropical green manures are guar (*Cyamopsis tetragonoloba* (L.) Taubert), cowpea (*Vigna unguiculata* (L.) Walp.), *Crotalaria* spp. and *Sesbania* spp. Many species have been tested in the past, but few have shown promise (Botton & Hallé, 1957, 1958; Keuchenius, 1924).

Green manure can be grown in a rotation with other crops, in a simultaneous association with the main crop (Singh, 1984) or as a relay crop. As rotation crops, they are worked into the soil before sowing the next crop. Green manures may compete with short-duration pulses. When soil moisture is adequate for a short-duration pulse, farmers will plant the latter. When water supply is only assured for less than two months, then green manures are preferred. When farmers lack resources to grow pulses over large acreages as catch crop, green manure legumes may do well (Singh, 1984).

Before being incorporated into the soil green manure may be sown directly in a given field, or grown first on the bunds or nearby wasteland to be cut and transported to the selected field later on ('cut and carry system').

Many species have been reported as being useful as green manure. Several of these just happened to grow as weeds, were ploughed in and found to provide organic matter, without further verification of whether they are better than other species. Some of them are included in this volume.

Mulches

Plants used as mulches are treated differently from green manures. Their leaves and branches (green or dried) are removed and placed on the soil where physical protection of the surface soil is required, and left to decompose, sometimes eventually to be ploughed in. During decomposition organic matter and nutrients are added to the soil.

Plant material with good mulch properties is characterized by a high C/N ratio and a high lignin content (Tian, 1992). Applied to the soil it decomposes slowly and can thus provide a long-lasting soil cover.

Mulches are mainly used to protect the soil surface. Many plants can be cut or pruned, and the prunings can be spread over the soil in a layer. The benefits include a reduction in soil temperature, and a more optimal soil biology, less evaporation and erosion and prevention of mud splashing on vegetable products. Temperatures in the upper 5 cm of soil mulched with *Leucaena leucocephala*, *Gliricidia sepium*, and *Flemingia macrophylla*, respectively, were lowered by 2.9°C, 4.6°C, and 6.6°C compared to the control (37.1°C) unmulched soil. The soil moisture under these mulches during a period of 60 days was 7.1%, 8.7% and 9.4% compared to 4.8% observed in unmulched soil (Budelman, 1991).

Some of the worst weeds such as *Chromolaena odorata* (L.) R.M. King & H. Robinson make good mulch provided plants are cut prior to flowering (Slaats, 1995). Mulching with material containing seed is an effective way of introducing a major weed problem.

The introduction of the agroforestry techniques of alley farming or hedgerow intercropping has renewed interest in the potential of using prunings from fast-growing shrubs and woody species for mulch. The legumes *Gliricidia sepium*, *Leucaena leucocephala* and *Senna siamea* (Lamk) Irwin & Barneby are particularly interesting. Their prunings have more of the characteristics of green manure: they are succulent, rich in nitrogen, decomposing rapidly, and enriching the soil.

Fallow crops

Auxiliary crops are used in fallow systems to improve the plant nutrient supply for subsequent crops, to improve the physical conditions of the soil, to suppress weeds (especially grasses) and/or to provide income. Fast-growing leguminous trees have several advantages as a fallow compared with the naturally regenerating vegetation. For example, *Sesbania sesban* (L.) Merrill is grown for one to two years as a fallow crop in maize cropping systems in southern Africa to accumulate nitrogen in the biomass, to smother weeds and to provide poles and firewood (ICRAF, 1993). However, caution should be observed in selecting planted fallow species. Plants like *Sesbania sesban* harbour root-knot nematodes which may be harmful to certain crops, in particular root and tuber crops. In alley-cropping trials with a one year fallow period in which the trees are left unpruned, shading has proved to be effective in weed control. Alley cropping with *Leucaena leucocephala* resulted in a shift from fast-growing annual weeds characteristic for frequently cropped fields to shade-tolerant and less competitive weeds (Akobundu et al., 1995).

In areas in which weed control is an important consideration (e.g. in *Imperata* grasslands) *Peltophorum dasyrhachis* (Miquel) Kurz, with its dense umbrella-shaped canopy, appears to be promising for low-cost reclamation of weed-infested land and also as a woody component of alley cropping (van Noordwijk et al., 1992). In long-term trials in farmers' fields in Benin, West Africa, short velvet bean (*Mucuna pruriens* cv. group Utilis) fallows have proved to be very effective in smothering *Imperata* and improving soil fertility (Versteeg & Koudokpon, 1994). An interesting research finding in the 1920s and 1930s in North Sumatra, Indonesia was that a fallow crop of *Mimosa diplotricha* C. Wright ex Sauvalle was rather effective in reducing bacterial wilt disease caused by *Pseudomonas solanacearum* in a subsequent tobacco crop (Wiersum, 1983). However, the effect appeared to be only modest when the fallow period was not longer than about 8 years (Van der Laan, 1949).

Live fences

Around houses, farms or fields and along roads, live fences serve the useful role of physically separating areas. These fences are sometimes managed as hedges, i.e. are pruned and pollarded. Live fences mark boundaries between properties, contain or exclude livestock, and provide shade, fuelwood, fodder, mulch material or green manure. Suitable species for live fences include *Acacia* spp., *Casuarina* spp., *Leucaena* spp., and *Tithonia diversifolia* (Hemsley) A. Gray. Ornamental species are often used in hedges near houses. These are mainly dealt with in the volume on Ornamental Plants, however. If properly established, hedges can avoid high costs of erecting non-living fences, and may prove very economical in maintenance. Their role as fodder bank may be considerable, especially during the dry season. An inedible hedge, e.g. of *Euphorbia tirucalli* L., provides protection from browsing livestock. Hedges should be pruned regularly, to keep them at a manageable size.

Wind-breaks and shelter-belts

Wind-breaks are strips or rows of trees and shrubs that are planted very closely together along the edges of a field or garden to protect crops and soil from the detrimental effects of wind. Sometimes they are planted on a much larger scale in semi-arid regions to protect areas against desertification. Strong, or hot and dry winds blowing from a predominant direction, are alleviated by fences planted windward to the field.
Very few species are grown solely as a wind-break. Usually this role is combined with other uses such as providing shade, fuelwood, fodder, or green manure. Live fences withstand pruning, and the prunings can be fed to livestock if palatable, or used as green manure or mulch. The species most used, combined with the latter two purposes, is probably *Leucaena leucocephala*. Other species commonly used for wind-breaks and shelter-belts in South-East Asia are *Casuarina equisetifolia* L., *C. junghuhniana* Miquel, *Erythrina variegata* L. and *Gliricidia sepium*. *Flemingia macrophylla* is a successful wind-break on steep slopes in the Philippines.

Erosion-controlling plants

The areas rendered unpractical for cultivation for reasons of erosion, or those prone to erosion due to the slope of the terrain, can be protected by species that have good rooting properties to fix the soil. To cover waste areas a pioneering habit forming a dense ground cover is required. This may be a disadvantage as plants with these characteristics, such as *Mimosa diplotricha*, run the risk of becoming noxious weeds. *Tephrosia purpurea* (L.) Pers. is less invasive. *Cyperus* spp. produce many seeds and some species have long stolons that form an underground mat which holds the soil.
The well-known beach plant *Ipomoea pes-caprae* (L.) R. Br. binds sand and helps combat wind erosion. *Vetiveria zizanioides* (L.) Nash, a coarse perennial grass, is now widely used in the tropics to protect contours. Harvesting its roots containing an essential oil, however, may be a major cause of erosion. Therefore, its cultivation for erosion control was prohibited in Java. Wet or dry,

sandy or compacted wastelands can be seen covered with various plants, such as *Cyperus* spp., but this is most undesirable with nutsedge (*Cyperus rotundus* L.), the most notorious weed in the world (Holm et al., 1977). When the pioneer role has been fulfilled, these sedges can be replaced by other plants.

Land reclamation species

Vast areas of wastelands such as abandoned open mines and mine spoils and eroded land have been used with limited success for agriculture in South-East Asia, as they require high inputs of capital and labour for rehabilitation. Auxiliary plants have been shown to improve the properties of soils on these difficult sites. Chemically they will increase the organic carbon and nutrient contents of the soils and improve the pH. The physical properties of the soil, such as its water-holding capacity, are improved by the good soil cover and accumulation of leaf litter provided by fast-growing auxiliary plants. Furthermore, their usually dense and shallow root system make such plants suitable for stabilizing eroding land.

Acacia crassicarpa A. Cunn. ex Benth. has shown outstanding potential in land reclamation and soil improvement in a wide range of degraded sites in the subhumid and humid tropics, as do *A. auriculiformis* A. Cunn. ex Benth. and *A. mangium* Willd. in the rehabilitation of tin tailings in Malaysia and *Imperata* grassland in Indonesia. These species and also *A. aulacocarpa* A. Cunn. ex Benth. produce numerous root nodules, survive on land low in organic matter and nitrogen where most other species fail, and are able to suppress *Imperata* grass, thus making them useful reclaimers.

Live supports and stakes

Many food and spice plants are climbers that need support from poles or trellis to economize space and induce flowering. Pepper (*Piper nigrum* L.) and betelvine (*P. betle* L.) cultivation is unthinkable without plant support. *Erythrina* spp. are good examples for live supports. *Gliricidia sepium* and *Leucaena leucocephala* are other examples of live stakes for yam cultivation in Africa (Budelman, 1991).

Maize and sorghum serve as live support for beans, but obviously that is not their primary role. Bamboo poles may be used to stake vegetables. The material used to make trellis is rarely specified.

Fuelwood (firewood and charcoal)

From many studies on forecasting the demand and supply of fuel sources it appears that fuelwood will be a necessary commodity in South-East Asia, at least for the rural economies, for many decades to come. Fuelwood plantations will play an increasingly important role in this, if forests are to be managed in a sustainable way. Crop residues, particularly from woody species (e.g. *Cajanus cajan* (L.) Millsp., even stems of cassava (*Manihot esculenta* Crantz) are becoming more valuable in the provision of firewood.

Fuelwoods are often planted in marginal areas, where they also protect the land against degradation and erosion. Those woody species that can be grown in agroforestry or forestry systems to produce firewood have a definite service role as well. Timber species from which fuelwood is obtained by pruning of branches or thinning, are not included in this volume, however, and roadside trees have been included only if their firewood or protective role are important. Mangrove species of *Avicennia*, *Bruguiera* and *Rhizophora* are important as fuel; because of excessive cutting, the protection afforded by mangroves to many low-lying coastal areas in the tropics is threatened. The mangrove swamps are economically important sources of crustaceans (shrimps, crabs and lobsters), are nursery grounds for many species of fish and house many sea birds and other wildlife. Conservation of the mangrove forests is urgent; the mangrove vegetation near centres of population has sometimes been entirely consumed for firewood.

Fast-growing trees for communal fuel plantations are becoming increasingly important (e.g. in Thailand, Nepal), but are not a universal panacea. The private cultivation of trees for firewood is also increasing. Species commonly used for fuelwood include *Acacia auriculiformis*, *Calliandra calothyrsus* Meisner, *Casuarina equisetifolia*, *Eucalyptus camaldulensis* Dehnh., *Gliricidia sepium* and *Prosopis* spp.

Firewood is used not only for the domestic purposes of cooking, and in hilly and mountain areas for heating, but also supplies energy for rural industries (Bhattacharya, 1986; Smiet, 1990), even when fossil fuels are available.

In Java, 90% of all fuelwood is used for domestic purposes. This island has a centuries-old tradition of agroforestry. About 3 million ha are under agroforestry, which provides fuel for more than 100 million people. Only 10% of the fuelwood is supplied by natural forest (Smiet, 1990).

In the Philippines, 60 000 ha of wood-energy plantations have been established since 1979. It is government policy to substitute wood for imported fuel for some industrial processes, in order to reserve more fuelwood for the growing population, but it is planned to generate power for rural electricity grids in 60–70 plants using firewood. Tall *Leucaena leucocephala* cultivars are used in 90% of the total area planted. Reported annual growth rates range from less than 20 m^3 (8 t) to 90 m^3 (36 t) per ha, less for coppice crops. Harvests are taken after 3–5 years (Perlack et al., 1995).

Although the importance of domestic fuel in Malaysia has declined due to the considerable increase in the standard of living, rural people still use firewood and charcoal as a source of energy. These fuels are also consumed in substantial amounts in the manufacture of bricks, roof tiles, pottery, for the curing of tobacco, and in sawmills with kiln-drying facilities. Most of the charcoal is used in steel mills. In Peninsular Malaysia alone, the average annual consumption from 1972 to 1978 was 34 008 m^3 firewood and 163 569 m^3 charcoal (average of 1972, 1974, 1976 and 1978) (Wong & Kader, 1980). The most popular Malaysian fuelwoods are *Bruguiera* spp. and *Rhizophora apiculata* Blume. Three large areas in Malaysia are managed sustainably for the production of charcoal and firewood: Matang (Perak), Kelang (Selangor) and South Johor. The Matang mangroves have the reputation of being the best managed in the world (Frisk, 1984).

In Vietnam, about 75% of the total energy consumed is contributed by biomass fuel. The proportion in the domestic sector is nearly 100%. This includes about 45% fuelwood and 55% residues (Ministry of Forestry, 1992).

Burma (Myanmar) also relies heavily on biomass-based fuel: about 85% of the total amount of energy is provided by firewood and charcoal. As in Thailand, bamboo provides good fuel. As the rotation cycle of bamboo is usually shorter than for other fuelwood, the use of bamboo will diminish pressure on other sources of biomass fuel (Bhattacharya, 1986; U Saw Thun Khiang, 1993).
Other more recent estimates on the share of biomass in the total energy consumption for South-East Asia are presented in Table 2, some differing from the values given above.
Some wood is particularly suitable for charcoal. *Casuarina equisetifolia* and *C. junghuhniana*, for example, are widely used in Thailand. *Rhizophora mucronata* Poiret produces excellent charcoal too. Charcoal is preferred in many households in South-East Asia particularly in the slightly more affluent urban ones. It has a higher energy value than plain firewood, provides higher temperatures for industrial purposes (such as for smithies), is cheaper and easier to transport and provides cleaner cooking (less smoke).

Water-clearing agents

Domestic and industrial waste water may be treated by biological means: many microbial agents and water plants purify water by producing oxygen and taking up inorganic substances, even including heavy metals.
Small amounts of drinking water can be purified by adding vegetal products. These products are traditionally used in Africa and on the Indian subcontinent; their use is limited in South-East Asia. Flocculating agents or coagulants that clean water include crushed seeds of *Moringa oleifera* Lamk (Folkard & Sutherland, 1996), dried leaves of *Strychnos colubrina* L., and gum of *Anacardium occidentale* L. or *Lannea coromandelica* (Houtt.) Merrill that clarifies cane sugar or palm sugar juice e.g. in Indonesia (Jahn, 1988). Larger amounts of domestic or industrial waste water can be treated by channelling it into basins, water courses or lakes where water plants act as biological clearing agents (National Academy of Sciences, 1976). Common aquatic weeds in swamps can clean waste water. Situations where water moves slowly are ad-

Table 2. Share of biomass in the total energy consumption (%).

	Share of biomass (%)
Burma (Myanmar)	80– 90
Cambodia	n.a.
Indonesia	40– 50
Laos	90–100
Malaysia	0– 10
Papua New Guinea	n.a.
The Philippines	40– 50
Thailand	20– 30
Vietnam	50– 60

n.a. = not available

Source: FAO (1996).

vantageous for biological cleaning. Reeds (e.g. *Phragmites australis* (Cav.) Trin. ex Steudel), rushes (e.g. *Scirpus lacustris* L.), water hyacinth (*Eichhornia crassipes* (Martius) Solms), Nile cabbage (*Pistia stratiotes* L.) and submerged plants such as *Ceratophyllum demersum* L. take up nitrogenous and phosphorous compounds, harbour active microbial organisms and render the water safe for release to rivers or for use (or re-use) as domestic water. Anaerobic conditions should be avoided, by maintaining a partially free water surface or feeding oxygenated pretreated water to the weed-filled treatment ponds. Plants that have treated raw sewage must be disposed of safely. Water hyacinth can be fermented to methane gas.
In situ water clearing, even if not yet practised deliberately, occurs in all water courses with abundant plant life. In Belgium, dirty water from the Schelde river is treated in shallowly flooded reed beds. In the Netherlands, long ditches in which reeds grow reduce the investments and operating costs of activated sludge installations by 75% or more (de Ridder, 1996).
Water purification should only be tested with species present in the area, and never with newly introduced species, as water weeds are among the most dangerous weeds (National Academy of Sciences, 1976).

1.2.2 Importance

It is difficult to make sweeping statements about the actual role of auxiliary plants in terms of economic benefit, as statistical information is lacking. Only the value or tonnage of fuelwood can be estimated to a certain degree, using data from experiments (National Academy of Sciences, 1980). The fact that more than half of the world population depends on fuelwood for cooking, and that the consumption of fuelwood is still rising (FAO, 1994), illustrates the importance of this commodity.
The actual role of soil-protecting and soil-improving auxiliary plants is quantified in field experiments where the soil nutrient status and yield before and after the introduction of auxiliary plants have been measured. In some cases the effects are negative e.g. as a result of competition for resources between auxiliary and main crop plants and the overexploitation of the production function of the auxiliary plants. Possible yield losses of the main crop might, however, be compensated by these secondary products.
Auxiliary plants are important in maintaining soil fertility in the plantation agriculture of South-East Asia. This effect is such that soils are still highly productive even a hundred years after the forest vegetation has been cleared, even in areas with high rainfall and sloping land. However, over-exploitation and removal of products may result in nutrient mining and degradation of the soil.
Establishing contour strips of auxiliary shrubs and trees on slopes and then cultivating along the contours is an effective technique for erosion control. In the Philippines, this concept has been developed for farmers' use in the so-called 'Sloping Agricultural Land Technology' (PCARRD, 1986).
As long as land resources are adequate, improved fallows permit the fallow period to be shortened without much loss of yield and so contribute to intensification of production.
Atmospheric nitrogen fixation is an prominent attribute of the important category of leguminous auxiliary species. In many cropping systems the amount of

N supplied by legumes corresponds to at least 50 kg/ha per year. Generally speaking, farmers are only willing to adopt auxiliary crops if the rewards of the new practice appear substantial enough to make it worthwhile relinquishing traditional cropping practices. It is difficult to motivate farmers, particularly if the rewards are delayed, and show up in the productivity of subsequent primary crops (IITA, 1995). Participatory experimentation in these technologies as part of on-farm testing is essential, but many practical difficulties are involved (Versteeg & Koudokpon, 1994).

1.2.3 Selection of species

Plants having a service role as their primary use have been selected for inclusion as major species in this volume (Chapter 2); others are dealt with as minor species (Chapter 3). Mention has been made of the auxiliary role of plants in other commodity groups (Chapter 4), but only occasionally is such a species given a full treatment focusing on the service task (e.g. some forages).

1.3 Botany

1.3.1 Taxonomy

A large majority of the species dealt with in this volume are Dicotyledons. A few Gymnosperms (*Pinus caribaea* Morelet and other spp.), which are potentially of interest for reclamation purposes, are covered in the volume on Timber Trees. The major family harbouring plants with an auxiliary role is the *Leguminosae*. Table 3 shows that about 56% of the species treated in this volume as auxiliary plants are *Leguminosae*.
The most recent taxonomic classification has been followed, in accordance with international usage. Therefore several well-known *Cassia* species now have to be referred to as *Senna* or *Chamaecrista* species. The former subgenera in the large genus *Cassia* L. sensu lato have been elevated to genera, a taxonomic decision backed not only by morphology, but also by molecular and microbial data. However, it has been decided not to follow the split in *Acacia* L. in this volume, although this very large genus may well merit subdivision into several genera. This new classification of *Acacia* has only been carried out for the Australian species (Pedley, 1986), and this drastic step has met with some opposition. The genus *Racosperma* C. Martius has been reinstated, and the new combinations are listed in the relevant treatments as synonyms.

1.3.2 Growth and development

Certain characteristics of plants with different service functions are known; for instance, unbranched, rapidly growing stems are useful for trees producing stakes, prolific branching is useful for hedges, multiple stems produce firewood easy to fell, and rooting habit is important for cover crops. Fast growth is generally required. Good regeneration and coppicing abilities are major attributes for many plants in this commodity group. However, little is known about the growth and development of most auxiliary plants. Whatever information has become available is presented in the species treatments.

Table 3. Plant families contributing auxiliary plants.

Family	Major auxiliary plants	Minor auxiliary plants	Total	
			number	%
Actinidiaceae	–	6	6	2.8
Casuarinaceae	2	5	7	3.3
Ceratophyllaceae	–	2	2	0.9
Compositae	3	7	10	4.7
Convolvulaceae	3	1	4	1.9
Cyperaceae	–	7	7	3.3
Eriocaulaceae	–	5	5	2.4
Euphorbiaceae	1	1	2	0.9
Gramineae	–	10	10	4.7
Leguminosae	62	58	120	56.3
Caesalpinioideae	4	7	11	5.2
Mimosoideae	13	16	29	13.6
Papilionoideae	45	35	80	37.5
Meliaceae	2	–	2	0.9
Myrtaceae	3	–	3	1.4
Proteaceae	1	2	3	1.4
Rhizophoraceae	3	1	4	1.9
Scrophulariaceae	–	4	4	1.9
Other families	11	13	24	11.3
Total	91	122	213	100

1.3.3 Atmospheric nitrogen fixation and mycorrhizae

Atmospheric nitrogen-fixing organisms

Many of the auxiliary plants are associated with atmospheric nitrogen fixation, the reason why many cropping systems persisted to support reasonable levels of food production over the centuries without the addition of much fertilizer. Four groups of nitrogen-fixing organisms useful to plants can be distinguished (see also Table 4): root and stem-nodulating rhizobia, cyanobacteria (blue-green algae), *Frankia* species, and free-living nitrogen-fixing agents.

- *Root and stem-nodulating rhizobia* Rhizobia, the root-nodulating (*Bradyrhizobium* and *Rhizobium* spp.) and the stem and root-nodulating (*Azorhizobium caulinodans*) bacteria, that form symbiotic associations with *Leguminosae* and *Ulmaceae*, are the main group of nitrogen-fixing species. In water-logged conditions the associations between *Aeschynomene* spp. and *Bradyrhizobium* and between *Sesbania rostrata* Bremek. & Oberm. and *Azorhizobium caulinodans* and *Bradyrhizobium* are particularly interesting. Classification of these bacteria has made great strides in the last decade (Holt et al., 1994; Sprent, 1994; Sprent & Sprent, 1990; Woese, 1987).
  Sole crops of grain legumes in the tropics may fix from a few kg up to 200 kg N/ha annually in widely different cropping systems (Giller & Wilson, 1991). Trees and shrubs may fix up to about 270 kg N/ha per year, but here assess-

Table 4. Nitrogen-fixing organisms useful in plants.

Nitrogen-fixing organism	Host plant
Root-nodulating rhizobia	
Bradyrhizobium japonicum	soya bean
Bradyrhizobium sp.	cowpea
Rhizobium galegae	*Galega*
Rhizobium leguminosarum	
biovar. *phaseoli*	*Phaseolus* beans
biovar. *trifolii*	clover
biovar. *viciae*	*Pisum, Vicia*
Rhizobium loti	*Lotus*
Rhizobium meliloti	*Medicago, Melilotus*
Rhizobium tropici	*Leucaena, Phaseolus*
Stem-nodulating rhizobia	
Azorhizobium caulinodans	*Sesbania rostrata* Bremek. & Oberm.
Cyanobacteria (blue-green algae)	
Anabaena	*Azolla* (e.g. *A. pinnata* R. Br.)
Frankia spp.	*Alnus, Allocasuarina, Casuarina, Dryas, Elaeagnus, Gymnostoma, Myrica*
Free-living nitrogen-fixing agents	
Acetobacter diazotrophicus	sugar cane
Azospirillum lipoferum	grasses

Sources: Jones & Lewis, 1993; Sprent & Sprent, 1990.

ment of restricted root systems may not reveal the entire picture. Densely-planted saplings of *Leucaena leucocephala* may accumulate 500–600 kg N/ha in the aboveground mass annually, but these amounts are not due to nitrogen fixation alone. It should be recalled that it is notoriously difficult to quantitatively record and standardize atmospheric nitrogen fixation. Annual or short-lived perennial legumes are important for their role in rotations if crop residues are left in or returned to the field, or at least the root mass is left behind, or when these species are deliberately grown as green manure. In agroforestry the benefits are usually from leaf litter and ecological protection (shade, wind-break) but they may be offset by competition for light, water and nutrients. In that case, pruning treatments are called for (see *1.5.3*). Tropical pasture legumes have proven their value for nitrogen fixation, carbon storage and animal production ('t Mannetje, 1997). The use of nitrogen-fixing legumes is well established in Australia and there is reasonable adoption in parts of South-East Asia and Latin America. However, many countries, particularly in Africa, have problems related to land tenure, infrastructure and social justice that need to be solved first before improvements in agricultural production can take place.

Symbiotic nitrogen fixation by legumes is also important for phosphate nutrition. As a result of the availability of symbiotically fixed nitrogen, the plants will absorb more cationic than anionic nutrients. This uptake pattern causes the vicinity of the absorbing roots to acidify, and 'unavailable' soil phosphates and added rock phosphates may partially solubilize. As a result, leguminous plants are more efficient in phosphate uptake than, for example, cereals (Aguilar Santelises, 1981). Auxiliary leguminous plants can thus indirectly contribute to the phosphate nutrition of the main crop through leaf litter decomposition. There is also experimental evidence that P absorption of legumes can be enhanced further when vesicular-arbuscular mycorrhizae are active in addition to rhizobium bacteria (Aguilar Santelises, 1981).

– *Cyanobacteria (blue-green algae)* The second most important group of atmospheric nitrogen fixers covers the cyanobacteria (the blue-green algae), both the free-living ones and those associated with plant species, notably the aquatic fern *Azolla*, that harbours *Anabaena azollae* (Whitton, 1993). Free-living cyanobacteria can be cultivated and added to soils, the so-called algalization of rice paddies. In India, some two million ha are treated with mixtures of *Anabaena*, *Aulosira*, *Nostoc*, *Plectonema*, *Scytonema* and *Tolypothrix*. The inoculum is prepared in shallow open-air trays in which farm soil, superphosphate, starter inoculum and some insecticide are mixed. Lime is added to adjust the soil pH to 7.0–7.5. The cyanobacterial mat develops within 20 days and is then allowed to dry, producing flakes that can be harvested to inoculate the rice fields, typically about one week after transplantation of the seedlings. A tray of 1.6 m^2 provides sufficient inoculum for 1 ha. Preliminary results from Taiwan and Japan have not been as promising as in India, suggesting that prospects appear to be better in warmer regions. Local inocula may be more suitable than those introduced from other regions. The regional specificity of cyanobacterial strains needs to be verified by research (Whitton, 1993).

Of the six species of the microphyllous ferns, the only *Azolla* species used for agricultural purposes to date is *A. pinnata* R. Br. It is currently used in Thailand, North Vietnam, and China. In rice paddies, *Azolla* can accumulate 25–170 kg N/ha annually (Kikuchi et al., 1984), an average of 30 kg N per rice crop (Watanabe et al., 1977). *Azolla* requires particular conditions, which often restrict its applicability to certain areas. Permanent ponds are needed to maintain inocula, and high temperatures (30°C is optimum) and light intensities are generally not tolerated. Under proper conditions, *Azolla* spp. multiply rapidly: the population may double in two up to ten days in the field. *Azolla–Anabaena* combinations suitable for tropical conditions have to be selected; in China *Azolla*–rice cultivation occurs in 2% of the total 34 million ha used for rice. Competition with free-living bacteria, grazing and increased disease incidence under high temperatures are explanations for suboptimal performance. Rice cultivars less demanding of nitrogen fertilizer are often successfully grown with *Azolla* alone without fertilizer input (Whitton, 1993).

In the Philippines, a Bangkok strain of *Azolla pinnata* has been tested in the South Cotabato area and found to be successful: analysis after some years showed that up to 50 kg of fertilizer per ha was saved, and less labour was required to apply *Azolla* than to apply fertilizer (Watanabe et al., 1977). *Azolla* will be dealt with in the volume on Cryptogams.

- *Frankia species* A third important group in nitrogen fixation comprises *Frankia* species (Actinomycetes) grown in association with several woody species of some families like the *Casuarinaceae*, *Myricaceae* and the *Rhamnaceae*, which include perennials particularly important in agroforestry. This group has attracted interest relatively recently, and research in this field is increasing. Young *Casuarina* trees in symbiosis with *Frankia* have been found to fix 40–60 kg N/ha annually, but lower figures are also occasionally reported.
- *Free-living nitrogen-fixing agents* It is extremely difficult, if not impossible, to estimate the amounts of atmospheric nitrogen fixed by free-living N-fixing agents such as *Acetobacter* and *Azospirillum* present in the rhizosphere of plants. The amounts do not seem to surpass 5 kg N/ha per year; this is mainly observed in grassland.

For a review of the last hundred years of atmospheric nitrogen fixation research, see Bothe et al. (1988).

Mycorrhizae

The specific mycorrhizal associations of auxiliary crops are still largely unknown. Potentially, mycorrhizae can increase the efficiency of nutrient uptake of the auxiliary host plants. An interesting observation is that the P uptake of leguminous plants growing on soils with low P levels or on soils to which barely soluble rock phosphate has been applied can be improved by vesicular-arbuscular mycorrhizae (Aguilar Santelises, 1981). This implies that the often yield-limiting plant nutrient phosphate can be given in the cheap form of rock phosphate, and that when auxiliary crops are used, the crop–mycorrhiza association will not deplete assimilates at the expense of the main crop. For a recent review of the mycorrhizal associations in agriculture, forestry and horticulture, see Mitchel (1993). The finding that most indigenous trees in the tropical rain forest have vesicular-arbuscular mycorrhizae suggests that research on mycorrhizal associations in auxiliary tropical tree species is worthwhile.

1.4 Ecology

Climatic and soil conditions are important not only for the growth and development of the auxiliary crop in question, but also for the feasibility of its specific service function. The situations in which auxiliary plants are used vary widely, and hence the microclimate also differs accordingly. Auxiliary plants may influence microclimate by moderating the climatic factors, when grown as hedges, wind-breaks, shade trees and cover crops.
An overview of the ecological zones in which the most important auxiliary plants are grown is presented in Table 1.

1.4.1 Ecological interactions

The degree and type of interaction depend on the proximity of auxiliary plants and main crops in time and space. Sequential and simultaneous associations of auxiliary plants and main crop plants can be distinguished (Sanchez, 1995).

Sequential associations

In sequential associations the growth of auxiliary plants and main crops peaks at different times. In this case auxiliary plants usually enhance the growth of the main crop by improving the soil conditions. Herbaceous plants, shrubs and trees established as an improved fallow accumulate nutrients (and in the case of some leguminous species may also fix atmospheric nitrogen) which are released to subsequent crops through clearing and burning and the decomposition of non-burnt material.

Important attributes of fallow crops are easy establishment, rapid soil coverage, vigorous growth, deep rooting, no pest problems and, preferably, atmospheric nitrogen fixation. Easy removal and limited or no regrowth as a weed are also desired.

Improved fallows are only a relevant option if farmers own their land or have secure land tenure and can afford to stop cropping on part of it. Compared to natural fallows, improved fallows should either allow the fallow period to be shortened without reducing subsequent crop yields, or result in higher yields when fallowing for the same period. Compared to continuous cropping, yields after fallowing should be high enough to more than compensate for the yields forgone in the non-cropping period and for the costs of establishing and clearing the fallow vegetation. Improved fallows are especially attractive for farmers if they produce valuable products. However, appreciable removal of these products may interfere with the nutrient accumulation in the vegetation and topsoil.

The use of *Leucaena leucocephala* by farmers in the Philippines is an example of an improved fallow with auxiliary plants. This leguminous tree enables fallow periods to be reduced from 6–8 to 2–4 years without depressing subsequent yields of crops like rice and maize (MacDicken, 1991).

A transition between sequential and simultaneous associations is the use of cover crops in oil palm and rubber plantations. Cover crops are usually established 1–2 years before the main crop is planted. A few years later, by the time that competition for water and nutrients is becoming a serious problem, the cover plants phase out because of lack of light. The 4–5 year cover crop period, however, is long enough to enrich the soil with nitrogen, to recycle substantial amounts of nutrients for later use by the plantation crop and to provide favourable conditions for root development. In Malaysia, the combined action of these factors has been found to have a long-lasting positive effect on rubber yields (Broughton, 1977).

Another transitional type of association occurs when during the cropping season annual crops are interplanted with auxiliary fallow plants which are removed at the beginning of the next cropping season the following year. Research in Zambia (Sanchez, 1995) has demonstrated that relay intercropping maize with *Sesbania sesban* gives yields double those obtained when maize is the sole crop, whether or not fertilizer is applied. In this system *Sesbania sesban* reseeds itself. Initially, it grows slowly and hardly competes with the maize plants but later it grows fast and ultimately yields about 1.8 t fuelwood per ha annually. A two-year *Sesbania* fallow gave double maize yields over a six-year period in comparison with continuous maize production without fertilizers.

In south-western Ivory Coast, similar use is made of *Chromolaena odorata*, which has replaced the natural forest fallow vegetation on many sites. After a 2–4-year-old *Chromolaena* vegetation is slashed and burnt, one crop of maize is grown, while *Chromolaena* seedlings and sprouts from *Chromolaena* stumps quickly re-establish the new fallow vegetation (Slaats, 1995).
It can be concluded that in sequential associations the interactions between the components of the system are mainly positive.

Simultaneous associations

In all simultaneous associations, sharing of space and of the resources light, nutrients and water occurs. If one or more of these resources is in short supply, species compete unless they can occupy a different part of the same niche. This niche differentiation occurs, for example, in combinations of shade-tolerant crop plants and taller auxiliary plants. In this case, sharing of light is, in principle, beneficial for the output of the system, provided that nutrients and water are not limiting. The effect of shade on companion crops is very complex. It involves the reduction in light intensity, temperature and air movement and it affects relative humidity and soil moisture. Reduction in light is a very important effect, as radiation is one of the main factors governing photosynthesis. In a crop like cocoa in which the photosynthetic rate of individual leaves declines at light intensitites greater than 30% full sunlight, shade is needed, especially when young trees still have a single layer of leaves. The light requirements increase as trees start to develop a closed canopy with several layers of leaves. With higher light intensities the demand for nutrients also increases. This relationship between light and nutrition also means that shade can be used to balance nutrient demand and supply on less fertile soils. In addition to improving microclimate and light utilization, shade trees can contribute to improved nutrient cycling and to the supply of organic matter and nitrogen (see *1.4.2*). In a crop like cocoa, where the presence of shade trees generally improves the output of the system, the interaction between the components can be described as complementary.
Interactions in associations with species that do not tolerate shade have especially been investigated in alley cropping. In these agroforestry systems, food crops are grown between hedges of nutrient-cycling trees or shrubs which are periodically pruned during the cropping season to reduce shading and to provide green manure or mulch for the food crops. Fast-growing leguminous auxiliary species such as *Gliricidia sepium* and *Leuceana leucocephala* are often tested in experiments, using alleys about 4 m wide.
As a rule, the effects of prunings on crop yields, including the effects of nutrients and mulch, have been found to be positive and any negative shading effects have been minor when hedge plants are timely pruned. The subterranean sharing of resources, however, has often adversely affected crop growth, especially in semi-arid areas where soil moisture is limiting (Ong, 1994).
On the basis of two decades of research it can be concluded that alley cropping is most likely to work well only on moderately fertile soils without nutrient limitations and when rainfall is adequate during the cropping season (Sanchez, 1995). On sloping land the prospects for contour alley cropping in drier areas are more favourable. In long-term experiments in the semi-arid Machakos area

of Kenya the soil cover of prunings and the *Senna siamea* hedges themselves greatly reduced erosion, while increased infiltration rates in the soil under the hedges trapped runoff water. This accumulation of water under the hedges was such that no competition for soil moisture occurred (Kiepe, 1995).
It can be concluded that although in simultaneous associations the interactions between the components of the system may be positive, they are often negative.

1.4.2 Aspects of soil fertility

One of the most important service functions of auxiliary plants is the maintenance and improvement of soil fertility. Auxiliary plants can fulfil this function by reducing and/or preventing losses from the soil, improving the chemical and physical conditions of the soil and promoting soil biological processes on account of increasing inputs (e.g. nitrogen, organic matter).

Increasing inputs

Through carbon fixation in photosynthesis and its transfer via litter and prunings and subsequent decomposition and via root decay, auxiliary plants can help in maintaining and sometimes in improving soil organic matter levels. It has been estimated (Young, 1989) that to maintain soil organic matter in the humid, sub-humid and semi-arid tropics annual supplies of organic matter in the order of 8 t, 4 t and 2 t dry matter per ha respectively, are needed to compensate for decomposition and minor erosion losses. There is clear experimental evidence that these supply levels can be achieved in cropping systems with auxiliary plants. Some data are given in Table 5.
The use of leguminous crops to augment nitrogen in the cropping system is a well-known agricultural practice. Rates of biological nitrogen fixation in herbaceous legume crops in fallows and plantation agriculture range annually from a few to 50 kg and up to 200 kg per ha (Giller & Wilson, 1991). Low levels of available phosphate – a common feature of tropical soils – and a lack of soil moisture in drier areas are well-known factors limiting nitrogen fixation. Very few data are available on nitrogen fixation by legume trees and shrubs. Studies on *Leucaena leucocephala,* however, suggest that shrubs and trees which will yield 50–100 kg biologically fixed N per ha per year in agroforestry systems can be identified. Since most of the nitrogen from leguminous crops is taken up as mineral N from the soil, the N yield of leaf fall and prunings is at least twice as high (see Table 5).
As pruning prevents nutrients being translocated from the leaves to perennial organs (the normal process preceding natural leaf fall) it is an effective practice to ensure that nutrients are re-allocated from the auxiliary crop to the main crop at the proper time (see also *1.5.3*). This re-allocation involves the decomposition of residues of natural litter and prunings. The favourable effects of this re-allocation on the nitrogen nutrition of the main crop are well known in rubber. Results presented in Table 6 show that young rubber trees with a leguminous cover return twice as much nitrogen to the soil by annual leaf fall than with a grass ground cover (Watson, 1988).
The question of direct N transfer from the roots of auxiliary plants to companion crops is still controversial. Nitrogen-fixing plants in general acidify the rhi-

Table 5. Annual return of dry matter and nutrients by auxiliary crops in different cropping systems (kg/ha).

Auxiliary system	Annual return (kg/ha)					
	dry matter	N	P	K	Ca	Mg
Prunings of *Leucaena leucocephala* hedges planted with a 4 m wide interrow	7400	246	20	184	98	16
Litter and prunings of *Erythrina poeppigiana* trees at a 6 m × 6 m spacing in cocoa plantation	9400	122	7	27	n.a.	n.a.
Leguminous cover crops (mixed *Calopogonium mucunoides*, *Centrosema pubescens* and *Pueraria phaseoloides*) in rubber plantation						
litter only (average annual return during the first two years after establishment)	3019	70	6	16	n.a.	10
living biomass and litter at two years after establishment	n.a.	283	25	109	114	33

n.a. = not available

Sources: Alpizar et al. (1986, 1988), Kang & Wilson (1987), Rubber R.I.M. (1972), Watson (1988).

zosphere and there is evidence that this increases the P uptake from insoluble phosphate (see *1.3.3*). This would be an additional benefit of growing leguminous auxiliary crops (Aguilar Santelises, 1981).

Uptake of nutrients from deeper soil layers is another mechanism by which deep-rooting auxiliary crops can increase the input supply. There is still a lack of quantitative data on this. It is clear, however, that a substantial input of nutrients can only be expected if subsoils are chemically rich, which is rarely the case.

Table 6. Effect of different soil covers on nitrogen cycles and root development of young rubber trees.

	legume	grass
Total annual N return in cover and rubber leaf litter (kg/ha)*	240.2	22.4
Annual N return in rubber leaf litter only (kg/ha)**	40.5	19.1
Rubber roots, surface and 0–8 cm soil layer (kg/ha)***	7633	3605

* averages of 4 annual samplings over years 3–5.
** determined over 4th year, tree density 408 /ha.
*** determined during 3rd–4th year.

Source: modified after Watson (1988).

Reduction of losses from the soil

Auxiliary plants can play an important role in reducing or even preventing carbon and nutrient losses and erosion. Improved fallow crops and cover crops in plantation agriculture intercept and transpire a significant part of the rainfall which would otherwise have caused leaching of nutrients. Deep-rooting auxiliary plants can potentially recover and recycle nutrients leached into deeper soil layers, but the importance of this process is still unknown. The vegetation cover lowers the soil temperature and this slows down the decomposition rates of soil organic matter. Shade trees prevent and reduce losses in a similar way by providing an extra canopy layer.
A ground cover of auxiliary plants also reduces nutrient losses in runoff and erosion. Hedges along the contours of slopes have been found to be very effective in erosion control. They check erosion and runoff through the cover effects of prunings and reduce soil losses through a barrier effect. Moreover, they contribute to the development of terraces through soil accumulation upslope of the hedges. Recent results of a long-term experiment in Kenya confirm earlier findings in Nigeria that contour hedges on sloping land greatly reduce erosion, especially when prunings are applied to the soil surface in the inter-rows (Kiepe, 1995). A summary of the Kenyan results is presented in Table 7.

Improvement of physical soil conditions and biological processes

By providing a permanent well-developed living or mulch cover, soils under auxiliary crops exhibit a better structure, porosity and moisture characteristics than most soils under arable crops. The favourable effects of improved physical soil conditions on crop growth are well documented and are illustrated in Table 6. Improved soil structure and porosity are linked to the decomposition of plant residues by microorganisms and fauna. Their activity is stimulated by the ex-

Table 7. Mean annual soil loss in t/ha over 6 seasons on a 14% slope at Machakos Research Station, Kenya (*Cassia siamea** hedges planted at a distance of 4 m across the slope).

		Rainfall (mm)	Mean annual soil loss (t/ha)			
			Control	Mulch only	Hedge only	Hedge + Mulch
LR**	1990	631	36.1	4.6	2.2	0.2
SR**	1990	333	0.0	0.0	0.0	0.0
LR	1991	214	0.0	0.0	0.0	0.0
SR	1991	352	5.4	1.1	0.0	0.0
LR	1992	222	3.8	0.0	0.0	0.0
SR	1992	808	12.6	4.1	1.6	1.2
Annual mean		853	19.3	3.3	1.3	0.5

* *Senna siamea*
** LR: long rains, SR: short rains

Source: Kiepe (1995).

tra supply of litter and prunings, but depends greatly on the source of the plant biomass.
Plant residues can be classed as being of high or low quality in terms of decomposition rates. The first category has a low C/N ratio and low lignin and polyphenol contents, and decomposes and releases nutrients rapidly, mainly by microbial and fauna processes. *Gliricidia* and *Leucaena* species are among the plants with high-quality residues, hence these residues are a good source of nutrients for fast-growing crops. Low-quality residues with a high C/N ratio and high lignin and polyphenol contents decompose and release nutrients slowly. Mulching with plant residues improves soil conditions by lowering soil temperature and maintaining soil moisture, and slowly decomposing mulches have an advantage for this purpose (Tian, 1992).
The foregoing observations imply that auxiliary plants can be specifically chosen for their nutritional effects or as mulch, and that the timing of pruning is important to synchronize soil nutrient supply and crop nutrient demand.

1.5 Management

Farmers pay most attention to their primary food and cash crops. They are more interested in production functions than in service functions. Auxiliary plants will therefore probably not receive inputs such as fertilizer, irrigation and pest control. Management is needed in the form of assistance in establishing the plant stand, pruning and harvesting. Therefore, the introduction of auxiliary crops in existing cropping systems is often not attractive, as more labour is involved, and the system becomes more complicated. A green manure that produces an edible by-product is likely to be accepted more readily by farmers.
It is likely that in the case of auxiliary crops, the removal of a product will result in depletion of soil fertility if not compensated. Auxiliary crops only increase the ecological sustainability of cropping systems if the emphasis is on their service functions. The production functions, however, can be vital in strengthening the economic basis of these systems.

1.5.1 Planting material

Most auxiliary species are established from seed. For seeds with very hard impervious testa, as found in many leguminous crops (such as *Centrosema pubescens*), mechanical or chemical scarification or hot water treatment is used to ensure a quick and even germination. Sometimes seeds are dusted or coated with phosphate fertilizer to improve early growth. Inoculation of seeds with *Rhizobium* strains to improve nodulation is still in an experimental phase but has given promising results in Brazil with *Centrosema macrocarpum* Benth. and *Pueraria phaseoloides* (Sylvester-Bradley & Mosquera, 1985). Some species with poor seed production, for example *Vigna hosei*, are established from cuttings. Sometimes cuttings are used for economic reasons. Kudzu (*Pueraria lobata* (Willd.) Ohwi) cuttings, for example, can be planted at 1 m spacing; only the planting spot has to be weeded, as the rapidly growing sprouts quickly overgrow the weeds in the surrounding area.
Some woody species like *Gliricidia sepium* are successfully and cheaply plant-

ed as cuttings. The seedless cross between the varieties *glabrata* Rose and *leucocephala* of *Leucaena leucocephala* is budded on one of the parent rootstocks in Indonesian plantation agriculture, to avoid weed problems caused by profuse seed production.

Azolla is propagated vegetatively by means of older secondary stems which detach themselves from the main stem after an abscission layer has been formed. As *Azolla* cannot stand desiccation, its application depends on the presence of irrigation or perennial ponds. Another condition for its use is the availability and conservation of inoculum (Cagauan & Pullin, 1994).

1.5.2 Establishment

The growing of cover crops in admixtures is often practised in oil palm and rubber estates in South-East Asia to quickly achieve a complete soil cover, a gradual phasing out when the canopy closes and to diminish the effects of diseases and pests. A common mixture is *Pueraria phaseoloides*, a vigorous grower which provides a thick cover and suppresses weeds, *Calopogonium mucunoides* which shows rapid initial growth but does not persist and is susceptible to pests, and *Centrosema pubescens* which forms a good cover after a slow initial growth and has some tolerance of shade. Recently, *Calopogonium caeruleum* (Benth.) Sauv. gained some prominence.

In simultaneous systems, planting patterns are important in view of competitive interactions. If crops are mutually non-competitive or beneficial, intimate spatial mixtures can be used. If there is strong mutual competition, auxiliary crops can best be grown in separate blocks or along field boundaries. Alley cropping in which auxiliary plants are arranged in rows or strips represents an intermediate degree of mixing. Distances between hedges depend on the auxiliary species, their possible secondary economic value, and the terrain (slope angle). In most experiments single hedgerows and alley widths of about 4 m have been used, which corresponds with a tree cover of 15–20%. Much greater distances are used for shelter-belts and wind-breaks.

During early establishment cover crops have to be weeded, unless they are on newly cleared forest soils. This is one of the reasons that farmers may prefer vigorous and self-seeding fallow crops such as *Chromolaena odorata* and *Sesbania sesban* or fast-growing large-seeded species such as velvet bean, rather than the well-known cover crops used in plantation agriculture.

1.5.3 Post-establishment practices

Once established, plantation cover crops are regularly removed from the tree weeding circles and slashed, especially at the beginning of dry periods, to reduce competition. In rotation systems the cover crops are ploughed into the soil before the next crop is planted. Shade trees are usually planted at a close spacing one or two years ahead of the main crop. Later they are thinned to a final stand, depending on the species and the shade requirements of the crop. Afterwards, shade levels are managed by pruning. Some shade trees such as *Erythrina poeppigiana* are regularly pollarded or pruned for shade management and the production of mulch.

Hedgerow trees and shrubs are periodically pruned to reduce shading and to provide prunings for mulch or fodder. Pruning at the beginning of the cropping season is essential for crop development. Pruning at this time is a major problem for most farmers, however, because it coincides with land preparation and weeding. Both the frequency and the height of pruning affect the biomass production and its N content. An experiment at Ibadan, Nigeria showed that a higher pruning height and less frequent pruning resulted in a higher N yield in a *Leucaena* hedgerow system, but reduced maize yields due to shading (Duguma et al., 1988). In farming practice a compromise has to be found between mulch production and maize yields.

The decomposition rates of prunings depend on the nature of tree and shrub species but also on the mode of application. *Leucaena* prunings, for example, usually decompose quickly (within 40 days), more rapidly if applied fresh than dried. The direct nutritional effect of prunings is better when they are buried in the soil, because they decompose faster (Young, 1989). Similar results have been obtained with *Gliricidia sepium*. For practical reasons, surface application is the normal practice. Dried material is easier to transport (less bulky) than fresh material.

As to the timing of pruning, additions of organic inputs should be directed at a nutrient release in synchrony with the crop's uptake pattern, not only to promote crop growth but also to reduce losses of released nutrients by leaching and denitrification.

The most important cultivation practice with *Azolla* in rice fields is to incorporate it into the soil. If grown as a sole crop before transplanting, a permanent water layer is needed. If grown as an intercrop, it is incorporated once or several times during the first month after transplanting. Incorporation at a later stage makes nitrogen available during the maturation period. In the intercropping system incorporation is very labour intensive. If *Azolla* is grown outside the rice field it can continuously produce a biomass which can be incorporated fresh or after composting before transplanting.

1.6 Genetic resources and breeding

There is such a diversity of species useful as auxiliary plants that it is complicated to involve institutions to include these genetic resources in their mandate. In addition to the occasional samples in certain botanic gardens, the agricultural research institutes have also gathered germplasm of auxiliary plants. The major international research centres focus on food and technical crops. The International Centre for Research in Agroforestry (ICRAF, Kenya) specializes in agroforestry, and maintains a large database of a multipurpose tree and shrub seed directory (von Carlowitz, 1986). International cooperation in multipurpose tree germplasm is well documented (Burley & von Carlowitz, 1984). The whereabouts of genetic resources of many auxiliary plants can be found in the Food Legumes and Forages volumes of the IBPGR (now IPGRI) Directories of Germplasm Collections (Bettencourt et al., 1992), including most relevant legume species and many browse plants (including legumes too). The various institutions are listed countrywise, and usually more than 80% of the samples are available without restrictions. In the South-East Asian region, the Malaysian Agricultural Research and Development Institute (MARDI) in Serdang, and the Philippine Institute of Plant Breeding (IPB), College of Agriculture in

Laguna are listed as having limited collections of forages. These institutes also have browse legumes in their collections. The Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia has also accumulated large germplasm collections of forage species with a potential auxiliary role.
The Centro Internacional de Agricultura Tropical (CIAT, Colombia) has included South-East Asia in its worldwide search for potential fodder crops, and amongst these several species have auxiliary roles. Although several catalogues are available, they provide few data below the genus level (Schultze-Kraft, 1990, 1991a, 1991b). The Kew seed bank at Wakehurst, England, maintains many species for the semi-arid and arid tropics. It provides samples, but in small quantities for research purposes only and in small numbers per species.
Unlike many of the food crops, auxiliary species do not have numerous cultivars. Where large amounts of seed are required, it is difficult to obtain the proper ecologically adapted seed source. Information as obtained from the species treatments in this volume points to CIAT and CSIRO as organizations that have the occasional selection of improved fodder crop cultivars, but few particular cultivars have been specially bred for e.g. green manure. An exception is the attention *Leucaena* has received; many selections of this crop have been released. In several countries with a long-established practice of plantation cropping, such as Malaysia and India, seed of clover and other auxiliary plants can be obtained from commercial companies.

1.7 Prospects

Until the 1970s auxiliary crops mainly received attention in plantation agriculture. Suitable species were selected, their service functions and cultivation practices studied and documented, and this resulted in a general adoption in plantation management. Auxiliary crops will continue to play an important role in commercial tree crop cultivation but no major breakthroughs can be expected in this field. During the last 30 years, when degradation of natural resources became an important issue, the need to develop production systems which would integrate growing of trees or shrubs, arable crop production and/or animal husbandry in order to optimize tropical land-use systems became apparent. The study and development of these so-called agroforestry systems has renewed interest in auxiliary crops and put them back on the agenda of international and national research and development organizations. By delivering services and products and by spreading the risk of crop failure, agroforestry systems have the potential to strengthen the ecological and economic basis of agricultural production systems. Ethnobotanical surveys indicate that many multipurpose plants with auxiliary functions are used in traditional agriculture.
In the transition from semi-permanent arable cropping to more intensive land-use systems, the role of auxiliary species is likely to increase. However, when the stage of permanent arable cropping is reached, only short-duration fallows with auxiliary crops will be used. Farmers will only adopt this strategy if soil moisture is inadequate for other short-duration crops such as pulse crops. Strip cropping with auxiliary shrubs and woody species has been proposed in permanent arable cropping systems, but multi-locational experiments have clearly

shown that these so-called hedgerow intercropping systems are only suitable when soil moisture and soil fertility are not limiting.
In some parts of South-East Asia where large areas of wasteland need to be reclaimed for agriculture and forestry, the role of auxiliary plants is becoming very important. Finally, the need to take marginal land into cultivation may also imply an increase in use of auxiliary crops as well. Contour planting with auxiliary trees and shrubs has shown promise, especially on sloping land.
Being of less direct importance than the primary crops, research on the role and performance of auxiliary plants has until recently received little attention. Their large potential for fodder and fuelwood production and soil conservation, and their specific, often customized role in traditional cropping systems merits further research.
Research on the lesser-known auxiliary plants covered in this volume will prove useful, especially to corroborate the few studies done sofar. The adoption of cropping systems that include auxiliary plants would be facilitated if seed of auxiliary species were more readily available from national and international research centres and from commercial suppliers.

M. Wessel & L.J.G. van der Maesen

2 Alphabetical treatment of species

Acacia aulacocarpa A. Cunn. ex Benth.

London Journ. Bot. 1: 378 (1842).
LEGUMINOSAE – MIMOSOIDEAE
$2n = 26$

Synonyms *Acacia aulacocarpa* A. Cunn. ex Benth. var. *macrocarpa* Benth. (1864), *A. lamprocarpa* O. Schwarz (1927), *Racosperma aulacocarpum* (A. Cunn. ex Benth.) Pedley (1987).

Vernacular names Brown salwood, hickory wattle, New Guinea brown wattle, New Guinea wattle (En).

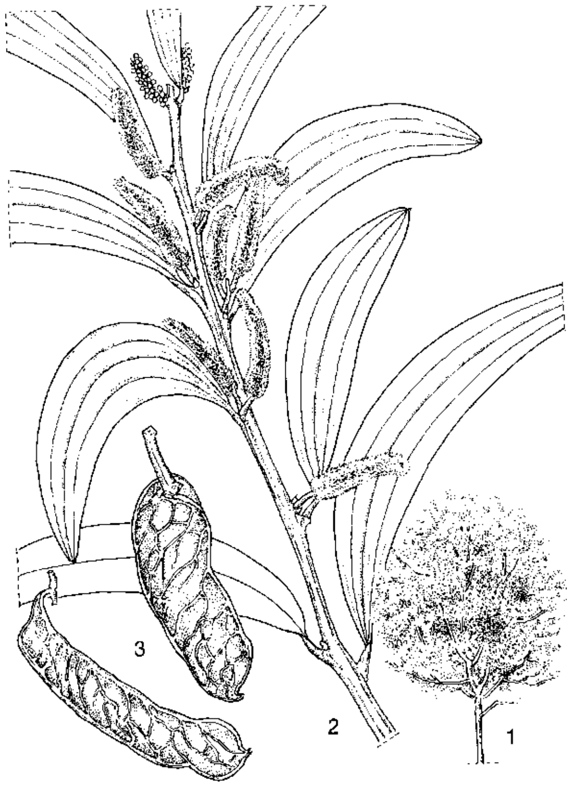
Origin and geographic distribution *A. aulacocarpa* occurs naturally in Australia, Papua New Guinea and Indonesia. It extends from northern New South Wales, eastern Queensland and the northern parts of the Northern Territory in Australia to southern Papua New Guinea and adjoining areas of south-eastern Irian Jaya. It has been tested in most countries of South and South-East Asia.

Uses The wood of *A. aulacocarpa* is suitable as firewood, for construction and flooring, boat building, furniture and cabinet work, tool handles, boxes and crates, joinery and turnery. It has excellent potential as a source of fibre for pulping and paper-making industries, producing one of the strongest bleached kraft pulps among acacias. *A. aulacocarpa* is used in reforestation of poor soils.

Properties Nutrient content of the foliage per 100 g dry matter is: N 2.2 g, P 0.09 g, K 0.74 g, Ca 0.43 g, S 0.31 g, Mg 0.26 g, Cu 0.9 mg, Zn 4.5 mg, Mn 28.1 mg, Al 8.1 mg, B 3.5 mg. Dry matter digestibility and protein content of the foliage are low, making it unsuitable as a fodder. The weight of 1000 seeds is 12.5–25 g.

The sapwood of *A. aulacocarpa* is narrow, pale yellow to straw-coloured, distinct; heartwood pale olive-brown to grey brown, often attractively streaked with grey bands. The wood is hard, strong, and moderately heavy with a basic density of 600 kg/m^3, an air-dry density of 645–720 kg/m^3 at 12% moisture content, and an energy value of 21 600 kJ/kg. In a test, wood of a 12-year-old tree gave a screened pulp yield of 55.4% with Kappa number 19.3. The sapwood is susceptible to attack by *Lyctus* borer and the heartwood has low to moderate durability in contact with the ground. Charcoal made from *A. aulacocarpa* wood has a density of 500 kg/m^3 at 1.25% moisture and an energy value of 37 100 kJ/kg.

Description Shrub to slender, large tree, 3–40 m tall; trunk up to 1 m in diameter, sometimes fluted. Bark hard, brownish, about 1 cm thick, longitudinally fissured, peeling in long strips. Phyllodes straight or falcate, acute or subacute, 5–15 cm × 0.6–3.5 cm, 3–12 times as long as wide, glabrous, greyish-green or dull grey, with 3 prominent longitudinal veins somewhat crowded towards the lower margin at base, usually not yellowish, and with many parallel, not anastomosing, secondary veins; pulvinus 4–6 mm long with an ellipsoid basal gland. Inflorescence a spike, 2–6 cm long, yellow, 1–3 together; peduncle 2–8 mm long, scurfy; flowers 5-merous, bisexual; calyx broadly cupular, 0.5–1 mm long, membranous, with broad, obtuse, scurfy lobes 0.2–0.3 mm long; corolla 1.2–1.9 mm long, lobed to the middle, glabrous, 2–3 times as long as the calyx; stamens many, 2.5–3 mm long; ovary 0.5 mm long, shortly pubescent or scurfy. Pod oblong, up to 10 cm × 2 cm, light brown, coriaceous to subwoody, with prominent obliquely transverse, dark brown veins, glabrous, often twisted when old. Seed elliptical-oblong, 5–8 mm × 2.5–3.5 mm, shiny black, transverse or oblique in pod, with pale terminal aril.



Acacia aulacocarpa A. Cunn. ex Benth. – 1, habit; 2, flowering branch; 3, pods.

Growth and development Mature seeds germinate readily. After the cotyledons have fully unfolded, a pinnate leaf with 8–10 leaflets emerges. This is followed by a bipinnate leaf. A second bipinnate leaf follows, and usually it is from this leaf position onwards that the flattened petiole expands to form a phyllode, but with a bipinnate leaf remaining intact at the tip. Following this stage, seedlings develop to full phyllode stage, producing phyllodes without intact bipinnate leaves. The adult foliage form is reached about 6 weeks after germination.

Trees attain 12–16 m in height and 11–14 cm in diameter in 4 years. *A. aulacocarpa* was tested in Guyana on strongly leached, white quartz sandy soil with pH 4.7 and an annual rainfall of 2400 mm. It grew to 12.5 m tall in 3 years, while *A. auriculiformis* A. Cunn. ex Benth. attained only 7.8 m, and *Pinus caribaea* Morelet and *Paraserianthes falcataria* (L.) Nielsen failed completely.

A. aulacocarpa is an evergreen atmospheric nitrogen fixing species. The main and lateral shoots grow almost throughout the year, but growth may stagnate during the very hot and dry season. Trees generally start to flower after 3 years. The main period of flowering is from February to April in subtropical Australia and from April to June in tropical parts of its natural range. Insects, especially bees, are believed to be the main pollinating agent. Seeds mature 4–5 months after flowering. It is not uncommon for *A. aulacocarpa* to produce two seed crops per year.

Other botanical information Two varieties have been distinguished: var. *aulacocarpa* and var. *fruticosa* C.T. White. The former is a tree, phyllodes with crowded nerves, 7–15 cm long, 4–12 times as long as wide; calyx 0.7–1 mm long; pod usually 1.5–2 cm wide; the latter is a bushy shrub up to 3 m tall, phyllodes with less crowded nerves, 5–10 cm long, 3–5 times as long as wide; calyx 0.5–0.6 mm long; pod 1–1.2 cm wide. Var. *fruticosa* is restricted to southern Queensland. These and other differences between populations in humid and dry areas are the focus of current taxonomic attention.

The most closely related species is *A. crassicarpa* A. Cunn. ex Benth., whose distribution overlaps that of *A. aulacocarpa* in northern Queensland and Papua New Guinea. *A. crassicarpa* has very narrow (2–4 mm), long fruits, whereas *A. aulacocarpa* has contorted, wider (1–2 cm) ones. *A. aulacocarpa* is also closely related to *A. auriculiformis* which has contorted fruits with undulate margins. *A. aulacocarpa* has phyllodes without anastomosing secondary veins, in *A. auriculiformis* these veins are somewhat anastomosed. *A. aulacocarpa* may infrequently hybridize with *A. crassicarpa*.

Ecology The main occurrence of *A. aulacocarpa* is in warm to hot humid and sub-humid zones of the tropics and subtropics, at the latitudinal range 6–30°S, and it extends from near sea level in New Guinea up to about 1000 m altitude in Australia. Mean annual rainfall ranges from 500–3000 mm with a monsoonal distribution. The mean minimum temperature of the coolest month is 10–21°C and the mean maximum temperature of the hottest month is 29–38°C.

A. aulacocarpa is mainly a species of open forest and woodland, but with limited extension into rain forest. In open forest it grows in association with *Eucalyptus miniata* Cunn. ex Schauer and *E. tetrodonta* F. v. Mueller, on the edges of semi-arid woodland with *E. polycarpa* F. v. Mueller and *E. papuana* F. v. Mueller. On rain forest fringes it is often associated with *E. pellita* F. v. Mueller, *E. intermedia* R. Baker, *Acacia cincinnata* F. v. Mueller, *A. mangium* Willd. and *A. polystachya* A. Cunn. ex Benth. On the swampy coastal plains of north-eastern Australia and south-western Papua New Guinea, it occurs with *A. mangium* and *A. crassicarpa* between wet depressions dominated by *Melaleuca* spp.

A. aulacocarpa grows in a wide topographical range including undulating highlands, ridges, and steep rocky slopes, as well as on the flat and gently undulating terrain of coastal plains and foothills. It is found frequently on yellow earths, red or yellow podzolics that are usually acid or very acid and of low fertility, and on sandy clay soils. It tolerates a wide pH range.

Propagation and planting Propagation is generally by seed, although cuttings and air layering can also be used. Seeds have a hard seedcoat which requires heat treatment or nicking to break dormancy. Immersion in boiling water for 1 minute is a suitable treatment. Treated seeds are sown in germination beds and seedlings are transplanted into polythene bags when they reach the 2 leaf-pair stage. Seeds can also be sown directly into polythene bags. Young seedlings should initially be kept at 50% sunlight, but this can be increased to 70% once the seedlings are established. Excess shading often results in attack by mildew and other fungi and damping off. In general, the seedlings are 25–30 cm tall and ready for transplanting 3–4 months after sowing. A spacing of 3–4 m × 3–4 m is considered suitable for firewood and pulpwood plantations.

Husbandry *A. aulacocarpa* competes very well with weeds including *Imperata cylindrica* (L.) Raeuschel. In plantations with 2–3 m × 2–3 m spacing, it will totally suppress *I. cylindrica* grass within 2–3 years. However, weed control is necessary in the first 2 years to help establishment.
An 8–10-year rotation is recommended for pulpwood plantations, and a 15–20-year rotation for saw logs.
A. aulacocarpa does not coppice well, but there is evidence that trees from Queensland respond to coppicing better than those from Papua New Guinea. The coppicing mechanism is not well understood.

Diseases and pests Apart from infestation by powdery mildew in the nursery, trees are sometimes attacked by a *Sinoxylon* sp. that girdles small stems and branches of less than 2 cm in diameter only, causing them to break at the point of attack. Attack by a stem pinhole borer (*Lyctus* sp.) has been reported in Sabah, Malaysia.

Yield *A. aulacocarpa* has shown considerable variation in growth and yield. In general, provenances from Papua New Guinea grow much faster than those from Australia. At a planting site in southern Thailand, a seedlot from Oriomo, Papua New Guinea, produced an above-ground dry biomass of 103 t/ha in 3 years, twice as much as that produced by material from Queensland. Papua New Guinea provenances have also shown satisfactory growth in Sabah.

Genetic resources The Australian Tree Seed Centre, Commonwealth Scientific and Industrial Research Organization (CSIRO, Canberra), has a good coverage of genetic material from the natural range in Australia and Papua New Guinea. Seed from Papua New Guinea provenances is also available from the Forest Research Institute in Lae. Seed from seed orchards established in Thailand is now available.

Breeding Current breeding programmes are limited to a small number of progeny trials, which are being converted into seed orchards in Australia, Indonesia, Malaysia and Thailand.

Prospects Because of its good fuel, timber and pulping characteristics, *A. aulacocarpa* has great potential as a plantation species in the humid and sub-humid tropics. Its tendency to have a fluted stem may reduce its value for some purposes, like veneer. Its light to moderate shade makes it also useful for shade and ornamental planting. Further study of the coppicing mechanism is warranted.

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K. Pinyopusarerk

Acacia auriculiformis A. Cunn. ex Benth.

London Journ. Bot. 1: 377 (1842).
LEGUMINOSAE – MIMOSOIDEAE
$2n = 26$

Synonyms *Racosperma auriculiforme* (A. Cunn. ex Benth.) Pedley (1986). *Acacia auriculaeformis* A. Cunn. ex Benth. is a formerly commonly used orthographic variant of *A. auriculiformis*.

Vernacular names Northern black wattle (Australian standard trade name), ear-pod wattle, tan wattle (En). Earleaf acacia (Am). Indonesia: akasia, ki hia (Sundanese). Malaysia: akasia kuning. Papua New Guinea: Papua wattle. Philippines: Japanese acacia, auri. Cambodia: smach'té:hs. Thailand: krathin-narong (Bangkok).

Origin and geographic distribution Natural stands of *A. auriculiformis* are found in Australia (Cape York Peninsula, Queensland, northern areas of the Northern Territory), south-western Papua New Guinea and Indonesia (Irian Jaya, Kai Islands). The domestication of *A. auriculiformis* began about 50 years ago. It is planted widely in tropical Asia, with extensive plantings in China and India. In western Malesia it has also become naturalized. It is planted to a lesser extent in Africa and South America.

Uses *A. auriculiformis* is a major source of firewood, its dense wood and high energy value contributing to its popularity. It provides very good charcoal which glows well with little smoke and does not spark. In agroforestry systems, *A. auriculiformis* appears to be used mainly for fuelwood. Its superficial and densely matted root system makes *A. auriculiformis* suitable for stabilizing eroded land. It has been used widely in revegetation and rehabilitation of degraded land in Indonesia. It is planted to provide shelter along beaches and sea fronts. Because of its tolerance of poor soils it is used in reforestation of tin and bauxite mine tailings. Its phyllodes provide a very good, long-lasting mulch.

The wood of *A. auriculiformis* is extensively used for paper pulp and small saw timber. It makes attractive furniture. Crooked and multiple stems have long restricted its use as poles or other forms of timber that require to be of reasonable length, but genotypes with good trunk form have been identified and are now widely planted. Plantation-grown trees have been found to be very promising for the production of unbleached kraft pulp and high quality neutral sulphite semi-chemical pulp. Large-scale plantations have already been established e.g. in Kerala, India, for the production of pulp. The bark is collected locally for use as tanning material.

The foliage is not a good fodder and is rarely, if ever, browsed by cattle. Lac insects have been found on trees of *A. auriculiformis* in India, but it is probably not a good substitute for traditional host species. An edible mushroom, *Tylopylus fellus*, is common in plantations of *A. auriculiformis* in Thailand. The flowers are a source of pollen for honey producing bees.

The dense dark green foliage which remains throughout the dry season makes it an excellent shade tree. It is a popular ornamental tree with attractive, bright yellow flowers. The flowers are marketed in Burma (Myanmar) as altar flowers.

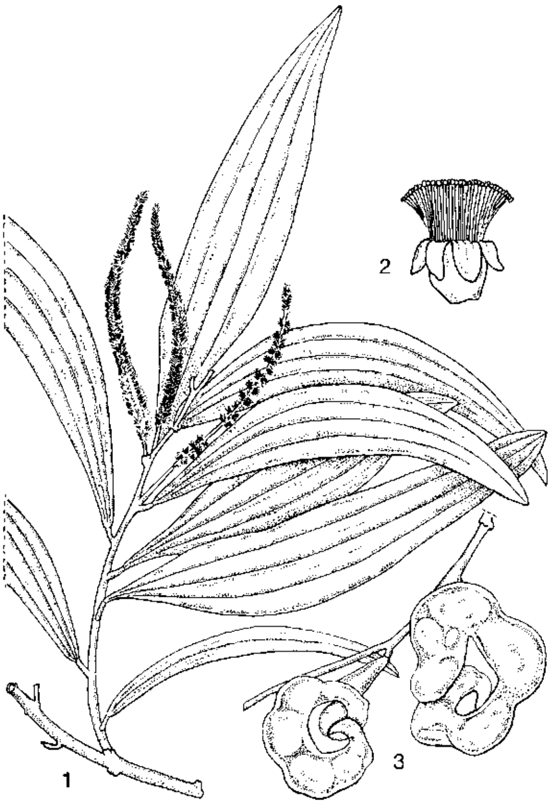
Properties Phyllodes decompose slowly in comparison with those of other leguminous trees like *Paraserianthes falcataria* (L.) Nielsen or *Leucaena leucocephala* (Lamk) de Wit; this has been attributed to a lower N content and a harder cuticula. In West Java, phyllodes used as a mulch were 95% decomposed after 16 months.

The bark contains sufficient tannin (13–25%) for commercial exploitation and contains 6–14% of a natural dye suitable for the soga-batik industry.

Leaves have an in vitro dry matter digestibility of 33–37%. Per 100 g dry matter, leaves contain: crude protein 13–16 g, P 0.06–0.11 g, K 0.45–0.72 g, Ca 0.52–0.77 g, Mg 0.18–0.24 g.

The wood of *A. auriculiformis* contains 66% cellulose, 31% lignin, 16% pentosans and 1.5% ash. Flavonoid substances are present. It is heavy with more than 70% of the volume being heartwood. The sapwood is yellow; the heartwood light brown to dark red, straight grained and reasonably durable. It has a fine to medium texture and is often attractively figured. The density is 490–840 kg/m^3 at 15% moisture content. The fibre is relatively short, about 0.85 mm long and 0.2 μm in diameter. The physical and mechanical properties of the wood as compared to teak as standard are considered high. The wood is easy to work, takes a good polish and finishes well. Boards, however, have a tendency to split when sawn. The energy value of the wood is 20 000–20 500 kJ/kg. Tests on *A. auriculiformis* charcoal carried out in Thailand, gave an energy value of 32 300 kJ/kg and a density of 404 kg/m^3. It gave little or no smoke or sparks. The weight of 1000 seeds is 15–30 g.

Description Tree up to 30 m tall with trunk up to 12 m long and 50 cm in diameter, often smaller with crooked stem and heavily branched; branchlets angular, glabrous. Bark grey or brown, more



Acacia auriculiformis A. Cunn. ex Benth. – 1, flowering branch; 2, flower; 3, pods.

or less smooth in young trees, becoming rough and fissured with age. Phyllodes curved or falcate, 10–16 cm × 1–3 cm, glabrous, greyish-green, 3–4 longitudinal veins prominent, usually not yellowish, running towards the lower margin or in the middle near the base, with many, fine, crowded, somewhat anastomosing secondary veins; pulvinus 4–6 mm, with at the top a distinct, swollen gland with small rimmed orifice. Inflorescence an axillary, somewhat interrupted spike, 7–10 cm long, growing in pairs; peduncle 5–8 mm long; flowers 5-merous, bisexual, tiny, sessile, golden-yellow, fragrant; calyx tubular, 0.7–1 mm long, shortly lobed, glabrous; corolla 1.7–2 mm long, about 2 times as long as the calyx; stamens many, about 3 mm long; ovary densely pubescent. Fruit a flat pod, about 6.5 cm × 1–2.5 cm, cartilaginous or woody, brown, glaucous, transversely veined with undulate margins, initially straight, on maturity becoming very twisted with irregular spirals. Seed broadly ovate to elliptical, 4–6 mm × 3–4 mm, shiny black, hard, transversely attached, encircled by a long red or orange funicle; areole large, almost closed.

Growth and development Under favourable conditions, seedlings grow quickly and reach a height of 25–30 cm in 3–4 months, 6 m in 2 years, and 6–12 m in 3 years. Young seedlings produce 2–3 bipinnate leaves, soon followed by phyllodes. Phyllodes are retained during the dry season; their average life is about 1 year in West Java.

Under favourable conditions, *A. auriculiformis* grows into a tree, 25–30 m tall, with a straight stem dominant for a greater part of the tree height. Where it is introduced, e.g. in India, it is commonly a low tree, 8–12 m tall, much branched and with a crooked stem. Inbreeding in introduced populations with a narrow genetic base has been suggested as a major cause of poor form.

Flowering usually starts within 2 years after sowing. Though flowering occurs throughout the year, there is usually a distinct peak flowering season. These periods vary considerably with locality. In Java, for example, peak flowering is from March to June. Seeds mature in 4–5 months and store well. Germination rate is adequate after storage in airtight containers at room temperature for 18 months or for several years in air-conditioned rooms.

Nodulation and atmospheric nitrogen fixation by *A. auriculiformis* are profuse under good growing conditions, but this potential can only be reached where soil fertility, especially in terms of P content, is adequate. In trials in the Philippines, 52–66% of nitrogen uptake has been derived from nitrogen fixation. Nodulation is profuse, with a range of *Rhizobium* and *Bradyrhizobium* species. Ecto-mycorrhizal fungi (*Thelephora* spp.) and endo-mycorrhizal fungi (*Glomus etunicatum*, *Glomus macrocarpum* and *Gigaspora margarita*) have been shown to form effective associations.

Other botanical information *A. auriculiformis* is closely related to *A. aulacocarpa* A. Cunn. ex Benth. and *A. leptocarpa* A. Cunn. ex Benth. It is difficult to distinguish from *A. aulacocarpa*, which has phyllodes with non-anastomosing veins, while those of *A. auriculiformis* are somewhat anastomosing. *A. leptocarpa* has long, non-contorted pods with seeds disposed longitudinally, and the veins in the phyllodes are spaced more widely.

The natural habitat of *A. auriculiformis* overlaps with that of several closely related species. Natural hybrids with *Acacia mangium* Willd. and *Acacia leptocarpa* occur. The hybrids with *A. mangium* are intermediate between the two parents in flower, fruit, and seed characteristics and in physical and mechanical wood properties. They inherit the better stem straightness of *A. mangium* and the self-pruning ability and better stem roundness of *A. auriculiformis*. Their growth is sometimes more vigorous and resistance to heart rot is better.

Ecology *A. auriculiformis* occurs in the humid to sub-humid lowland tropics, growing naturally in narrow strips along river banks but also on coastal dunes, tidal flats, saline lagoons and floodplains. Individual trees may be widely scattered in savanna woodland or swamp forest dominated by tall *Melaleuca* spp. It occurs naturally from sea level to 400 m. In plantations in Nepal and Zimbabwe it has done well up to 1000 m altitude. In its natural range, the mean maximum temperature of the hottest month is 32–38°C and the mean minimum temperature of the coldest month 12–20°C. Rainfall varies between 760 mm in the Northern Territory (Australia) and 2000 mm in Papua New Guinea; its distribution is monsoonal and the dry season may last 6 months. Plantations have been established in areas with as little as 650 mm to over 6000 mm rainfall annually. Frost does not occur in its natural range, but elsewhere light frost is tolerated. It does not tolerate shade. Wind tolerance is low, as branches break easily in strong winds.
A. auriculiformis is exceptionally tolerant of adverse soil conditions. In Papua New Guinea it grows well on well-drained acid soils and on imperfectly drained heavy clay soils subject to temporary or prolonged waterlogging and flooding. Soils in its natural range in Australia include dune sands, black cracking clays, and alluvium derived from sandstone or laterite. The pH usually ranges from 4.5–6.5, but in the Northern Territory it grows on beach sands with a pH of 8–9, as well as on the spoils of uranium mines with pH 3. It is highly tolerant of soil salinity. In an experiment in Thailand, it continued growing under saline conditions ranging from 0.15 to 7.25 dS/m, in both wet and dry soils.

Propagation and planting The use of local, often inbred seed sources should be discouraged to avoid inbreeding depression and the resulting poor tree form. Seeds picked at physiological maturity do not show dormancy, but mature seeds require a pregermination treatment, such as immersion in boiling water for 1–2 minutes followed by soaking in cold water overnight or soaking in warm water for 24 hours. After suitable treatment, germination starts about 6 days after sowing and typically exceeds 75%.
Seeds are mostly sown in nurseries. Direct sowing is also possible. Sowing from the air has sometimes been successful, but site preparation prior to sowing is required. Seedlings in the nursery require little attention and there are no serious diseases and pests. Newly emerged seedlings should receive 50% shade; once established, 70% full sunlight is optimal. In general, 3–4 months are needed to raise transplantable seedlings that are 25 cm tall. Inoculation with rhizobia and mycorrhizae is rarely necessary, unless seedlings are raised in sterilized media or planted in highly degraded soils or mine spoils.
Methods of vegetative propagation through juvenile cuttings have been developed and are now a routine and simple operation. Trees can be pollarded to produce cuttings.
The optimum planting density is not clearly established. Most current plantings employ spacings of 2–4 m × 2–4 m, the closer spacing being more suitable for firewood and pulp plantations. In China, spacings of 1–1.5 m × 1.5–2 m are favoured by farmers producing fuelwood and poles.

Husbandry Removal of lower branches of young plants has been suggested as a means of improving stem form and of reducing the incidence of multiple stems. *A. auriculiformis* responds well to pollarding. Tree age, stump diameter and height are important factors in sprouting, although their effects are not well understood and warrant detailed investigation. Plantings in *Imperata* grasslands have survived fires, but are generally too severely damaged to make *A. auriculiformis* a suitable tree for *Imperata* control.
The effect of intercropping with annual crops varies. Increased tree growth has been found with kenaf (*Hibiscus cannabinus* L.), upland rice and groundnut in Thailand, reduced growth with maize in Cameroon.

Diseases and pests No serious diseases and pests occur. Seedlings in the nursery are reported to be infested by powdery mildew and rust, but these do not usually cause serious damage. In nurseries and young plantations in Indonesia growth rates have been impaired by the rust *Uromyces digitatus*. Root rot caused by *Ganoderma lucidum* is reported from India. A beetle (*Sinoxylon* sp.) can girdle young stems and branches, causing them to break. This insect is of concern, because the tree will develop multiple leaders if the main stem is damaged, and the length of the bole will be reduced. Experimental results suggest that *A. auriculiformis* has some resistance to termites.

Harvesting *A. auriculiformis* does coppice well, but it does not sprout vigorously or prolifically. Better results are obtained when the stump is cut at a height of 0.6–1 m above the ground. Tree age, stump diameter and season of cutting also influence coppicing ability. It responds well to pollarding.

Yield Under favourable conditions, trees may reach a height of 15 m in 5 years, and produce an average annual wood increment of 15–20 m^3/ha over 10–12 years, the age at which it is usually harvested. On very poor or severely eroded soils, mean annual increment drops to 8–12 m^3/ha. Under rainfall conditions of 1000–1400 mm/year and a pronounced dry season in West Bengal, India, the mean annual increment was only 2–6 m^3/ha. Differences between provenances are large. On a well-drained site in Thailand receiving about 1500 mm rainfall annually, a provenance from Balamuk (Papua New Guinea) produced a total above-ground biomass of 135 t/ha in 3 years, while a provenance from Springvale (Australia) reached only 60 t/ha. On a regosol overlaying marl in West Java in a region with a rainfall of 2700 mm/year, the biomass increment from year 3 to 4 was 15.7 t reaching 96.1 m^3 in year 4; stemwood made up 60% of the total above-ground biomass; stem diameter increased from 12.2 cm to 13.6 cm; litter production was 10.7 t/year of which 6.4 t were leaves.
Up to 500 g of seed per tree has been collected.

Genetic resources The Australian Tree Seed Centre of the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Canberra maintains seed stocks of representative provenances from throughout the natural range of *A. auriculiformis*. Comprehensive living collections are currently maintained on Melville Island, Australia, and in provenance trials in China, Thailand and elsewhere.

Breeding High levels of genetic variation exist in *A. auriculiformis*. Intra and inter-population genetic variation is considerable and important in initial selections in domestication programmes. Generally, 3 distinct groups can be distinguished, corresponding to their geographic distribution in Queensland, Northern Territory, and Papua New Guinea, respectively. International provenance trials were established in 1989 to examine the extent of genotype × environment interactions. Results from Australia and Thailand show that provenances from Queensland have a higher proportion of straight stems. Several countries have genetic improvement programmes which aim to improve this characteristic. Collection of seeds from phenotypically superior trees, field progeny trials, and seedling-seed orchards have produced promising results.
Natural hybridization of *A. auriculiformis* with *A. leptocarpa* and *A. mangium* has been observed in both natural stands and plantations. Many hybrids show desirable characteristics, such as vigour, fine branching and tendency for strong apical dominance, which will eventually lead to a tree with single stem and a long, straight, branchless bole.

Prospects Few species can match the ability of *A. auriculiformis* to grow on harsh sites in the tropics. Although it grows slower than some other species under optimal conditions, its fast growth rate, the ability to fix atmospheric nitrogen and its tolerance of infertile, acid, alkaline, saline and seasonally waterlogged soils, and of moderately dry seasons make it a most useful tree for the rehabilitation of degraded lands. Its ease of cultivation and multiple uses make it suitable for growing by farmers. Straight-stemmed forms have outstanding prospects for industrial plantations to produce paper pulp and other timber products. The use of *A. auriculiformis* as a parent of hybrids is of great potential, perhaps even exceeding the potential of the species itself.

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J.W. Turnbull & Kamis Awang

Acacia crassicarpa A. Cunn. ex Benth.

London Journ. Bot. 1: 379 (1842).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26$

Synonyms *Racosperma crassicarpum* (A. Cunn. ex Benth.) Pedley (1987).

Vernacular names Northern wattle, Papua New Guinea red wattle (En).

Origin and geographic distribution *A. crassicarpa* occurs naturally in north-eastern Queensland, south-western Papua New Guinea and south-eastern Irian Jaya. Experimental plantings have been made in several countries in South-East Asia.

Uses The wood of *A. crassicarpa* is suitable for firewood, making charcoal and timber, e.g. for construction, furniture, flooring, board, boat building. It appears suitable for pulping, but more study is required to confirm this use. The tree provides shade and can be planted for weed control and is often cited as an effective species for the rehabilitation of land infested with *Imperata cylindrica* (L.) Raeuschel. In Papua New Guinea, it is reported to be a very vigorous colonizer of degraded soils following shifting cultivation.

Properties The leaves decompose slowly and are useful as mulch. The sapwood is pale yellowish-brown and heartwood golden-brown. The wood is strong and durable with a density of 670–710 kg/m^3 at 12% moisture content and a basic density of 620 kg/m^3. Its energy value is 22 600 kJ/kg. The weight of 1000 seeds is 20–30 g.

Description A small to medium-sized tree, up to 25(–30) m tall; bole often straight and branchless for up to 13–18 m, up to 50 cm in diameter, sometimes fluted at base. Bark dark or grey-brown, hard, with deep vertical furrows; inner bark red and fibrous. Phyllodes falcate, 8–27 cm × 1–4.5 cm, 2.5–12 times as long as wide, greyish-green, glabrous; primary veins 3–5, prominent, yellowish, longitudinal, tending to run into the lower margin at the base; secondary veins parallel, not anastomosing, crowded; pulvinus 4–20 mm long with a circular gland at top. Inflorescence a bright yellow spike, 4–7 cm long, clustered in groups of 2–6 in the upper axils; peduncle 5–10 mm long, rachis thick; flowers 5-merous, bisexual; calyx broadly cupular, 0.5–0.7 mm long, lobes con-

Acacia crassicarpa A. Cunn. ex Benth. – 1, habit; 2, flowering branch; 3, pod.

cave, lobed to about halfway down; corolla widely spreading, glabrous, 1.3–1.6 mm long, 2–3 times as long as the calyx; stamens 2–3 mm long; ovary shortly pubescent, more densely hairy at the top. Pod woody, ovoid-oblong, flat, 5–8 cm × 2–4 cm, glabrous, dull brown, transversely veined but hardly reticulate. Seed oblongoid, 5–6 mm × 2–3 mm, black, arranged transversely in separate compartments; areole large and almost closed; funicle folded and thickened, forming a long aril below the seed, pale creamy-yellow.

Growth and development Young seedlings first produce pinnate leaves, but develop phyllodes from the 3rd or 4th leaf pair. Under favourable conditions, seedlings grow rapidly reaching 25–30 cm in 3–4 months. *A. crassicarpa* is one of the fastest growing tropical *Acacia* spp. It appears to maintain active shoot growth almost the year round, although a few months of stagnation may occur in the dry season.

In Sabah, it attained a mean height of 15–23 m and a mean diameter of 10–16 cm in 4 years, outperforming other fast-growing *Acacia* species including *A. auriculiformis* A. Cunn. ex Benth. and *A. mangium* Willd. Assessment at 15 months after planting in a progeny/provenance trial in northern Australia showed that the mean height and diameter at breast height of Papua New Guinea provenances were 5.2 m and 5.1 cm respectively. The corresponding averages for Queensland provenances were 3.3 m and 2.9 cm respectively. This faster growth of Papua New Guinea provenances is consistent with results from trials in southern China, southern Queensland and Thailand. In Queensland, *A. crassicarpa* trees are often small, hardly exceeding 10 m; the typical form is bushy with a heavy crown, although long and straight boles can also be found.

Flowering starts as early as 18 months after planting, while seed is produced in abundance after 4 years. Seeds mature 5–6 months after flowering. In its natural range it flowers from June to September and bears mature fruits from October to March.

A. crassicarpa is a vigorous atmospheric nitrogen fixer and nodulates well with a group of related *Rhizobium* strains.

Other botanical information *A. crassicarpa* is sympatric with *A. aulacocarpa* A. Cunn. ex Benth. to which it is closely related. *A. crassicarpa* is distinguished by its broader and more woody pods. *A. crassicarpa* may infrequently form natural hybrids with *A. aulacocarpa* in northern Queensland (Australia).

Ecology *A. crassicarpa* occurs mainly in the humid and sub-humid tropics from 8–20°S and from 0–200(–450) m altitude. Annual rainfall in its natural habitat is from as low as 500 mm in Australia to as high as 3500 mm in Papua New Guinea and Irian Jaya. Length of the dry season ranges from 6 months at the southern limit of the distribution area near Townsville, Queensland, to 3 months at the northern limit in Papua New Guinea and Irian Jaya.

The mean minimum temperature of the coolest month is 15–22°C and the mean maximum temperature of the hottest month is 31–34°C. No frost occurs in its natural range.

In Australia, *A. crassicarpa* is commonly found immediately behind beaches, on the coastal plains and foothills. It appears to be tolerant of salt spray and soil salinity. It occurs on a variety of soil types, from calcareous beach sands, yellow earths derived from granite, red earths on basic volcanic rock to alluvial and colluvial soils derived from a variety of parent material. In Papua New Guinea and Irian Jaya *A. crassicarpa* is found on the gently undulating terrain of the Oriomo Plateau, on well-drained, strongly acid soils, and also on imperfectly drained soils that flood in the wet season. On former rain forest wetlands with a sandy-loam soil it is superior in growth to *Acacia mangium* Willd. In the southern coastal lowlands of Queensland *A. crassicarpa* occurs in the understorey of open forest and in open woodland dominated by *Eucalyptus pellita* F. v. Mueller, *E. tereticornis* Smith or *E. tessellaris* F. v. Mueller. On frontal sand dunes it is found as a wind-sheared shrub or small tree, 2–8 m tall, behind *Casuarina equisetifolia* L. and associated with *Alphitonia excelsa* Reissek ex Endl. On Cape York Peninsula it is associated with *Eucalyptus tetrodonta* F. v. Mueller, *Allocasuarina littoralis* L.A.S. Johnson, and *Melaleuca* spp. In Papua New Guinea, *A. crassicarpa* occurs frequently with *A. aulacocarpa*, *A. auriculiformis* and *A. mangium*.

Propagation and planting Seeds remain viable for many years and heat treatment or nicking of the seedcoat is required to break dormancy. Immersion in boiling water for 1 minute is a suitable treatment. Treated seeds are sown in germination beds. Germinated seedlings having 2 pairs of leaves can be transplanted into polythene bags containing a mixture of soil and river sand. Seedlings are raised under partial shade, then in the open, and planted out when stem height reaches 25–30 cm. Inoculation of nursery seedlings with a selected *Rhizobium* strain prior to planting out is recommended for maximum nodule development. Vegetative propagation through air layering has given promising results in Thailand. Spacing of 3 m × 3 m (1100 trees/ha) to 4 m × 4 m (625 trees/ha) is suitable for land reclamation, fuelwood and pulpwood plantations.

Husbandry On sites dominated by *Imperata cylindrica* or other weedy plants, weed control is necessary in the first 1–2 years to ensure establishment. Trees do not coppice well. In open situations, the crown is strongly branched and casts a moderate shade. Preliminary observations indicate that *A. crassicarpa* is resistant to low-intensity fires.

Diseases and pests Fungal pathogens of leaves and shoots such as *Cercospora* sp. can affect productivity, particularly during prolonged periods of high humidity. *A. crassicarpa* is susceptible to attack by a stemboring beetle (*Platypus* sp.), in Sabah. The beetle, native to Sabah, bores into the stem and is a vector for fungi and bacteria which weaken and stain the stemwood. Young trees are also attacked by a beetle (*Sinoxylon* sp.) that girdles small stems and branches of less than 2 cm in diameter, causing them to break at the point of attack.

Yield At Sai Thong in Thailand with 1500 mm mean annual rainfall, *A. crassicarpa* derived from Woroi Wipim in Papua New Guinea produced a total above-ground dry biomass of 207 t/ha in 3 years, much more than several other species tested. At a poorer site in Ratchaburi in central Thailand it performed as well as other *Acacia* species tested, producing a total above-ground dry biomass of 40 t/ha in 3 years.

Genetic resources The Australian Tree Seed Centre, Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra has a good coverage of genetic material from the natural range in Australia and Papua New Guinea. The Papua New Guinea Forest Research Institute in Lae supplies seed of Papua New Guinea provenances. Selected *Rhizobium* strains are available from the Department of Agriculture, University of Queensland, Brisbane, Australia.

Breeding Current research is limited to a small number of progeny and provenance trials, which are being converted to seedling seed orchards.

Prospects Because of its fast growth and its ability to produce large volumes of wood even on infertile land, *A. crassicarpa* has great potential for various forestry practices. It is also suitable for planting for land reclamation, but is too competitive to grow in combination with annual crops. Investigation into the factors affecting coppicing ability is warranted.

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K. Pinyopusarerk & C.E. Harwood

Acacia glauca (L.) Moench

Methodus: 446 (1794).
LEGUMINOSAE – MIMOSOIDEAE
$2n = 26$

Synonyms *Mimosa glauca* L. (1753), *Acacia villosa* (Swartz) Willd. (1806), including forma *glabra* Backer (1963), *Acaciella villosa* (Swartz) Britton & Rose (1928).

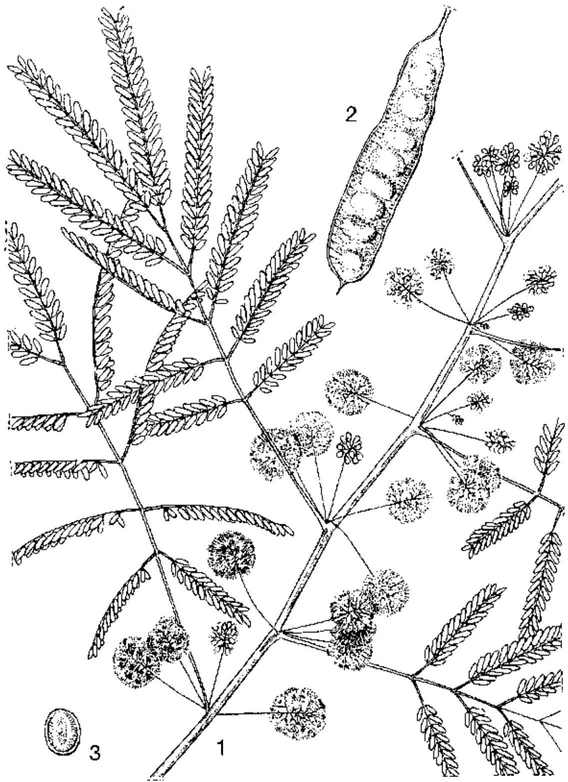
Vernacular names Wild dividivi, redwood, wata pana (En). Acacia (Am). Amourette (Fr). Indonesia: mlanding sabrang, mlanding merah (Java), petes merah (West Timor).

Origin and geographic distribution *A. glauca* originated in tropical America. It is common in parts of southern Central America and on many West Indian islands, in particular on Curaçao and Barbados. In 1920, *A. glauca* was introduced into Java, where it then naturalized, especially in the region of Yogyakarta. It has been planted experimentally in the Philippines, where it is said to have naturalized as well.

Uses In Indonesia *A. glauca* was originally planted as an alternative undershrub to *Leucaena leucocephala* (Lamk) de Wit in teak plantations. At present, it is mainly used to rehabilitate degraded and denuded lands and as a stabilizer of terrace ridges. It is a common ornamental throughout the tropics.
The wood is suitable for fuel and for making household tools. *A. glauca* has been used as a host plant for the lac insect *Laccifer lacca* in East Java. In West Timor it is used as a forage, but it is generally reported for Java that goats and other livestock do not like it, although chicken eat the seeds.
In the Caribbean an infusion of the roots or leaves in vinegar and of the bark in water is used as a gargle to relieve sore throat and alleviate oral inflammations. A decoction of peeled branches with vinegar and sugar is taken as a cough medicine.

Properties An analysis of dried leaves from Indonesian material gave per 100 g: crude protein 27 g, ether extract 4.8 g, non-digestible fibre 24 g, total phenolics 12.6 g, tannins 6 g. Weight of 1000 seeds is 11 g.

Botany Erect, unarmed shrub or small tree, 1–3(–5) m tall, with open crown and many dark red stems and branches. Root system tough and spreading, superficial. Branches terete, sparsely pubescent to glabrous, younger twigs more strigose. Leaves bipinnately (sometimes tripinnately) compound, pinnae in 2–10 pairs, 4–9 cm long, rachis 8–12 cm long, glandless; leaflets 10–30 pairs per pinna, opposite, oblong-lanceolate, 4–10 mm × 1–2 mm, unequal sided, base rounded, top blunt with acute tip, hairy to glabrescent; stipules lanceolate, early caducous. Inflorescence a short, sometimes subcapitate, 20–40-flowered spike, 2–6 together in the upper axils, the uppermost arranged in racemes; peduncle up to 2.5 cm long, pedicel 1–2 mm, articulated; flowers 5-merous, bisexual, white turning yellowish; calyx campanulate, 0.5–1 mm long, 5-lobed; corolla tubular, 5-lobed, 2–4 mm long; stamens numerous, ovary stipitate with 5 mm long style. Fruit a flat, membranaceous pod, oblong to strap-shaped, 1.5–10 cm × 0.5–2 cm, stalk about 1 cm long, apiculate, glossy brown, 1–8-seeded, valves swollen where seeds develop, transversely veined along the margins. Seed ovoid to lenticular, brown.



Acacia glauca (L.) Moench – 1, flowering branch; 2, pod; 3, seed.

A. glauca extends itself by root suckers from its comparatively superficial root system. In experiments in Indonesia comparing its performance with other fast-growing legumes, *A. glauca* was consistently among the fastest growing species, especially on very poor soils. It can reach a height of about 3 m and a stem diameter of 3 cm in 13 months from planting. Growth during the juvenile phase is often stronger than in *Leucaena leucocephala*; after 6 months, however, it loses its advantage. Flowering and fruiting may start very early; in an experiment in Indonesia flowering started within 6 months from planting. It flowers throughout the year.

The habit of *A. glauca* is quite similar to the shrub forms of *Leucaena leucocephala*, but young twigs are more reddish and pods shorter and more rounded.
The synonymous name *Acacia villosa* is still very commonly used in South-East Asia. In 1753, Linnaeus described this species as *Mimosa glauca*. Later, however, he used this name for a species that is now known as *Leucaena leucocephala*, causing much confusion.

Ecology *A. glauca* prefers a rather dry climate. It even grows well where mean annual rainfall is as low as 200–500 mm and the relative humidity 55–70%. In Indonesia, optimum rainfall is about 1200 mm/year in regions up to 1200 m altitude. It performs poorly under low temperature and does not tolerate frost.
A. glauca occurs in secondary vegetation, especially on limestone, but also on non-calcareous soils. On very poor soils it will grow better than *L. leucocephala* and most other legume species. It is less tolerant of shade than *L. leucocephala*, but reports of its tolerance of waterlogging are contradictory.

Agronomy Propagation is by seed or by root suckers. Germination is irregular, unless seeds are scarified or treated with hot water. In the West Indies *A. glauca* spreads very easily and is never planted. Nevertheless, it has not become a noxious weed in Indonesia.
A. glauca tolerates heavy pruning and produces root suckers regularly. In comparison with *L. leucocephala*, it has a more superficial root system and produces fewer leaves. *A. glauca* is generally free of diseases and pests.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained and there are no known breeding programmes.

Prospects Observations over many years and experimental results in Indonesia and the Philippines indicate that *A. glauca* is a very useful undershrub in forest plantations, a shrub legume in agroforestry and a species to rehabilitate degraded soils. In view of its good performance on very poor soils and its unpalatibility to livestock, its use as an alternative to *Leucaena leucocephala* deserves wider attention.

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J. Jukema & S. Danimihardja

Aeschynomene afraspera J. Léonard

Bull. Jard. Bot. Etat Brux. 24: 64 (1954).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 80$

Synonyms *Aeschynomene aspera* auct., non L., *Sesbania leptocarpa* auct., non DC.

Vernacular names Sola pith (En). Thailand: sano (refers to related species as well).

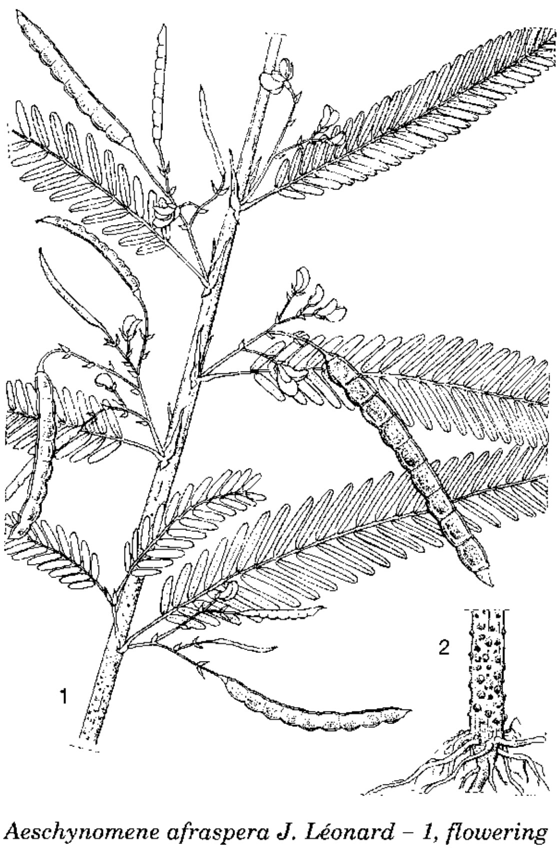
Origin and geographic distribution *A. afraspera* is believed to have originated in sub-Saharan Africa between Senegal and Sudan. It is widely distributed in the lowlands of western, central, north-eastern and southern Africa. In 1986 it was introduced into the Philippines and since then has been grown experimentally across South and South-East Asia.

Uses The potential use of *A. afraspera* as a fast-growing nitrogen source for wet-rice fields has only recently been noted. Since the late 1980s it has been widely used as a pre-rice green manure crop

on experimental stations and in extension demonstration trials. So far it is only occasionally used by farmers in South and South-East Asia.
In its region of origin *A. afraspera* is grazed by ruminants. In Zambia it is valued as a palatable forage legume. In Senegal the pith of the stems is used as insulation material and medicinally it is applied to stop bleeding.

Properties The fresh biomass of young *A. afraspera* contains 10–20% dry matter and has a C:N ratio of 10–16. Per 100 g dry material the above-ground parts contain: N 2.5–3.7 g, P 0.28–0.55 g, K 1.3–2.3 g, lignin 9–13 g. As a green manure *A. afraspera* mineralizes rapidly. The weight of 1000 seeds is 21–29 g.

Description Erect to suberect, branching, herbaceous, annual shrub, 1–3 m tall. Root and stem hollow or pith-filled. Stem glabrous, soft, with abundant, spirally arranged, white or pale green adventitious root primordia, which may develop into hemispherical, green nodules. Leaves alternate, composite, stipulate, sensitive; petiole and rachis 3–18 cm long, 1.5–3 cm in short, axillary branchlets; leaflets (20–)50–100, linear-oblong, 8–20 mm × 1.5–3 mm, 4–7 mm long in leaves on axillary branches, entire or finely denticulate, glabrous. Inflorescence an axillary raceme, 2–6 cm long with 1–6 flowers; bracts glabrous, 3–8 mm × 2–5 mm; pedicel 5–9 mm long (in fruit up to 12 mm), pubescent; calyx bilabiate, glabrous or slightly pubescent on the outside, 6–8 mm long and 4–4.5 mm wide; corolla pale to bright yellow; standard elliptical to obovate, 9–12 mm × 7–10 mm; wings free, 7 mm × 2 mm; keel petals pubescent, about elliptical, loosely adnate, 9–11 mm × 3–4 mm. Pod 5–8 cm × 7–8 mm, venose when young, very warty and dark brown to black when mature, with 6–10 1-seeded segments.



Aeschynomene afraspera J. Léonard – 1, flowering and fruiting stem part; 2, base of stem with roots and nodules.

Growth and development Initial growth until 5-leaf stage is slow. With the onset of stem nodulation and/or closure of the canopy *A. afraspera* grows rapidly, reaching 0.6–1.5 m in 2 months. Plants growing in isolation are sub-erect to spreading, with abundant branching. In a dense stand, plants grow erect with a single stem. Under flooded conditions, a shallow taproot with abundant intervascular aerenchyma develops and root primordia grow into adventitious roots.
In the Philippines *A. afraspera* starts flowering 65 days after sowing during the short-day season, and after 80 days when daylength exceeds 12 hours. With prolonged soil flooding, the otherwise short flowering period can extend to over 2 months. Fruit ripening causes drying and brown discolouration of leaves and stems, ending the growth cycle.
The most distinctive characteristic of *A. afraspera* is the presence of nitrogen-fixing nodules, not only on the roots but also on predetermined, sub-epidermal primordia of adventitious roots on stems and branches. Upon infection with rhizobia via rain splash or insect activity the root primordia can develop into nitrogen-fixing nodules. Since root nodules are scarce under anaerobic conditions in flooded soils, *A. afraspera* has to rely on stem nodules to fix atmospheric nitrogen. Root primordia on stems become visible in 2-week-old plants, and profuse stem nodulation is apparent 3–5 weeks after germination. Up to 400 nodules can be found on the stem of a 2-month-old plant and 70–80% of the nitrogen in the biomass is reportedly derived from biological nitrogen fixation, indicating the high efficiency of the symbiosis in stem nodules. Though the roots of *A. afraspera* are nodulated by several rhizobium strains, the rhizobia nodulating both roots and stems seem to be

highly host-specific. Strain ORS 322, isolated from a stem nodule of *A. afraspera* at the Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM) in Senegal, effectively nodulates only *A. afraspera* and *A. nilotica* Taub. It is believed to belong to the genus *Bradyrhizobium*, but also seems closely related to purple photosynthetic bacteria (*Rhodospirilliaceae*) as it forms bacteriochlorophyll 'a' and is capable of photosynthesis. The new generic name *Photorhizobium* has been proposed. Preliminary observations indicate that the nitrogen-fixation rate of stem nodules is less reduced by available soil nitrogen than is the case in root nodules.

Other botanical information In the past *A. afraspera* (strictly African) has been confused with *A. aspera* L. from tropical Asia. *A. aspera* is often glandular-pubescent, the calyx is 7–10 mm × 5–6 mm, the standard 10–16 mm × 8–15 mm, the wings 7–12 mm × 4–5 mm and the fruit segments bear spiny warts. At least 18 species of the genus *Aeschynomene* L. have been shown to produce stem nodules, including the Asian species *A. indica* L. In most species stem nodulation is less profuse than in *A. afraspera*.

Ecology *A. afraspera* is found from 0–900 m altitude in tropical areas with a distinct dry season and a monomodal rainfall distribution. It is a semi-aquatic pioneer plant of marshes and temporarily wet places. Seeds require high soil moisture or flooded conditions for germination, but more than 2 cm of standing water prevents seedling growth. It can form dense stands in soil depressions that are waterlogged during the rainy season, and in coastal freshwater lakes and rivers. It occasionally appears as a weed in rice fields. Provided with sufficient plant-available phosphorus (at least 10 ppm Olsen P), *A. afraspera* will grow in a wide range of soils, from pure dune sands along rivers to peat soils in mangrove swamps. Soil reaction can range from alkaline in salt flats to highly acidic in acid sulphate soils.

Propagation and planting Dormancy and an extremely hard seedcoat prevent easy germination. For agronomic use, seeds need to be mechanically scarified or immersed for 30–60 minutes in concentrated sulphuric acid. Vegetative propagation is possible using stem cuttings with root primordia. Cuttings 15–20 cm long from the basal stem show the highest survival rate and best growth. Vegetative propagation may not be economic for green manure purposes, and is mostly used to establish seed production plants, e.g. along the bunds of wet-rice fields. Planting can be done throughout the year: e.g. at the International Rice Research Institute, Los Baños, the Philippines, planting date had little effect on yield and a limited effect only on the rate of atmospheric nitrogen fixation.

Husbandry The ability of *A. afraspera* to form above-ground nodules and to fix nitrogen in waterlogged and marginal soils largely determines its value as a green manure in wet rice. Due to its soft structure, *A. afraspera* green manure is easily incorporated into the soil and mineralizes rapidly even under flooded conditions. After 6–8 weeks of growth it is ploughed in and rice is transplanted 1–7 days later. In eastern India it is sometimes sown as an intercrop between rows of rice and trampled into the soil before it starts shading the rice. Relay planting of *A. afraspera* has been used successfully to exploit the short fallow period between two rice crops in multiple cropping systems.

Diseases and pests Few diseases and pests are reported. This may be related to the limited use of *A. afraspera* in agriculture so far. A bacterial wilt is reported to affect biomass production in some areas. The leaf-eating larvae of the Lepidopterous species *Eurema lecabe* can become a problem when *A. afraspera* is grown in the short-day season. Stunted growth of upland *A. afraspera* may in some cases be associated with cyst-forming nematodes. However, under favourable wet conditions, *A. afraspera* seems to largely outgrow disease and pest-related damage. When grown for longer than 75 days *A. afraspera* can effectively control the rice root nematode *Hirschmanniella oryzae*.

Yield An 8-week-old crop grown in a pure stand can accumulate a dry biomass of 4–6 t/ha with a corresponding N yield of 80–200 kg/ha, provided sufficient water and soil P are available; 70% or more of this may be the result of biological nitrogen-fixation. As an intercrop, 35–60 kg N/ha can be accumulated. A rice crop following *A. afraspera* may recover 90% of the nitrogen contained in the green manure, compared with a recovery rate of 60% from urea. Reported increases in rice grain yield due to the incorporation of a 6–8-week-old *A. afraspera* green manure range from 0.8–3.2 t/ha.

Genetic resources and breeding The biofertilizer germplasm collection at the International Rice Research Institute, Los Baños, the Philippines, maintains 45 *Aeschynomene* species, including 3 accessions of *A. afraspera*. Other collections of *Aeschynomene* are maintained at the Office de la Recherche Scientifique et Technique d'Outre-Mer in Dakar (Senegal), and at Tamil Nadu Agricultural University (TNAU) in Coimbatore, India.

No breeding programmes are known to exist.

Prospects Flood tolerance, rapid growth, high nitrogen-fixing activity and rapid decomposition and mineralization give *A. afraspera* a high potential as a short-duration green manure in wet-rice systems. Growing concern for agricultural sustainability coupled with the rising cost of mineral N fertilizer mean that it may become more important in South and South-East Asia. Its high nitrogen content and good palatability make it a promising forage crop as well.

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M. Becker

Albizia chinensis (Osbeck) Merrill

Amer. Journ. Bot. 3: 575 (1916) (*Albizzia chinensis*).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26$

Synonyms *Mimosa chinensis* Osbeck (1757), *Albizia stipulata* (DC.) Boivin (1838), *A. marginata* (Lamk) Merrill (1910).

Vernacular names Silk tree (En). Chinese albizia (Am). Indonesia: jeungjing (Sundanese), sengon (Javanese), keura (Eastern Sumba). Cambodia: kôôl. Laos: kha:ng (Xieng Khouang), kha:ng hu: (Vientiane). Thailand: kang luang, san-kham (Northern), khang hung (Khon Kaen). Vietnam: s[oos]ng r[aws]n t[af]u, cham (Ha Tuyên), chu m[ef] (Quang Ninh).

Origin and geographic distribution *A. chinensis* occurs naturally in India, Burma (Myanmar), Thailand, Indo-China, southern China, Java and the Lesser Sunda Islands (Bali and Nusa Tenggara). In Borneo and Sumatra, it is possibly only found in cultivation. It is cultivated in many tropical countries.

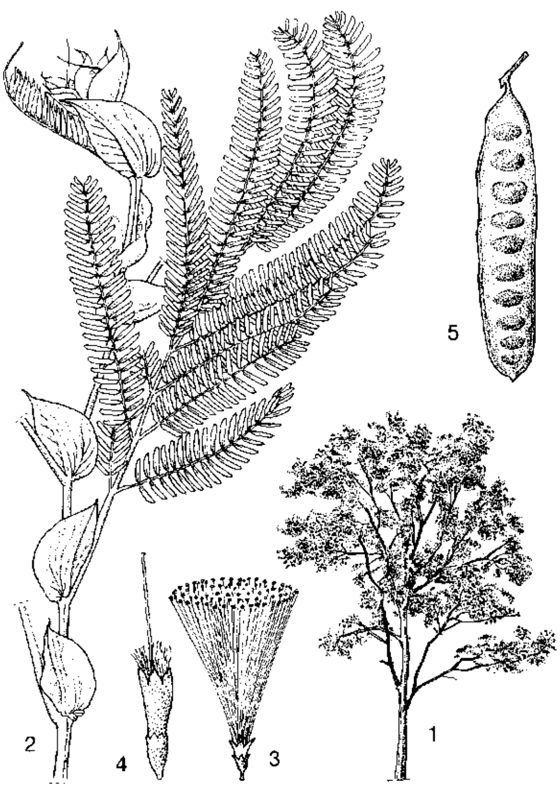
Uses *A. chinensis* is commonly used as a shade tree in tea and coffee plantations, often in a mixture with other trees like *Paraserianthes falcataria* (L.) Nielsen and *Erythrina* spp. In China shade-tolerant herbs are sometimes planted under *A. chinensis*. It is planted for slope stabilization and soil improvement. In parks and gardens and along roads it is grown as an ornamental. The tree has shown some potential as a fodder: the leaves are readily eaten by goats but the bark of branchlets is hardly touched, possibly because of its high saponin content. Due to the light weight of its wood, timber use is limited to house building, light furniture, tea chests and veneers. In India, it is used in boat building. As a firewood it is of low quality.

Properties Foliage of *A. chinensis* contains per 100 g dry matter: crude protein 21–28 g, fat 5 g, neutral detergent fibre 35–60 g, acid detergent fibre 25–35 g, lignin 15 g, tannins 23–33 g, and ash 5–15 g. In rumen degradation tests, digestibility of freeze-dried leaf dry matter was 39% after 48 hours, nitrogen digestibility was 27%. Drying leaves at 60°C in a forced-draught oven decreased total tannin content and increased N digestibility to 45%, while dry matter digestibility decreased to 30%. The bark of *A. chinensis* contains triterpenes with spermicidal activity. The trunk of the tree contains gum of low quality. It has been mixed with other gums to be used as extender.

Weight of 1000 seeds is about 20 g.

The wood of *A. chinensis* is soft and not very durable. Sapwood is white, while heartwood is light to dark brown. It is resistant to the European subterranean termite (*Reticulitermes lucifugus*) and somewhat resistant to attacks by *Cryptotermes* and other insects. An extract of the wood has a repellent property to subterranean termites.

Description Unarmed, deciduous or evergreen tree with flat, spreading crown, up to 30(–43) m tall and trunk up to 70(–140) cm in diameter; bark dark grey, rather smooth, densely hooped, lenticellate, thin; live bark 5 mm thick, pinkish-red. Branchlets slightly angular in the distal parts, terete, puberulous to tomentose, glabrescent. Leaves bipinnate; stipules auriculate, very prominent, 1–1.5 cm × 0.6–3 cm, caducous, pinkish-orange, pubescent, with filiform tail, base much dilated at one side; rachis stout, 10–25 cm long,



Albizia chinensis (Osbeck) Merrill – 1, habit; 2, leafy branch; 3, central flower; 4, marginal flower; 5, pod.

lenticellate, sparsely and minutely tomentellous, glabrescent, with an elliptical, raised gland near the base of 2–3 mm × 1–1.5 mm; pinnae 4–14(–20) pairs, 4–14 cm long, puberulous to tomentose, glabrescent, with glands at the junctions of the 1 or 2 distal pairs of leaflets, narrowly elliptical to slit-like, concave, 1 mm long, glands sometimes absent; leaflets (10–)20–30(–45) pairs per pinna, opposite, sessile, thinly chartaceous, asymmetrically subulate, 6–10 mm × 1.5–3.0 mm, apex sharply acute, base obtuse, oblique, midrib close to the upper margin, sparsely sericeous or glabrous on either side. Inflorescence consisting of pedunculate glomerules (heads) aggregated into terminal, yellowish-green, tomentose to hirsute panicle; peduncle 1–3 cm long, up to 5 in clusters, often with auriculate stipules at base; glomerule composed of 10–20 flowers; flowers pentamerous, dimorphic; in a glomerule the central flower is male, the marginal flowers are bisexual; calyx tubular to narrowly funnel-shaped, 2.5–5.0 mm long, tomentose to hirsute, ending in small triangular teeth; corolla funnel-shaped, 6–10 mm long, puberulous to hirsute especially on the lobes, lobes triangular-ovate, acute; stamens numerous, 2 cm long, at the base united into a tube as long as or slightly longer than the corolla tube; ovary glabrous, sessile. Pod thin, flat, strap-shaped, 6–20 cm × 2–3 cm, often with slightly sinuate margins, indehiscent or breaking irregularly, reddish or yellowish-brown, glossy, 8–12-seeded. Seed flattened ellipsoid, 7(–10) mm × 4–6 mm × 0.5–1 mm, dull dark brown, areole nearly circular, 1 mm in diameter. Seedling with epigeal germination.

Growth and development *A. chinensis* is evergreen or leafless for a short period. In South-East Asia trees flower between September and June, fruits ripen between October and August. In northern India old leaves fall in January–February, new ones appear in March–April; flowering takes place soon after the appearance of the leaves; while pods attain full size by about September and ripen during December–March. The pods remain on the tree for a very long time and eventually dehisce, but are sometimes blown away by the wind before dehiscence. Without seed treatment the germination rate is only 5–7%.
Growth is very rapid, to 1.5 m within the year of planting. In natural forest an annual diameter increment of 2.7 cm has been recorded.
Nodulation is abundant and effective, and the nodules, which are dichotomously branched, grow throughout the year.

Other botanical information Philippine specimens, formerly referred to this species, have been referred to *Albizia philippinensis* Nielsen. They differ from *A. chinensis* in having smaller stipules, petiolar glands and flowers, and seeds with a larger areole. The related American species *Albizia carbonaria* Britton (synonym *Albizia sumatrana* v. Steenis) is also occasionally used as a shade tree in tea in Java and Sumatra.

Ecology *A. chinensis* is a native of mixed deciduous forest and rain forest in humid tropical and subtropical monsoon climates with annual rainfall varying from 1000–5000 mm. It occurs in secondary forest, along river banks, and in savannas up to 1800 m altitude. Light frost is tolerated. It is adapted to poor soils, high pH, is fairly salt-tolerant and thrives on lateritic alluvial soil and sandy mining areas. In growth trials on poorly drained, infertile, gleyed, podzolic soils it had a survival rate of nearly 100%.

Propagation and planting *A. chinensis* is mostly propagated by seed. Dormancy can be broken by scarification or soaking seed in concentrated sulphuric acid for 10 minutes, followed by washing and soaking in water for 18 hours. After 6–8 weeks, the seedlings can be transplanted into the field. In tea plantations in India *A. chinensis* is planted at a spacing of about 7–15 m; for fodder production, the trees are grown at a spacing of 3 m × 1 m. At planting a small amount of a mixture of 60% lime, 30% superphosphate and 10% urea is mixed with the soil in each planting hole, to promote early growth.

Husbandry Weeds have to be controlled regularly after transplanting until the plants reach a height of 1 m. Trees grown for shade are left to grow to about 7 m tall and are then cut back to 4 m.

The trees can be harvested for fodder twice a year during the growing season by cutting the stem back to 1 m. Such cutting is well tolerated.

Diseases and pests No serious diseases have been reported, though the risk of canker reduces the life expectancy in north-eastern India to about 20 years. Attacks by thrips sometimes prevent flower opening and young pods can be damaged by beetles and larvae of various bruchids.

Yield In trials in south-eastern Queensland, with 1500 mm annual rainfall, the mean annual leaf dry matter yield was 454 g per tree with stem dry matter yield of 584 g per tree. In north-eastern Thailand with 1200 mm rainfall, annual yield per tree was 360 g leaf dry matter and 480 g stem dry matter.

Genetic resources and breeding It is unlikely that substantial germplasm collections exist and there are no known breeding programmes.

Prospects As a fast growing tree legume, *A. chinensis* remains important as a shade tree especially in tea and in the reforestation of degraded land. Because of its tolerance of frequent pruning during the growing season it deserves testing in alley cropping systems. The tree has shown some value as a source of fodder, warranting further testing. Breeding and selection for low tannin content may result in higher dry matter and nitrogen digestibility.

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R. Akkasaeng & R.C. Gutteridge

Albizia procera (Roxb.) Benth.

London Journ. Bot. 3: 89 (1844).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26$

Synonyms *Mimosa procera* Roxb. (1799), *Acacia procera* (Roxb.) Willd. (1806), *Mimosa elata* Roxb. (1832).

Vernacular names White siris, forest siris (Australian standard trade name), tall albizia (En). Indonesia: ki hiyang (Sundanese), wangkal, weru (Javanese). Malaysia: oriang. Papua New Guinea: brown albizia. Philippines: akleng parang. Burma (Myanmar): sit, kokko-sit. Cambodia: tramkâng', tronum' kâmphé:m. Laos: tho:nx. Thailand: thingthon (central), suan (northern, north-eastern). Vietnam: mu[oof]ng xanh.

Origin and geographic distribution *A. procera* occurs naturally from India, throughout South-East Asia to northern Australia, extending northwards to southern China, including Hainan and Taiwan. It does not occur spontaneously in Peninsular Malaysia and has been collected only once in Borneo. It has been introduced into a number of African countries and into Panama and Puerto Rico.

Uses *A. procera* is used for amenity planting, wind-breaks, fire-breaks and the rehabilitation of eroded and degraded soils. It is occasionally planted as a shade tree in tea and coffee.

A. procera is planted for fuelwood and gives excellent charcoal. The wood is used for agricultural implements, moulding, furniture, veneer, and cabinet work. It is also a substitute for walnut. On mountain slopes in Benguet Province in the

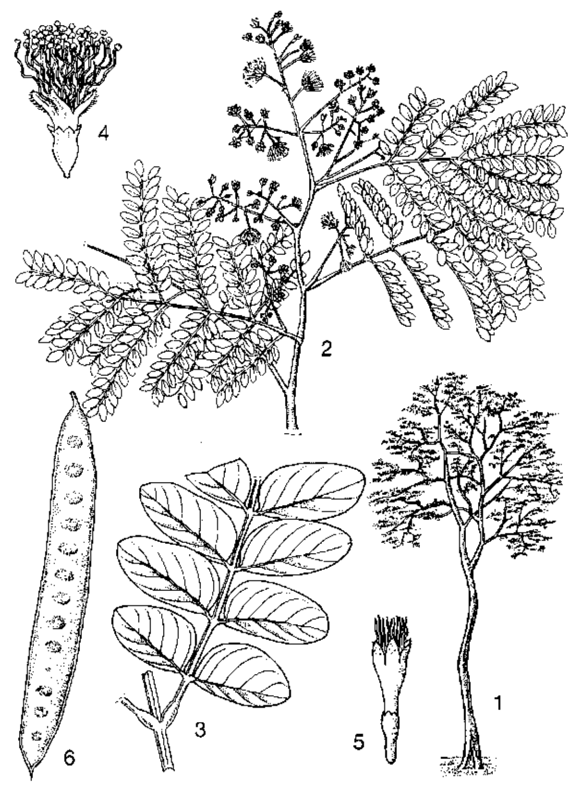
Philippines the farmers leave *A. procera* trees untouched when clearing land for crops, as the trees cast only a light shade, add nitrogen to the soil and conserve water, and function as a cash reserve as the wood is sought after by local wood carvers. In India and Nepal the leaves are cut for fodder. In former times the bark provided tanning material. Low tannin content (13%), considerable weight loss in drying and difficult harvesting have limited its importance. The pounded bark is used as a fish poison. In Nepal the leaves are used as an insecticide.

Properties Analysis of the mineral composition of leaves from two-year-old trees grown on an ultisol (pH 4.5) in South Sumatra indicated per 100 g dry material: N 1.76 g, P 0.08 g, K 1.07 g, Ca 0.66 g, Mg 0.28 g, Na 0.01 g, S 0.17 g. Digestibility analysis of this material gave: neutral detergent fibre 64%, acid detergent fibre 65%, ash 4%, lignin 42%, and lipids 5.5%. Under favourable conditions and intensive management in Puerto Rico higher values were found per 100 g dry matter: N 3.3 g, P 0.3 g, K 1.5 g. The amounts of nutrients immobilized in the trunk and branches were also high. The leaf has a high raw fibre and lignin content, indicating poor digestibility. Mineral content of the leaves for N, K, Ca, and Mg is adequate for animal production, but the Na and P contents are inadequate. Use for fodder is therefore recommended only in mixtures with other species. The oil content of the seed is about 7.5%. The weight of 1000 seeds is 30–60 g.

A large proportion of the stem is non-durable, straw-coloured to off-white sapwood. The heartwood is deep brown, hard and heavy, with an air-dry density of 640–880 kg/m^3. It is fairly durable when exposed. The wood is diffuse-porous; growth rings are present but inconspicuous. Crystals are present. Energy value is 20 500–21 000 kJ/kg.

The wood is resistant to several species of termites, including *Bifiditermes beesoni*, *Cryptotermes cynocephalus* and *Coptotermes curvignathus*, though the latter is reported as a pest of the tree in India.

Description Tree with an open canopy, up to 30 m tall with trunk of 35(–60) cm in diameter; bole straight or crooked, up to 9 m. Bark smooth, pale grey-green, yellowish-green, yellowish-brown or brownish with horizontal ridges, sometimes flaking in thin, small scales, underbark green, changing to orange just below the surface, inner bark pinkish or straw-coloured. Branchlets terete, glabrous. Leaves bipinnate with 2–5 pairs of sub-opposite pinnae; rachis 10–30 cm, glabrous, with a



Albizia procera (Roxb.) Benth. – 1, habit; 2, flowering branch; 3, part of leaf; 4, central flower; 5, marginal flower; 6, pod.

gland 1–2.5 cm above the base; gland narrowly elliptical, 4–10 mm long, sessile, flat and disc-like or concave with raised margins; pinnae 12–20 cm long, glabrous, with elliptical glands below the junction of the 1–3 distal pairs of petiolules, 1 mm in diameter; petiolule 2 mm; leaflets 5–11 pairs per pinna, opposite, rigidly chartaceous to subcoriaceous, asymmetrically ovate to sub-rhomboid, 2–4.5(–6) cm × 1–2.2(–3.2) cm, base asymmetrical, half truncate, half cuneate, apex rounded or subtruncate, often emarginate, mucronate, both surfaces sparsely appressed puberulous, rarely glabrous above. Inflorescence composed of pedunculate glomerules collected in an axillary, sparsely puberulous panicle up to 30 cm long; peduncle (0.8–)1.5–2(–3) cm long, 2–5 together; flowers 15–30 per glomerule, sessile, uniform (central flowers usually larger than marginal ones), bisexual, pentamerous; calyx tubular to narrowly funnel-shaped, 2.5–3 mm, glabrous, light green, teeth triangular, 0.75–1.2 mm, acute; corolla funnel-shaped, 6–6.5 mm long, greenish-white, tube glabrous, with elliptical lobes of 2–2.5 mm, acute, puberulous at the apex; stamens numerous, united at the base into a tube that is longer than the corolla tube; ovary glabrous. Pod straight, flat, chartaceous, 11.5–20 cm × 2–2.5 cm, glabrous, dark or red-brown, with distinct marks over the seeds, dehiscent. Seed flattened obovoid-ellipsoid, 7.5–8 mm × 4.5–6.5 mm × 1.5 mm; areole 4.5 mm × 3 mm with pleurogram nearly parallel to the margins of the seed. Seed with epigeal germination.

Growth and development Though reported to be moderately fast-growing, having a mean annual increment in diameter of 1–4 cm and reaching 40–60 cm diameter at breast height in 30 years in northern India, performance has been very poor in trials in the Philippines (33.8 cm after 3 years) and on ultisols in South Sumatra (less than 1 m after 2 years). During the dry season the tree becomes almost leafless for a short time. In India, flowering starts around June after the onset of the monsoon, ripening of the pods takes approximately 8 months. Elsewhere, it is reported to flower and fruit throughout the year.

The tree can be heavily pruned or pollarded to give a bushy crown. *A. procera* fixes atmospheric nitrogen.

Ecology *A. procera* is commonly found in open secondary forest and in areas with a pronounced dry season. Its habitat ranges from monsoon forest, savanna, pyrogenic grassland, roadsides, dry gullies, to stunted, seasonal swamp forest. It occurs up to 1500 m altitude in the tropics and up to 1200 m in the subtropics. Planting at higher elevations is limited by its susceptibility to frost.

The mean annual rainfall is 1700 mm, ranging from 500 mm to 3000 mm, the annual mean minimum temperature is 21°C and annual mean maximum temperature is 32°C. In its natural range in Australia the mean minimum temperature of the coldest month is 11–19°C, the mean maximum temperature of the hottest month 31–34°C. It grows well on shallow soils with a pH of 5.5–7.5, and has a moderate light requirement. In the absence of burning it will colonize alang-alang (*Imperata cylindrica* (L.) Raeuschel) grassland.

Propagation and planting Freshly harvested seed has a germination rate of 90–100%, dropping to below 50% after storage. The seeds retain their viability at least one year. Soaking seed that has been stored for 4–5 months in boiling water for 5 seconds, immediately removing them from direct heat and then soaking them in tap water overnight doubled the germination percentage. In the dry season seed is sown in nursery beds in drills 20 cm apart, at 5 cm spacing and lightly covered. Direct sowing in the field has proved more successful than transplanting from a nursery, provided regular weeding and loosening of the soil is carried out; line-sowing facilitating weeding has given greatest success. Transplanting of 1-year-old seedlings can be done in the rainy season, preferably during wet weather, with or without pruning.

A. procera can be propagated quite successfully by stumps and stem or root cuttings provided that the peaks of the rainy and the dry season are avoided. It may produce root suckers when damaged.

Spacing at 2–3 m × 0.5 m in pure stands gives closure of the canopy in about 3 years. Trees which are suppressed in dense stands will die as a result of lack of light.

Husbandry Due to the light crown, regular weeding and control of the undergrowth are required. Therefore, *A. procera* is often mixed with other species and planted at a spacing of 3 m × 1 m. Mixed planting and pruning in open stands can improve stem form. Thinning is necessary after 9 years.

Diseases and pests *A. procera* trees in India and Malaysia have sometimes been defoliated by larvae of Lepidoptera species such as *Rhesala imparata*, *R. inconcinnalis* and *R. moestalis*. In Africa the termite *Ancistrotermes amphidon* is a serious pest on young trees.

Yield Annual wood production of about 10 m^3 per ha has been recorded from Java. A 4-year trial on an ultisol of pH 4.5 at Nakau, South Sumatra showed a very low growth rate when compared to *Leucaena leucocephala* (Lamk) de Wit, *Acacia mangium* Willd., and *Paraserianthes falcataria* (L.) Nielsen. Harvesting of stem and leaves above 1 m height yielded 0.10 and 0.69 kg of wood (fresh weight per tree 36 and 50 months after transplanting of seedlings respectively), and 1.1 kg of dry leaves after 50 months.

Prospects Since *A. procera* grows moderately fast in areas with poor, seasonally swampy, shallow soils and a long dry season and provides good quality wood and excellent charcoal, its potential as an alternative timber and fuelwood species should be further explored. The poor digestibility of its leaves make its usefulness as a fodder questionable.

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J.L.C.H. van Valkenburg

Alnus Miller

Gard. Dict. abr. ed. 4: 51 (1754).

BETULACEAE

A. japonica: $2n = 42$, *A. nepalensis*: $2n = 56$.

Major species and synonyms

- *Alnus japonica* (Thunb.) Steud., Nomencl. bot. ed. 2, 1: 55 (1840), synonyms: *A. oblongata* Willd. ex Regel (1861), *A. formosana* (Burkill) Makino (1912), *A. maritima* (Marsh.) Nuttall (1842).
- *Alnus nepalensis* D. Don, Prodr. fl. Nepal.: 58 (1825).

Vernacular names General name: alder (En).
- *A. japonica*: Japanese alder (En).
- *A. nepalensis*: Indian, Nepal or Nepalese alder (En). Burma (Myanmar): maibau.

Origin and geographic distribution *Alnus* consists of about 20(–35) species and is distributed mainly in temperate and subtropical areas of the Old World. *A. japonica* is a native of Taiwan, Japan and North-East Asia (China, Korea, Siberia) and is grown in the Philippines. *A. nepalensis* occurs naturally throughout the Himalayas from Pakistan through Nepal, northern India, Bhutan and Upper Burma (Myanmar) to south-west China and Indo-China. It has been introduced into South-East Asia, with particular success in the Philippines. Trial plantings of both species have been made in Malaysia and West Java. Plantations of *A. nepalensis* exist in tropical Africa, Costa Rica and Hawaii.

Uses As many other *Alnus* spp., *A. japonica* and *A. nepalensis* are important sources of firewood. They are useful trees in agroforestry, planted to improve the stability of slopes liable to erosion and land-slides and for mine reclamation. Being nitrogen-fixing trees they can improve degraded lands. In Burma (Myanmar) *A. nepalensis* has been used effectively to reforest abandoned fields. In north-eastern India, Sikkim and Nepal *A. nepalensis* is interplanted with annual crops and used as a shade tree for greater cardamom (*Elettaria subulatum* Roxb.) and for *Cinchona officinalis* L. *A. japonica* is planted for shade in coffee and as a nurse tree in *Pinus kesiya* Royle ex Gordon plantations in the Philippines, where it has also been planted for reforestation. It is also grown as living posts supporting a network of wires for chayote (*Sechium edule* (Jacq.) Swartz), a fruit vegetable. Leaves are used as animal bedding. In the Philippines *A. japonica* has been found to be suitable as bed logs for shiitake mushroom (*Cortinellus shiitake*) cultivation, and is also grown as an ornamental.

A. nepalensis is pollarded for poles and its wood is used for boxes, match splints and for general carpentry, furniture parts, turnery, as well as for newsprint pulp and the production of charcoal. It is suitable as core material for plywood. The wood of *A. japonica* is suitable for making furniture, tools and packaging, and for the production of charcoal for gunpowder.

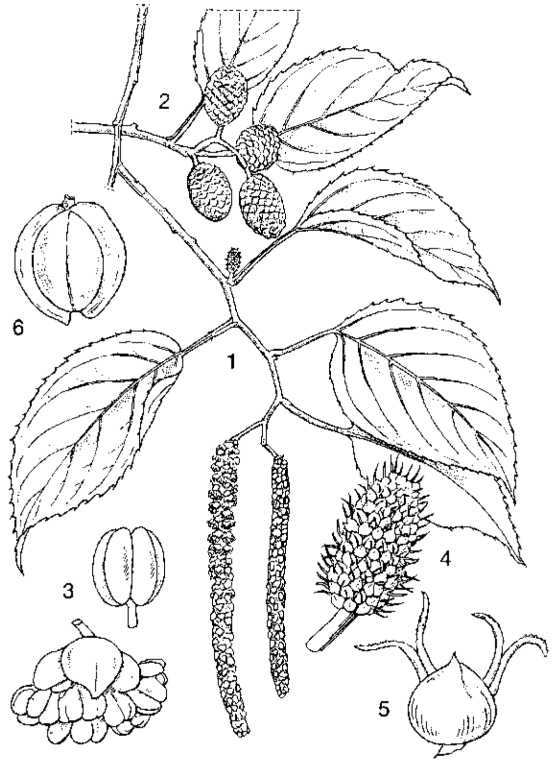
The bark of *A. nepalensis* has been used occasionally for tanning and dyeing. Its foliage is of low to moderate value as fodder for sheep and goats, but not suited for cattle.

Properties Considerable quantities of nutrients are recycled through the litter of *Alnus* spp. Leaf and twig litter of *A. nepalensis*, grown in the eastern Himalayas and producing annually 3–6 t/ha litter, contains per 100 g dry matter: N 3.4–3.7 g, P 0.08–0.10 g, K 0.6–0.7 g, Ca 0.2 g.

The wood of *A. nepalensis* is moderately soft and lightweight with a density of 320–590 kg/m^3. Its energy value is low (18 230–20 480 kJ/kg), but, like that of other alders, the wood dries rapidly and burns easily. The wood is pale brown or superficially bronze-coloured, with low lustre. Grain is variable, texture medium to fine. Although not among the best construction timbers, *A. nepalensis* seasons without excessive warping or splitting, but shrinkage figures are high. It is easy to saw and finish by hand or machine, with only slight blunting effects on tools. Planing and boring give good results while mortising and turning results are only fair with some picking up of grain. The wood preserves fairly well, but is non-durable in exposed conditions and is susceptible to discolouration by oxidation and fungal sap staining. The wood of *A. japonica* is largely similar to that of *A. nepalensis*; it shows slight discolouration by sunlight.

In the Philippines, kraft pulping of wood of an *Alnus* sp. showed a pulp yield of 47.6%. Bleaching improved the brightness to 76%. The pulp was suitable for the manufacture of good quality paper.

Seeds are very small: 1000 seeds of *A. nepalensis* weigh 0.28–0.43 g, seed of *A. japonica* is somewhat larger. Seed weight is sometimes given for seed including chaff, 1000 seeds weighing 8 g for *A. japonica*.



Alnus japonica (Thunb.) Steud. – 1, flowering branch; 2, fruiting branch; 3, triad of staminate flowers with anther; 4, female catkin; 5, diad of female flowers; 6, winged nutlet.

Description Monoecious shrubs and trees with a dense crown; bark generally grey and smooth; twigs with a 3-angled pith and stalked, perular buds. Leaves simple, alternate, in 3 rows, mostly with domatia in the vein axils and often glandular-lepidote below; stipules early caducous. Flowers in unisexual catkins. Male inflorescence a many-flowered pendulous catkin; flowers arranged in groups of 3 (triads) in the axil of a bract; flower with 4 perianth segments mostly connate at base; stamens 4, epipetalous, with short filaments. Female inflorescence a short, upright catkin; flowers in groups of 2 (diads) sustained by a bract concrescent with 4 bracteoles, without a perianth; styles 2 with stigmatose tip. Fruiting catkin cone-like, woody, with 5-lobed scales and minute 2-winged nutlets. Fruit a small nut, compressed, 1-seeded, crowned by the styles. Seed without endosperm.

- *A. japonica*. A deciduous or evergreen shrub or small tree, 3–10(–20) m tall; twig ends rather sharply triangular, glabrous or subglabrous. Leaf blade ovate-oblong to elliptical-oblong, 6–9.5(–13) cm × 2.7–5 cm, dentate, distinctly acuminate, base broadly or obtusely cuneate or subrotundate, with 6–7 pairs of lateral veins; petiole slender, 1–3 cm long. Male catkin 3–5 cm × 3–5 mm. Female catkins arranged in a terminal raceme on short shoots; catkin 1.5–2.5 cm × 1 cm; peduncle 0.5 cm long. Nut obovate-orbicular, not emarginate, about 3 mm in diameter including the wings.
- *A. nepalensis*. A deciduous or semideciduous tree, 8–15(–33) m tall, trunk straight, up to 80(–200) cm in diameter; twigs ribbed, glabrescent; bark thick, dark green or grey to silver-grey, often with yellowish patches and short, raised lenticels. Leaf blade ovate to oblong, 6–21 cm × 4–10 cm, shallowly crenate to subentire, acute to shortly acuminate, rounded or cuneate at the base, with 12–16 pairs of lateral veins; petiole strong, 1.5–2 cm long. Male catkins grouped in a terminal panicle up to 16 cm long; catkin 10–16(–25) cm long, yellow. Female inflorescences grouped in a short, axillary raceme of 3–8 catkins; catkin 1.0–1.7 cm × 0.6–0.7 cm; peduncle 3–6 mm long. Nut obtrapezoid, emarginate, 2 mm in diameter including the wings.

Growth and development Both *Alnus* species develop an extensive lateral root system and are fast growing. Diameter growth of *A. japonica* is faster in open areas than in shade, while height growth is faster in shade. For *A. nepalensis* a mean annual diameter increment of 2 cm is not rare and an annual increment of 2.7 m in height and 2.9 cm in diameter have been recorded in Nepal. Exceptionally high annual increment figures of 4 m in height and 5 cm in diameter have been reported for *A. japonica* in the Philippines. Growth rates vary considerably, particularly in response to soil moisture and altitude.

A. japonica is shade tolerant and tends to retain its lower branches. While it is deciduous in Japan, it seems evergreen in the Philippines. Under flooded conditions *A. japonica* retains its leaves and can almost maintain its growth rate by forming adventitious roots with abundant aerenchyma.

A. nepalensis and *A. japonica* form a symbiosis with N-fixing actinomycetes of the genus *Frankia*. In its natural habitat *A. japonica* flowers and fruits from April to November, *A. nepalensis* from November to March, depending on geographical locality.

Other botanical information *A. japonica* is sometimes considered to be different from the American *A. maritima* (Marsh.) Nuttall. *A. maritima* would have leaves that are more elliptical to obovate. *A. japonica* specimens from Taiwan have been accommodated in a separate variety (*A. japonica* (Thunb.) Steud. var. *formosana* (Burkill) Callier or *A. maritima* (Marsh.) Nuttall var. *formosana* Burkill) or even a distinct species (*A. formosana* (Burkill) Makino), but at present they are not considered different from *A. japonica*. The tropical American *A. acuminata* O. Kuntze (synonym *A. jorullensis* Kunth) is occasionally tested as an alternative to *A. japonica* and *A. nepalensis*. It grows under comparable conditions. Pollination and seed dispersal of *Alnus* spp. are by wind.

Ecology As pioneers, *A. japonica* and *A. nepalensis* grow well in full sunlight although shade is tolerated. *A. nepalensis* is found naturally in moist, cool, subtropical mountain monsoon climates, with a mean annual rainfall of 800–2500 mm and a dry season of 4–8 months. It occurs naturally at altitudes of 1000–1800(–3000) m, but it has been planted down to 300 m. Mean annual temperatures range from 13–26°C. *Alnus* spp., including the 2 species discussed, occur mainly in wet soils along streams and in swamps and also on exposed soils. *A. nepalensis* prefers moist and well-drained soils, varying from loam and loamy sand to gravel, sand and clay. It can withstand some imperfect drainage but does not tolerate prolonged periods of waterlogging. It grows poorly on dry, exposed ridge-tops. *A. japonica* occurs naturally in marsh or swamp forest in Japan with a generally high water table, and soil conditions tending to be anaerobic with high clay and organic matter contents. *A. japonica* does not require very fertile soil, but prefers permeable soils and should not be planted in compact soils.

Propagation and planting *A. nepalensis* is readily grown from seed, but may also be propagated vegetatively by tissue culture. Seed will retain its viability for at least a year if properly dried and stored in sealed containers. Likewise, *A. japonica* seeds retain their viability for 3–6 months. Fruits are collected from the trees and seed is released when fruits are left to dry in the sun. No pretreatment is needed. The fine seeds are broadcast in beds. Germination starts 1–2 weeks after sowing and is completed 2 weeks later. Transplanting seedlings into containers can begin 4–5 weeks after germination. Below 1200 m elevation seedlings reach a planting size of 25–35 cm in 4–5 months, but at higher altitudes they may take as long as 11 months. Young seedlings are liable to damage by ants and defoliation as a result of frost. Their survival rate is often very low.

Most planting of *A. nepalensis* is done with containerized seedlings, although bare-rooted seedlings have proven successful provided lifting and handling is done properly and moisture availability is high at the planting site. In the Philippines bare-rooted seedlings of *A. japonica* are generally used. Wildlings of *A. nepalensis* have been used successfully in Nepal, especially on north-facing slopes. Direct sowing is an alternative, even on exposed mineral soils. Seed must be fresh, as then it has a high germination rate. Ample quantities should be used. Good results are obtained when seed is mixed with soil from under old trees to facilitate even broadcasting and to introduce *Frankia* inoculum. Clonal micropropagation is feasible on a commercial basis for *A. japonica*, but other vegetative propagation methods have not been successful. Planting out stock of *A. japonica* of 30–45 cm tall is recommended for the Philippines in areas with altitudes over 600 m and a rainfall of less than 50 mm/month during 4–6 months.

A spacing of 2.5 m × 2.5 m is commonly used for plantations of *A. nepalensis* in Nepal, although a closer spacing is desirable for fuelwood crops. In the Philippines, *A. japonica* is planted at 15 m × 15 m to provide shade for coffee planted at 2 m × 2 m.

Husbandry After coppicing, regrowth is best when felling is done during the wet season and in moist localities. *Alnus* spp. are highly susceptible to wind damage. Trials in East Java with *A. nepalensis* were not successful because of a mortality rate of 95–100%. *A. japonica* shade trees in coffee plantations are pruned to a height of 3–5 m and branches are used as fuelwood. It is sufficiently tolerant of shade to be planted in *Pinus kesiya* stands transmitting as little as 30% light. *A. japonica* is reported to coppice easily and to be fire-sensitive.
On fertile sites poles and fuelwood can be harvested after 5 years. Small-diameter timber can be harvested in less than 10 years.

Diseases and pests *A. nepalensis* is very susceptible to attacks by defoliators (*Anomala* spp., *Oreina* spp.). Stem borers (*Batocera* spp. and possibly *Zeuzera* spp.) may also become pests. An aphid (*Eutrichosiphum alnifoliae*) is a pest of economic importance. Where *A. japonica* is introduced it suffers only very mild attacks by the sawfly (*Fenusa dohrnii*) compared with other *Alnus* spp. In Japan *A. japonica* is a host for *Eotetranychus tiliarium*, while in China both the larvae and adults of *Agelastica coerulea* feed on its leaves.

Yield In northern India the yield of *A. nepalensis* grown in plantations for timber and ranging in age from 7–56 years was estimated. When 7 years old and with a plant density of 715 trees/ha, bole biomass was 53 m^3/ha, at 17 years with 545 trees/ha bole biomass had increased to 138 m^3/ha, and at 56 years with 435 trees/ha it had reached 394 m^3/ha.

Breeding Research in Nepal on *A. nepalensis* has shown that local provenances perform best at any given site. None of the provenances, however, showed overall superiority. Interspecific crosses with the black alder, *A. rubra* Bong., have been made.

Prospects As *Alnus* spp. are capable of fixing atmospheric nitrogen, they have the ability to enrich soils. They are generally well suited for reforestation purposes, particularly in moist areas, and for improving soil fertility. On unstable slopes their extensive lateral root system contributes to watershed protection and erosion control. Further research into the genus seems appropriate as, to date, the full potential of these multipurpose trees in forestry and agroforestry has still to be uncovered.

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P.E. Neil

Azadirachta indica A.H.L. Juss.

Mém. Mus. Nat. Hist. Nat. Paris 19: 221, t.13, fig. 5 (1832).

MELIACEAE

$2n = 28, 30$

Synonyms *Melia azadirachta* L. (1753), *M. indica* (A.H.L. Juss.) Brandis (1874), *Antelaea azadirachta* (L.) Adelb. (1948).

Vernacular names Neem, Indian lilac, margosa tree (En). Neem (Am). Azadirac de l'Inde, margosier, margousier (Fr). Indonesia: mimba (Java), membha (Madura), intaran (Bali). Malaysia: baypay, mambu, veppam (Peninsular). Papua New Guinea: neem. Philippines: neem. Singapore:

kohomba, nimba, veppam. Burma (Myanmar): tamarkha, thinboro, tamar. Cambodia: sdau. Laos: kadau. Thailand: khwinin (general), sadao (central), saliam (northern). Vietnam: s[aaf]u d[aa]u.

Origin and geographic distribution The exact origin of neem is unknown. It is thought to have originated in the Assam–Burma (Myanmar) region and to be distributed naturally throughout the Indian subcontinent. It has long been cultivated in Peninsular Malaysia, Indonesia and Thailand, where it is completely naturalized and has modified deciduous forests. In the 19th Century South Asian emigrants took it to Fiji, Mauritius and Guyana, and the British to Sudan, Egypt, East Africa, and sub-Sahel West Africa, where it is widely grown and has also naturalized. It has recently been introduced into tropical South and Central America, Florida, Hawaii, Saudi Arabia, the Philippines, and northern Australia. Now it is probably one of the fastest-spreading trees and has become pan-tropical.

Uses Neem is a multipurpose tree, grown for shade and shelter, for timber and fuel, to control erosion and improve soils, while the oil from the seed is used in soap manufacturing. In the Indian subcontinent it is most famous for its medicinal and insecticidal properties. The large crown of neem makes it an effective shade tree, planted widely as an avenue tree in towns and villages and along roads in many tropical countries. Recently, 50 000 neem trees have been planted in the Arafath plane near Mecca in Saudi Arabia, to provide shade to Muslem pilgrims. Because of its low branching, neem is grown as a wind-break. In South-East Asia it is mainly planted to protect and improve very poor soils. In East Java, neem trees are tapped to extract gum exudates used for making paper glue.

The tree's hard, termite-resistant wood is used in construction, for making carts, agricultural implements and furniture, and is suitable for the manufacture of plywood and blockboard. It makes a good firewood and is extremely important as fuel for example in West Africa. Neem twigs are commonly used to clean teeth, whereas young twigs and young flowers are occasionally consumed as a vegetable. The leaves, though very bitter, are used as a dry season fodder.

Neem seed oil is used in South Asia for soap making. The residue after oil extraction or 'neem cake' serves as livestock feed and fertilizer. Recently, it has been used as an admixture or coating of urea fertilizer to reduce losses of N from urea through denitrification.

Neem is best known for its medicinal uses, described early on in classical Hindu texts, and detailed in the Ayurvedic and Unani schools of medicine. People bathe in water with neem extracts to treat health problems. Various parts have anthelmintic, antiperiodic, antiseptic, diuretic, and purgative actions, and are also used to treat boils, pimples, eye diseases, hepatitis, leprosy, rheumatism, scrofula, ringworm and ulcers. In Africa neem leaves are chewed and an infusion from the leaves is taken to prevent conception and induce abortion. In modern medicine, antibacterial, antifungal and anti-inflammatory effects have been demonstrated, but are still in the early stages of testing. Small but significant effects against malaria parasites have been found and the active chemicals have been isolated. Preliminary experiments indicate that neem-seed extracts may contribute to the control of Chaga's disease, a nerve disease affecting about 20 million people in Latin America caused by *Tripanosoma cruzi*, a parasite related to the cause of the African sleeping sickness, and transferred by kissing bugs (*Rhodnius* spp.). The extracts mainly act by repelling the vector, but also by interfering with its moulting and by killing the parasites in the vector. Neem oil has a strong spermicidal action and possibly prevents the implantation of the ovule. A neem oil-based product 'Sensal' is being marketed in India as an intravaginal contraceptive.

The tree's upcoming promise builds upon its traditional use for pest control, especially of storage insects. In northern India neem leaves are mixed with legume or cereal grain to prevent insect damage. More than 200 species of insects, mites, and nematodes, including destructive crop pests are controlled by extracts from leaves, seed, bark, or flowers. Over 30 pesticides based on azadirachtin, one of neem's many biologically active components, are being marketed and several have been registered by the Environmental Protection Agency of the United States. Commercial products are also available against lice and fleas of animals. Mosquito-repellent coils are among neem's other emerging uses.

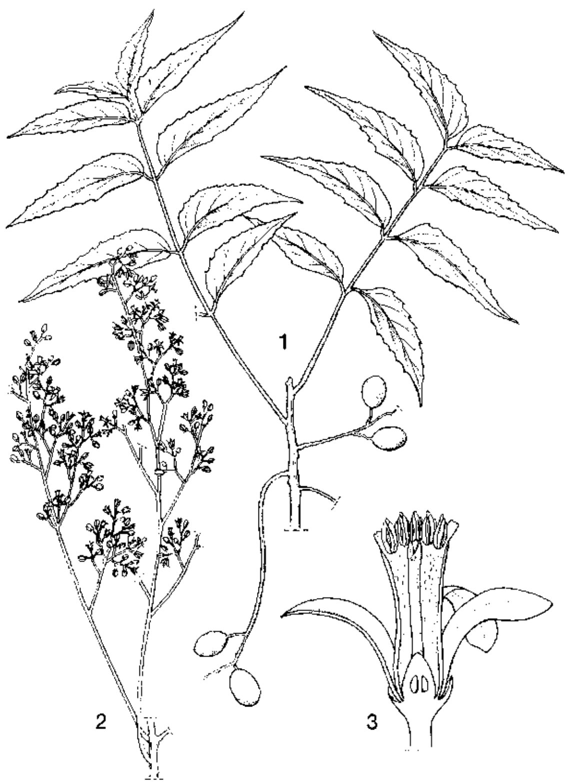
Production and international trade In India more than 18 000 t of neem-seed oil is used for soap making. Assuming a fruit yield of 25 kg per tree and an oil content of 10%, this oil must come from about 7.2 million trees. Less than 25% of India's neem trees (in 1975: 25 million) are currently exploited. International trade seems limited to small quantities of leaves imported by two American companies manufacturing neem-based pesticides. Neem oil is valued at about US$ 700/t (1990).

Properties Neem seed contains 20(–50)% oil. The oil (and to a lesser extent the leaves) contain many biologically active tetranortriterpenoid compounds, especially limonoids. The following groups of limonoids are the most important: azadirachtin, meliacarpin, nimbin, nimbolinin and salannin. Azadirachtin ($C_{25}H_{44}O_{16}$), a steroid-like, highly oxidized tetranortriterpenoid, structurally similar to insect hormones (ecdysones), has deterrent, antifeedant, anti-ovipositional, growth-disrupting, fecundity and fitness-disrupting properties in insects and several other groups of animals. By blocking the release of these hormones, azadirachtin appears to disrupt the moulting cycle of the insects. Azadirachtin concentrations in seed range from 2–4 mg/g, a maximum of 9 mg/g is reported from Senegal. Biological activity appears greater in trees from drier areas. In hot climates, the azadirachtin concentration is lower. However, the relative roles of genetic and environmental factors are not yet clear. The other compounds of neem are less well studied. Compounds of the azadirone, gedunnin, meliacarpin, nimbin, salannin and vilasinin groups of tetranortriterpenoids appear to be powerful feeding inhibitors, while the nimbolinins and gedunnins have growth-disrupting properties. Compounds of the nimbin group are also bactericidal and cytotoxic, while nimbin and nimbolinin may have anti-viral properties. Other chemically important compounds found in neem include glycerides, polysaccharides, sulphurous compounds, flavonoids and their glycerides, amino acids, and aliphatic compounds.

The wood of neem is hard and resembles mahogany. The density of the wood is 720–930 kg/m³ at 12% moisture content. The heartwood is reddish when freshly exposed, but fades in sunlight to reddish-brown, clearly demarcated from the greyish-white sapwood. The wood is aromatic when fresh and beautifully mottled. The grain is narrowly interlocked, medium to coarse in texture and often uneven. The timber seasons well with little degrade. Pre-boring is necessary when nailed. The wood is durable even in exposed situations, and not attacked by termites or woodworm. It is easy to work by hand or machine, but does not polish well. The energy value of the wood is 20 830 kJ/kg. The energy value of neem seed oil is 45 300 kJ/kg. Neem charcoal is of good quality with an energy value only slightly below that of coal.

Neem leaves contain per 100 g dry matter: crude protein 12–18 g, crude fibre 11–23 g, N-free extract 43–67 g, ash 8–18 g, Ca 1–4 g, P 0.1–0.3 g. The weight of 1000 seeds is (105–)185–270(–350) g.

Description A small to medium-sized, usually evergreen tree, up to 15(–30) m tall with round, large crown up to 10(–20) m in diameter; branches spreading; bole branchless for up to 7.5 m, up to 90 cm in diameter, sometimes fluted at base; bark moderately thick, with small scattered tubercles, deeply fissured and flaking in old trees, dark grey outside and reddish inside, with colourless, sticky foetid sap. Leaves alternate, crowded near the end of branches, simply pinnate, 20–40 cm long, exstipulate, light green, with 2 pairs of glands at the base, otherwise glabrous; petiole 2–7 cm long, subglabrous; rachis channelled above; leaflets 8–19, very short-petioluled, alternate proximally and more or less opposite distally, ovate to lanceolate, sometimes falcate, (2–)3.5–10 cm × 1.2–4.0 cm, glossy, serrate, apex acuminate, base unequal. Inflorescence an axillary, many-flowered



Azadirachta indica A.H.L. Juss. – 1, fruiting branch; 2, part of inflorescence; 3, vertical section through flower.

thyrse, up to 30 cm long; bracts minute and caducous; flowers bisexual or male on the same tree, actinomorphic, small, 5-merous, white or pale yellow, slightly sweet scented; calyx lobes imbricate, broadly ovate and thin, puberulous inside; petals free, imbricate, spathulate, spreading, ciliolate inside; stamens 10, filaments fused into a 10-lobed staminal tube, glabrous and slightly ribbed outside, anthers sessile, opposite the rounded to laciniate lobes; disk annular, fused to the base of the ovary; ovary superior, style slender, stigma capitate, 3-lobed. Fruit a 1(–2)-seeded drupe, ellipsoidal, 1–2 cm long, greenish, greenish-yellow to yellow or purple when ripe; exocarp thin, mesocarp pulpy, endocarp cartilaginous. Seed ovoid or spherical, apex pointed, testa thin. Seedling with epigeal germination; cotyledons thick, fleshy, elliptical with a rounded apex and sagittate base; first pair of leaves opposite, subsequent pairs either opposite or alternate, first few leaves usually trifoliolate, later 5-foliolate with deeply incised, pinnatifid, or partite leaflets.

Growth and development At germination the radicle emerges at the end of the seed and the hypocotyl arches, withdrawing the cotyledons from the ground. Growth in the first year is generally slow, 15–25 cm in height, becoming faster when the root system that forms associations with vasicular-arbuscular mycorrhyzal fungi is developed. Trees may reach 4–7 m after 3 years and 5–11 m after 5 years. The annual biomass increment of neem plantations has been reported at 3–10 m^3/ha. Under moderately favourable conditions mean annual diameter increment is 0.7–1.0 cm, under optimal conditions 2 cm/year may be reached. In irrigated plantations in India 16-year-old trees reached a diameter of 40 cm. Under cool conditions seedling growth ceases and new shoots appear in spring.

Neem trees may start flowering and fruiting at the age of 4–5 years, but economic quantities of seed are produced after 10–12 years. Pollination is by insects. In India, a bitter-tasting honey is produced. Certain isolated trees do not set fruit, suggesting that self-incompatibility occurs. The flowering and fruiting season largely depends on location and habitat. In Thailand neem trees flower from December to February and fruit in March to May. Fruits ripen in about 12 weeks from anthesis and are eaten by bats and birds which distribute the seed. Neem trees can live for over 200 years. They are normally evergreen, but may shed all or part of their leaves under extremely hot and dry conditions. Timing and duration of leaf shedding, flowering and seed set vary across geographic zones and provenances.

Other botanical information The genus *Azadirachta* A. Juss. is morphologically and anatomically closely related to *Melia* L., from which it can be easily distinguished by its simply pinnate leaves (bipinnate in *Melia*). *Azadirachta* has 2 species: *A. indica* and *A. excelsa* (Jack) Jacobs. The latter is a larger tree with larger leaves having 14–23 leaflets with entire margins, occurring naturally in Malaysia, the Philippines, Indonesia and New Guinea and producing valuable timber.

In Thailand, 2 varieties of the neem tree are sometimes recognized: var. *indica*, referred to as 'sadao India', and var. *siamensis* Valeton, called 'sadao Thai'. The latter grows wild and is widely distributed in the country; its branches are directed upright, contrary to the more spreading habit of var. *indica*. Opinions about their taxonomic status vary. Flora Malesiana reduced them to synonyms of *A. indica*, other sources have proposed to raise them to species rank. The two varieties can easily be crossed.

Ecology Neem grows under a wide range of conditions. It is found naturally from 0–700 m altitude, but can grow at elevations up to 1500 m. In the Philippines neem growing is largely restricted to the southern islands, as trees are too severely damaged by typhoons in Luzon. Mean annual minimum temperatures may range from 9.5–24.0°C, mean annual maximum temperatures from 26.3–36.7°C. Adult neem trees tolerate some frost, but seedlings are more sensitive. Optimal growth has been observed in areas with an annual rainfall of about 1000 mm, but rainfall may vary from 400–1400 mm. On well-drained soils, up to 2500 mm rainfall is tolerated, but then fruiting is generally poor. Neem does not tolerate waterlogging. Soil textures suitable for neem may range from pure sand to heavy clay. The soil pH may vary between 3 and 9, but best growth occurs on soils with a pH of 6.2–7.0. Neem prefers medium-textured fertile soils, but still performs better than most other species on shallow, poor soils, or on marginal sloping and stony locations, including crevices in sheer rock. It is occasionally found on moderately saline soils, and has been planted in former sugar-cane plantations abandoned because of increasing soil salinity.

Under natural conditions neem does not grow gregariously. In India, it is present in mixed forest with *Acacia* spp. and *Dalbergia sissoo* Roxb. ex DC.; in Indonesia, naturalized in lowland monsoon forest. In Africa it is found in evergreen forest and in dry deciduous forest.

Propagation and planting Neem is generally propagated by seed, but can also be propagated vegetatively by air layering, root and shoot cuttings, grafting, marcotting and tissue culture. Although it is best to harvest the ripe fruits from the tree, fruit collection within 1–2 days of natural dropping also gives satisfactory results and is more practical. The fruits are soaked in water for 1–2 days, depulped and the seeds are dried under shade, and stored in a cool well-ventilated place in cloth or gunny bags. They should not be stored in airtight containers or plastic bags, but should be sown as soon as possible. Mature seeds germinate readily within a week, with a germination rate of 75–90%. Seed remains viable for 4–8 weeks only, but storage of cleaned and dried seeds at 15°C will prolong this period up to 4 months. Kernels (depulped fruits) stored at −20°C retained their viability for as long as 10 years. Seed is normally sown in the nursery in lines at 15–20 cm × 2.5–5 cm, in a sunny place and covered lightly with soil or mulch. Damage by insects or birds eating the radicles can be prevented by covering with netting or by sowing at a depth of 2.5 cm. Seed beds should be watered sparingly and soil should be kept loose to prevent caking. In frost-prone areas seedlings should be protected by a screen. Seedlings are thinned to 15 cm × 15 cm when 2 months old. When they are 7–10 cm tall, with a taproot of about 15 cm long (about 12 weeks old), they are planted out in the field. Direct sowing in sunken beds, trenches, or on ridges also gives satisfactory results. Intercropping neem with pearl millet (*Pennisetum glaucum* (L.) R. Br.) has given good results in northern India.
Neem propagation by root suckers and stem cuttings can be done using 1000 ppm indole-3-butyric acid (IBA) and indole-3-acetic acid (IAA), and by air layering using IBA or naphtalene-1-acetic acid (NAA). Tissue culture is being tried; fresh cotyledons have been found to be the best source of material.

Husbandry Under favourable moisture conditions natural regeneration of neem is usually profuse, as seed is widely distributed by bats and birds. Weeding of neem plantations in dry areas is essential, as it cannot withstand competition, especially from grasses. Neem responds well to organic and chemical fertilizers. In West Africa rotation of neem plantations for firewood is 7–8 years at a final spacing of 5 m × 5 m; on good soils with adequate moisture in Haiti it is planted at 2.5 m × 2.5 m and managed with a rotation of only 4 years. As neem coppices well no replanting is necessary after harvesting. Moreover, coppicing is preferred for firewood production, as it facilitates harvesting and management of the plantation. Neem withstands pollarding well, a valuable asset for the use in wind-breaks, but seed production is adversely affected when trees are lopped for fodder.

Diseases and pests There are no records of fungi attacking neem in South-East Asia. In India and elsewhere *Pseudocercospora subsessilis* is the most common fungus attacking the leaves of neem, causing a shothole effect. In India, the bacterium *Pseudomonas azadirachtae* may damage leaves and a shoot borer damages shoots. Generally, neem appears not to be affected seriously by pests. In South and South-East Asia minor damage is caused by torticid moths (*Adoxophyes* spp.). Stored neem kernels have reportedly been damaged by *Oryzaephilus* larvae in India, and by *Carpophilus dinudiathus* in Ecuador.
Recently, a serious decline of neem has been observed in West Africa. Older foliage is shed, leaving crowns with an open appearance. Tufts of leaves remain at the branch apices, for which the disorder is now known as 'giraffe neck'. Preliminary observations indicate that the decline is not caused by a biotic agent, but is due to site-related stress (e.g. inadequate soil moisture, soil compaction, competition). In the state of Bornu in Nigeria, 80–95% of the neem trees have been seriously affected.

Harvesting The harvesting period of fruits is usually limited to 6–8 weeks after the monsoon rains. Leaves may be collected at any time. Pollarding is usually done on 5–10-year-old trees.

Yield Fruit yield is 10–30 kg/tree annually. Neem plantations in Thailand with a spacing of 2–4 m × 4 m yielded annually 6–7.5 m^3 wood per ha in the first 10 years on poor sites and 33–36 m^3/ha on favourable sites.

Handling after harvest Fruit collected for the extraction of neem oil is depulped immediately after collection, and the stones are dried in the shade and stored in a cool, dry place to avoid deterioration by oxidation, a reduction of the azadirachtin content and aflatoxin production by fungal growth. Properly dried stones can be stored for 8–12 months before oil extraction.

Genetic resources Germplasm collections are made, maintained, evaluated and distributed by Winrock International Institute for Agricultural Research in Thailand (Bangkok). Seeds are available commercially e.g. in India, at a price of US$ 0.50–1.00 per kg, excluding freight and certification, and cuttings cost US$ 50 per 100.

Breeding Phenotypically superior neem trees have been vegetatively propagated in Australia, India and Thailand. FAO and DANIDA have established provenance trials in Africa, Asia and South America.

Prospects Neem is an excellent multipurpose tree candidate for reforestation programmes. It is well adapted to depleted soils, is tolerant of repeated coppicing and pruning for firewood and a source of valuable oil. The quest for environmentally safe pesticides is increasing and neem's chemical properties provide an excellent source for further exploration. Ideally, neem pesticides should be based on crude extracts containing many of its compounds, rather than on single, refined and concentrated ingredients.

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S. Ahmed & Salma Idris

Bruguiera cylindrica (L.) Blume

Enum. Pl. Javae 1: 93 (1827).
RHIZOPHORACEAE
$2n$ = unknown

Synonyms *Rhizophora cylindrica* L. (1753), *R. caryophylloides* Burm.f. (1768), *Bruguiera caryophylloides* (Burm.f.) Blume (1827).

Vernacular names Black mangrove (En). Indonesia: tanjang, tanjang sukun (Java), lindur (Madura). Malaysia: berus (general), bakau belukap, berus ngayong (Sarawak). Philippines: pototan lalaki (general), bakáuan (Tagalog), kalapínai (Ilokano). Thailand: thua-daeng (Chanthaburi), thua-khao (Ranong, Krabi), rui (Phetchaburi). Vietnam: v[ej]t khang.

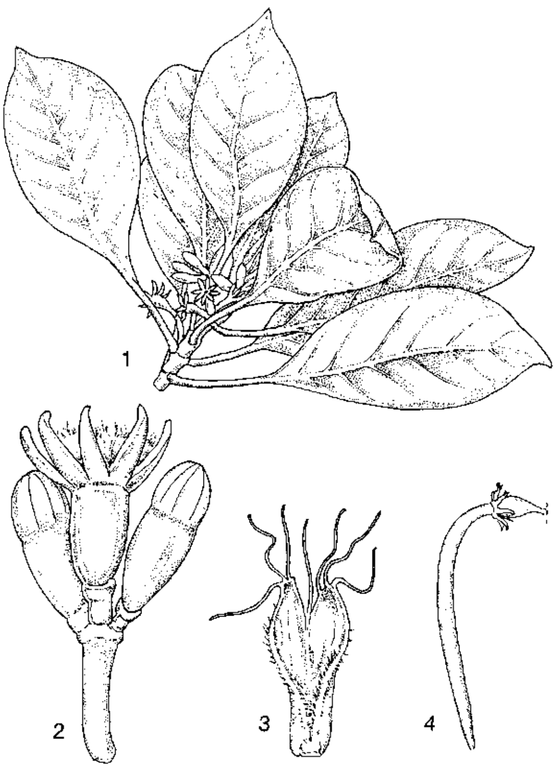
Origin and geographic distribution *Bruguiera cylindrica* occurs naturally in mangroves from India and Sri Lanka throughout South-East Asia to northern Queensland. It is also occasionally planted.

Uses The wood of *B. cylindrica* is a commonly used as firewood, for making charcoal and in temporary construction. The bark is said to be of some value for tanning. In Malaysia and Indonesia young hypocotyls are occasionally boiled and eaten as a vegetable or preserve, mainly in times of famine. In Vietnam young shoots are served as a salad.

Production and international trade The wood is mainly gathered from natural stands or from cultivated trees in reforestation areas. No statistics are available on its production and trade.

Properties The heartwood is reddish to reddish-brown upon exposure, hard, very heavy and strong, with a density of 840–1000 kg/m^3 at 15% moisture content. It is straightly grained and finely textured. Growth rings are indistinct or absent. The logs shrink and check excessively in seasoning, while the wood is easy to work and finishes well. It is non-durable when exposed to weather or in contact with the ground. The wood is lighter in weight and colour than *Rhizophora* wood, but both genera are traded together.

Botany A shrub or tree up to 23 m tall, stem diameter 20–30 cm; buttresses small, up to 1 m tall; bark surface grey, warty, with few, small, corky lenticels, inner bark evenly yellow; pneumatophores abundant, knee-like, forming new horizontal and anchor roots. Leaves decussately opposite, elliptical or oblong to oblong-lanceolate, 4–17 cm × 2–8 cm, entire, thin, bright green, apex acute, base cuneate, glabrous, usually with about



Bruguiera cylindrica (L.) Blume – 1, flowering branch; 2, 3-flowered cymose inflorescence; 3, petal after pollen release; 4, viviparous fruit with hypocotyl.

7 pairs of distinct veins on both surfaces; petiole 1–4.5 cm long; stipules in pairs, 2.0–3.5 cm long, early caducous. Inflorescence a cyme, 2–3 flowered; peduncle 6–8 mm long; pedicel 1–4 mm long; flowers greenish, at anthesis 10–12 mm long; calyx tube not ribbed, 4–6 mm × 2 mm, ending in 8 lobes as long as the tube; petals 8, 3–4 mm long, 2-lobed, white, soon turning brown, each lobe with 2 or 3 bristles at the apex, outer margins usually fringed with white hairs at the lower parts; each petal embraces a pair of stamens; stamens 16, 1.5–2.5 mm long; ovary inferior, style filiform, 3–4 mm long. Fruit a berry, enclosed by the persistent, sometimes enlarged calyx tube, 10–12 mm long; calyx lobes reflexed, not accrescent; hypocotyl cylindrical, often curved, 8–15 cm × 0.5 cm, grooved or angled, blunt, perforating the apex of the fruit and falling with it. Seed solitary, produced in large quantities.

In common with other members of the mangrove species of the *Rhizophoraceae*, the fruits are viviparous. In *B. cylindrica* the seed not only forms a hypocotyl, but may develop a considerable, rudimentary root system, while still hanging on the tree. In southern Thailand propagules develop for 3–4 months on the mother tree. The seedling still attached to the fruit drops from the tree, embedding itself in the mud, or floating to where it is washed up on the beach.

If sufficient light is available trees start flowering when 3–4 years old. Pollen is discharged explosively after being triggered by small insect visitors.

B. cylindrica grows under very harsh conditions and is known as the slowest-growing commercially used tree species in Malaysia. It takes over 10 years to reach a height of 6 m and over 15 years to attain a height of 9 m and a stem diameter of 6 cm. At the age of 60 years it has normally attained about 20 cm in diameter. In old naturally regenerated mangrove forest in Peninsular Malaysia the mean annual diameter increment was estimated to be 0.22 cm. Growth of one-year-old seedlings established in the open in mangrove forests in South Thailand was more than 10 times that of seedlings established in the shade.

Ecology In Malaysia *B. cylindrica* occupies the highest parts of the mangrove forest along the seacoast, where flooding is occasional only, up to about 20 m above sea level. It is usually absent from mangroves along rivers. On stiff clay soils behind the *Avicennia* zone, it grows gregariously, being one of the most tolerant species of anaerobic soil conditions. Towards the landward side of mangroves it remains as a scattered tree. On better drained soils it gives way to other species. Where land accretion occurs along the coast, it is a precursor of *Rhizophora* spp. In New Guinea, it is associated with *Rhizophora apiculata* Blume, *R. mucronata* Poiret, *Bruguiera sexangula* (Lour.) Poiret and *Nypa fruticans* Wurmb in the mangrove–fresh-water swamp transition zone.

The very poorly aerated soil habitually occupied by *B. cylindrica* makes the trees highly dependent on their pneumatophores for an adequate supply of oxygen and particularly susceptible to prolonged submersion.

Husbandry As *B. cylindrica* is such a prolific seed-bearer a healthy forest normally regenerates, even after clear-felling. Wildlings may be collected and used for planting, but regeneration has, so far, been left to nature in most cases. Young, pure stands can be extremely dense and may contain 55 000–70 000 stems per ha. Due to its extremely slow growth rate it requires a very long harvesting cycle. Its rotation should be longer than the 20 years now generally practised. Harvesting is done manually with an axe or matchet. This minimizes disturbance to the mangrove. Young trees from short-term rotations are preferred. Average annual wood production ranges from 2–16 m^3/ha.

Prospects *B. cylindrica* is one of the few economic species growing in brackish, anaerobic soil conditions. It requires and deserves increased research attention to attain its potential.

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T. Boonkerd & H.T. Chan

Bruguiera sexangula (Lour.) Poiret

Lamk, Encycl. Suppl. 4: 262 (1816).

RHIZOPHORACEAE

$2n$ = unknown

Synonyms *Rhizophora sexangula* Lour. (1790), *Bruguiera eriopetala* Wight & Arnott ex Arnott (1838).

Vernacular names Black mangrove (En). Indonesia: bakau tampusing, busing, mata buaya. Malaysia: tumu (putih) (Peninsular, Sarawak), berus putut (Sabah). Philippines: pototan (general), busain, tagasa (Tagalog). Cambodia: plaông prâsak'. Thailand: prasak, phangahuasum-dok-khao, prasak-nu. Vietnam: v[ej]t, v[ej]t d[uf].

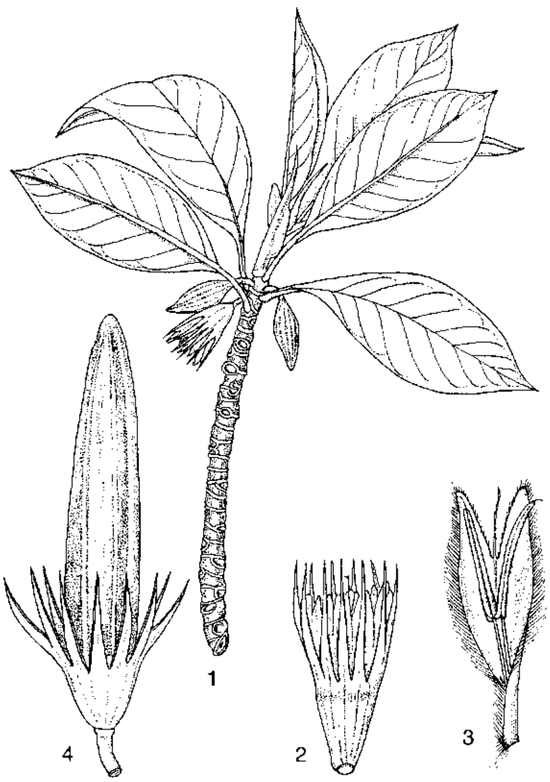
Origin and geographic distribution *B. sexangula* occurs naturally from India and Sri Lanka throughout South-East Asia to New Guinea and New Britain. It has been introduced into Hawaii, where it is now naturalized.

Uses Fuelwood, directly or after conversion to charcoal, is probably the main use of *B. sexangula*, especially at the local level. Wood from immature plants and branches is usually used for this purpose. The timber of well-grown trees is moderately durable and suitable for poles and house construction. It is traditionally also used for fishing stakes. The bark is used as a source of tannin; although it is thinner than the bark of *Rhizophora* spp., it contains more tannin. The bark also yields a flavouring and an adhesive. In Malaysia and Indonesia the fruit is sometimes used in the betel quid. *B. sexangula* can be used medicinally, the fruit is applied against shingles, the roots and leaves against burns. In Sulawesi the fruit is cooked, then soaked overnight and eaten, although it is very astringent.

Production and international trade No statistics are available on production or trade. Wood is mainly cut from wild stands.

Properties The wood of a full-grown tree is heavy, 820–1010 kg/m^3 at 15% moisture content and may have a very attractive colour. It is straightly grained and finely textured, and very strong. The wood is very hard, difficult to saw and work, and finishes well. It is non-durable when exposed to weather or in contact with the ground. Logs shrink and check excessively in seasoning. In the trade it is not distinguished from *Rhizophora* wood. The energy value of the wood is about 20 200 kJ/kg.

Botany Tree up to 33 m tall, trunk diameter up to 65–80 cm; buttresses up to 1 m high, tending to develop into plank-like non-arching stilt roots; pneumatophores knee-shaped, up to 45 cm long, forming horizontal and anchor roots. Bark smooth, greyish to pale brown with a few, large, corky lenticels, especially on the buttresses. Branching mostly sympodial. Leaves decussately opposite, elliptical to elliptical-oblong, rarely oblanceolate, 8–16 cm × 3–6 cm, pale green, entire, acute at both ends; petiole 1.5–5 cm long; stipules in pairs, 3.5–4 cm long, early caducous, green or yellowish. Flowers solitary, generally nodding, at anthesis 2.7–4 cm long; pedicel 6–12 mm long, green, yellow or brownish; calyx tubular with 10–12 lobes, yellow, yellow-brown or reddish, never bright red, tube 1–1.5 cm long and distinctly



Bruguiera sexangula (Lour.) Poiret – 1, flowering branch; 2, flower; 3, petal with enclosed stamen pair; 4, fruit and hypocotyl, with persistent calyx.

ridged to the base; petals 10–12, 1.5 cm long, 2-lobed, whitish turning yellowish-brown, densely fringed with hairs along the outer margins, lobes half the length of the petal, each with a reflexed and obtuse apex bearing 1–3 bristles, up to 1.2 mm long and a distinct bristle in the sinus between the lobes; each petal embraces a pair of stamens; stamens 7–14 mm long; style filiform, 1.5–2.2 cm long, with 3–4 short branches. Fruit a berry, more or less distinctly ribbed, enclosed in calyx, 1.5–1.8 cm long; hypocotyl cigar-shaped, rather angular, 6–8 cm × 1.5 cm, with narrow blunt end.

In common with other members of the *Rhizophoraceae*, the fruits of this species are viviparous. The seedling, still attached to the fruit, drops from the tree, embedding itself in the mud or floating to where it is washed up on the beach.

B. sexangula is the only *Bruguiera* species which sometimes forms stilt roots. The twigs and petioles lack the white, waxy covering, often characteristic of the closely related *B. gymnorhiza* (L.) Savigny that grows more towards the centre of mangrove communities.

Ecology *B. sexangula* occupies the inland parts of the mangrove forests which are not frequently submerged, and may be found along river banks. Occasionally, it is found on sandy shores. It occurs in soils with water that is less saline than seawater, and prefers easily drained soils. In India it is common along the outer fringes of mangrove swamps and sporadic along newly formed canals in their interior.

Husbandry In a trial in the Philippines seed germinated 5–10 days after sowing. Harvesting is done manually with axes or matchets, which minimizes disturbance to the mangrove. Young trees from short-term rotations are preferred.

Prospects *B. sexangula* is one of the less important mangrove species. It has some economic importance in mangrove vegetation close to the mainland.

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H.T. Chan & T. Boonkerd

Calliandra calothyrsus Meisner

Linnaea 21: 251 (1848).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 22$

Synonyms *Calliandra confusa* Sprague & Riley (1923), *C. similis* Sprague & Riley (1923), *C. acapulcensis* (Britton & Rose) Standley (1936).

Vernacular names Calliandra, red calliandra (En). Indonesia: kaliandra. Malaysia: kaliandra. Philippines: calliandra.

Origin and geographic distribution Although originally described from Surinam, where it was probably introduced, *C. calothyrsus* is native to humid and sub-humid Central America from southern Mexico to central Panama, between 8–19°N. In 1936 it was introduced from Guatemala into Java, where it became well established. In view of its excellent performance in Indonesian plantations it is now planted in other countries of South-East Asia and tested in Africa, Australia, some Latin American countries and Hawaii.

Uses In its native area, *C. calothyrsus* was not known to be useful. However, in Indonesia where it was originally introduced as a green manure crop for timber plantations, it has become favourably known for its many uses. It is primarily grown as a source of small-size fuelwood for household use and small industries, is widely planted for soil improvement, for erosion control on sloping lands and in ravines, and to suppress alang- alang (*Imperata cylindrica* (L.) Raeuschel). The wood is suitable for charcoal, pulp and paper, and fibre board production. *C. calothyrsus* is also used in alley-cropping systems as a source of green manure, in planted fallow, and in firebreaks. It has shown promise as an understorey plant in coconut plantations with about 60% light transmission. In forestry it is used as a nurse tree for partially shade-tolerant timber species (e.g. *Agathis* spp.). It has potential as a high quality source of leaf protein for supplementing low quality forages and crop residues. Its beautiful red 'powderpuff' flowers make it an attractive ornamental, and the flowers produce a good quality nectar for honey. It is a suitable host for the lac insect (*Laccifer lacca*).

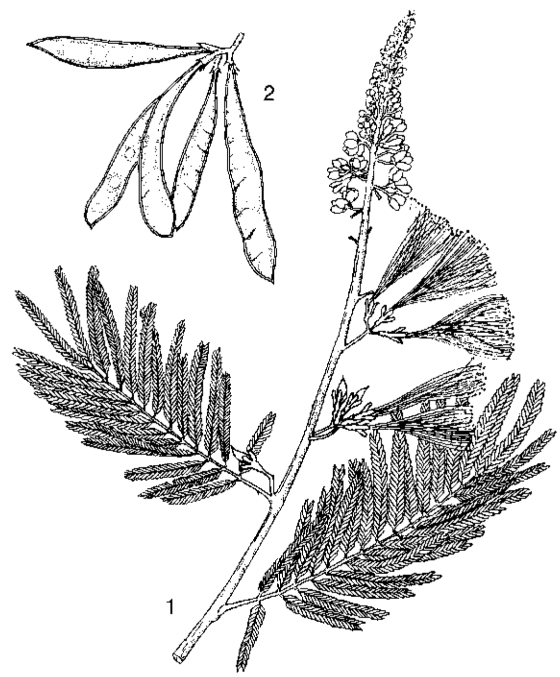
Production and international trade During the 1970s, *C. calothyrsus* became well established in Indonesia, its area increasing from about 60 000 ha in the late 1960s to 170 000 ha by the early 1980s.

Properties Leaves of *C. calothyrsus* contain per 100 g dry matter: crude protein 22 g, fibre 30–75 g, ash 4–5 g, fat 2–3 g, N 3–3.5 g, P 0.17 g, and K 0.58 g. The high content of tannins (up to 11%) results in low in vitro digestibility of dried foliage of only 35%. There is however, increasing evidence that fresh material has a higher digestibility rate of 60–80%. Such fresh foliage can be fed to livestock in addition to or as a replacement for commercial concentrates; it can compose up to 30% of mixed diets. High levels of tannin also slow down the rate of microbial breakdown of the organic matter, reducing its value as a source of nitrogen-rich green manure.

The weight of 1000 seeds is 50–70 g.

The wood has an air-dry density of 510–780 kg/m^3 and is strong and easy to saw. The fibre length is 0.66–0.84 mm and the wood contains 49–54% cellulose and 20–23% lignin. The pulp and paper-making properties of calliandra are satisfactory and are comparable to dipterocarps and appropriate for kraft paper manufacture. Calliandra pulp is easily bleached, but wood dimensions are generally small, making handling and chipping difficult. The energy value of the wood is 18 900–19 950 kJ/kg.

Description Unarmed shrub or small tree, (1.5–)4–6(–12) m tall, bole up to 30 cm in diameter, bark blackish brown, crown dense. Leaves alternate, bipinnate, rachis 10–19 cm long, without glands, with (3–)6–20 pinnae (2–)4–7(–11) cm long, each with 19–60 pairs of dark green leaflets; leaflets opposite, oblong, 5–8 mm × 1 mm, acute. Inflorescence terminal, composed of few to many umbelliform flower heads aggregated into a spike-like raceme 10–30 cm long; flower actinomorphic, showy; calyx 2 mm long; corolla 5–6 mm long, pale green; stamens numerous, 4–6 cm long, united at



Calliandra calothyrsus Meisner – 1, flowering branch; 2, peduncle with pods.

base, purplish red. Fruit a pod, linear-oblong and slightly tapering from top to base, flattened, 7–11 cm × 1.0–1.3 cm, margins thickened and raised, sometimes finely pubescent, dehiscing elastically from the apex, 3–15-seeded. Seed ellipsoid, flattened, 5–7 mm long, dark brown mottled.

Growth and development Early growth is rapid, on good soil seedlings can reach 2.5–3.5 m in height in 6 months and 3–5 m in 1 year. Calliandra reached 6.0 m in height and 5.8 cm in diameter in 2 years in the Philippines. Roots develop quickly and may reach 1.5–2 m depth in 4–5-month-old plants. It forms both superficial and deep penetrating roots. It easily forms root nodules in association with *Rhizobium* in which nitrogen is fixed. In its natural area of distribution *C. calothyrsus* flowers predominantly at the end of the rainy season and at the beginning of the dry season, but in Java it flowers throughout the year. Flowering may start in the first year, but good fruit set starts in the second year. Protandrous flowering and the difference in length between the stamens and style indicate outcrossing; the species has a low tolerance of selfing. Pollination is by insects and bats and fruits ripen 3 months after anthesis. Normally, relatively small quantities of seed are produced each year; most seed is produced during the dry season. In areas where pollinators are not in abundance, seed production is very poor as observed in tropical Africa. The presence of numerous thrips can also cause flower abortion and low seed production.

In humid climates the tree is evergreen, but in areas with a long dry season it is semi-deciduous. During severe drought trees die back, but generally recover when the rains return.

Around the age of 12 years the stem turns brittle, but vigorous new sprouts are readily formed. After pollarding a tree coppices vigorously and annual coppicing may be carried out for 10 years or more.

Other botanical information *Calliandra* Benth. comprises about 130 species of shrubs and small trees of tropical and warm temperate regions, some of which are widely cultivated as ornamentals. *C. acapulcensis*, which occurs in an area geographically separated from the main distribution of *C. calothyrsus*, has long been considered a separate species. Because the differences between these two taxa are only slight, it is now considered a subspecies occurring in the northern range of *C. calothyrsus*. Due to the morphological similarity of *C. calothyrsus* to *C. grandiflora* (L'Hér.) Benth. and *C. houstoniana* (Miller) Standley, and the occurrence of hybrids between the latter two species, there is some confusion about species delimitation.

The white-flowered *C. tetragona* Benth. from Guatemala was also introduced into Java at the same time as *C. calothyrsus*. Because of its slower growth however, *C. tetragona* became less popular for plantations.

Ecology In its native habitat, *C. calothyrsus* grows at 0–1300(–1850) m altitude in areas with an average annual precipitation of 700–3000 mm. It is not drought tolerant, but can withstand dry periods of (1–)2–6(–7) months with a rainfall of less than 50 mm. Waterlogging for 2 weeks or longer will kill the tree. In Java it is grown up to 1500 m altitude, but grows best between 250–800 m in areas with 2000–4000 mm annual rainfall and a dry period of 3–6 months. The plants require a mean annual temperature of (20–)22–28°C, with mean maximum temperature range in the hottest month of 24–30°C and mean minimum temperature range in the coldest month of 18–24°C. *C. calothyrsus* is an aggressive colonizer due to its early flowering and seed set, but can be outcompeted in later successional stages by other species. It often invades areas with continual disturbance such as roadsides, river banks and shifting cultivation plots.

It grows on a variety of soil types, mainly cambisols, acrisols and nitosols with soil conditions ranging from fertile to relatively infertile, and from acidic to mildly alkaline. It can also be found on andosols in volcanic deposits, shallow or eroded metamorphic sandy clays or recent alluvial deposits. In Indonesia it prefers light soils and slightly acid conditions; best growth is observed on acid soils of volcanic origin. It tolerates acid soils of poor fertility, but growth decreases on compacted soils and trees are not tolerant of a lack of oxygen.

Propagation and planting Calliandra is generally propagated from seed, either by direct seeding or by raising seedlings in the nursery. Seed germinates without pretreatment, but acid scarification or hot water treatment followed by soaking in the cooling water for 24 hours may improve the germination rate. The seed, however, is more heat sensitive than those of other legume trees and therefore hot water treatment should be applied cautiously. Seeds retain their viability for at least 2–3 years if stored at 4°C in sealed containers; viability drops from 75% to 60% when stored at room temperature for one year.

Direct sowing in the field can be done in planting holes (5 seeds/hole) in furrows or by broadcasting

on ploughed or burned lands. Aerial sowing has proved satisfactory in Java. Potted plants are transplanted when they are 20–50 cm tall and have a root-collar of 0.5–1 cm. Stumps may be taken from plants approximately 1 m tall by cutting the stem back to 30 cm and the roots to 20 cm. Vegetative propagation by cuttings is also possible, but use of large cuttings has not proved very successful. Two-node cuttings taken from young coppice shoots and treated with indole butyric acid (IBA) will root in about 14 days. Seedlings usually nodulate with native rhizobia and inoculation is only required in new areas. In Indonesia plants have been inoculated using *Rhizobium* strains CB 756 and CB 3171. Effective mycorrhizal associations may be slow to develop, resulting in poor early growth. However, once an effective mycorrhizal association has formed, growth is vigorous.
Areas to be planted are cleared completely. Spacing varies according to purpose. For firewood, planting distances applied are 1 m × 1–3 m; in alley cropping a spacing of 25–50 cm in contour rows and generally 4–6 m between the rows is used. For optimal leaf production in fodder banks, stands of up to 40 000 trees per ha (spacing 0.5 m × 0.5 m) can be used.

Husbandry Because seedlings grow quickly, no special plantation management is needed, except for weeding in the first year. On infertile soils fertilizer will improve early growth, but calliandra is less responsive to fertilizer than other tree legumes. In alley-cropping systems, calliandra should be pruned in cycles of up to 4 months to limit shade on associated crops. In East Java the productivity of sugar cane and maize could be maintained in a rotation of 4 years of calliandra, followed by sugar cane for 4 years and maize for 2 years, although both sugar cane and maize require large amounts of nitrogen. In Western Samoa, however, alley cropping *C. calothyrsus* for 4 years with an annual dry matter yield of 7–13 t/ha could not sustain yields of the companion crop taro. At present, no specific management practices can be recommended for obtaining optimal wood, fodder or biomass production from *C. calothyrsus* and little is known about this species' potential to be combined with fodder grasses or other tree species in intensive systems. As *C. calothyrsus* is a pioneer species, growing in the early stages of a succession, it lacks the ability to compete in later successional stages; therefore mixed plantations with taller trees and dense crowns are not recommended.

Diseases and pests No serious diseases or pests are recorded in Indonesia, but in the Philippines a stem-borer (*Callimetopus* sp.) causes damage to branches, without causing tree mortality, and *Leucopholis irrorata* attacks leaves, causing damage in trees planted as ornamentals. In Kenya, a rose flower beetle (*Pachnoda ephippiata*) has caused floral abortion and poor seed production to such an extent that the insect might limit the use of *C. calothyrsus*.

Harvesting Harvesting for firewood can start after the first year, and can be followed by annual coppice cuts at the end of the dry season. Fodder can be harvested in cutting cycles of 6 weeks to 6 months. A cycle of 12 weeks proved satisfactory in a fodder production trial in South Sulawesi. To enhance growth, cutting should be carried out at 20–50 cm above the ground. If plants are coppiced too low or during too wet periods, stumps are liable to fungal attack.

Yield On moderately fertile soils in Java, first harvests produced 5–20 m^3/ha per year of fuelwood. On favourable sites on volcanic deposits, annual coppice harvests continued for 10–20 years with an annual yield of 35–65 m^3/ha. For the Philippines the mean annual volume increment was 25.2 m^3/ha on a fertile site during the first 2 years. In plantations in Indonesia annual dry fodder yield is 7–10 t/ha. In a trial in South Sulawesi up to 22 t/ha of leaves and up to 22 t/ha of wood were obtained with a tree density of 40 000/ha and a cutting cycle of 12 weeks. In Western Samoa an annual yield of 46.2 t/ha was achieved in an alley-cropping system when cut at an interval of 6 weeks during the first 1.5 years. When grown in fences, fodder dry matter yields of 1.8–3.2 t per km of fence in 10 months have been obtained. In Western Samoa alleys 4 m wide gave an annual dry matter yield over 4 years of approximately 10 t/ha. Calliandra will often outyield other legume trees on infertile soils, but the yields tend to be similar on more fertile, less acidic soils.

Genetic resources A collection of *C. calothyrsus* germplasm covering 40 sites from 7 countries in Central America is maintained by the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Turrialba, Costa Rica and the Oxford Forestry Institute in the United Kingdom. It is assumed that the introduction of material of *C. calothyrsus* into Indonesia originated from only two germplasm sources from Guatemala. Therefore, genetic variation in the Indonesian material is very limited.

Breeding The large morphological variation and wide ecological amplitude of calliandra suggest that significant genetic variation will exist between different geographic areas. Iso-enzyme research has shown the existence of 3 groups of provenances. Although genetic improvement of calliandra is still in its infancy, results of some early provenance testing show clear provenance × site interactions, e.g. for drought tolerance. However, no differences have been detected between provenances for wood density, energy value, or ash content. It appears that the seed originally introduced into Indonesia was derived from a fast-growing, less branching, taller ecotype. All existing plantations in Indonesia are derived from this introduction. As seed production is early and abundant, the proposed strategy for future breeding activities is to start an 'open-pollinated' programme with careful progeny testing and heavy thinning before each seed harvest for the next generation.

Prospects *C. calothyrsus* is a versatile plant used for various auxiliary applications. It has become popular because its high-quality, small-sized fuelwood can be readily produced in annual coppice rotations. Calliandra can also be used in different farming and in a number of agroforestry applications. It grows under a wide range of soil fertility conditions and is often outstanding on infertile sites. It is used extensively for reclamation of bare and degraded lands, including *Imperata* grasslands. Special attention has been given to its use as an alternative to *Leucaena leucocephala* (Lamk) de Wit on acid soils or areas infested with leucaena psyllid. Due to its high tannin content the microbial decomposition of calliandra green manure is slower than that of leucaena, resulting in slower nitrogen release. Its high production potential and high protein content make it a promising fodder crop to supplement low-quality forages. It has, for example, potential for use as a high protein feed for fish, rabbits and poultry. However, also due to the high tannin content, the palatability of calliandra is less than that of *Leucaena leucocephala* or *Gliricidia sepium* (Jacq.) Kunth ex Walp. Further studies are needed to ascertain its full potential as a green manure and as a fodder crop, with emphasis on its ability to improve soil fertility, on its nutritive value and potential for direct grazing. Care must be taken that this hardy plant does not become a weed.

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K.F. Wiersum & I.K. Rika

Calopogonium mucunoides Desv.

Ann. Sci. Nat. Sér. 1, 9: 423 (1826).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 36$

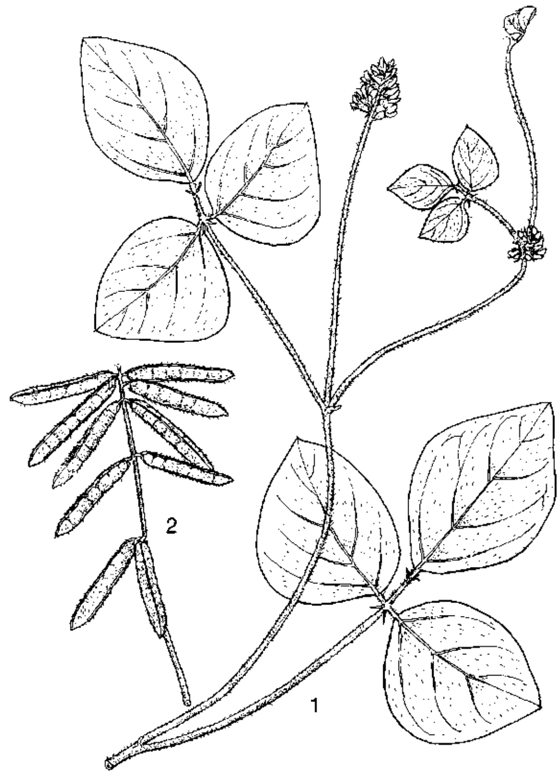
Vernacular names Calopo (En). Indonesia: kacang asu (Javanese), kalopogonium (Indonesian). Philippines: santing (Sulu), karaparapak sara naw (Mar.). Thailand: thua-khalapo.

Origin and geographic distribution Calopo is indigenous to tropical America and the West Indies. It was introduced into tropical Africa and Asia in the early 1900s and to Australia in the 1930s. Calopo was taken into use as a green manure and cover crop in Sumatra in 1922 and soon thereafter in the rubber and sisal plantations of the central and eastern parts of Java. It was then brought to Malaysia as a cover crop for rubber. Calopo became naturalized in Indonesia and Malaysia, and has spread to most humid tropical areas of the world.

Uses Calopo is well recognized as being a valuable pioneer legume to protect the soil surface, reduce soil temperature, fix atmospheric nitrogen, improve soil fertility and control the growth of weeds. It is an important cover crop for plantation crops, especially rubber and oil palm, where it is often grown in a mixture with centro (*Centrosema pubescens* Benth.) and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.). In Africa this mixture has been tested in young forest plantations, where it reduced the cost of weeding. Calopo is also used as a green manure for soil improvement. It is grown as a forage, used especially during the latter part of the dry season.

Properties Although calopo is a widely used green manure crop, little is known about its chemical composition. A chemical analysis of stems and leaves of plants grown in pots in Malaysia indicated per 100 g dry matter: N 3.8 g, P 0.24 g, K 2.0 g, Ca 1.0 g, and Mg 0.25 g. Nitrogen percentages of 2.6–3.8% have been recorded, but lower values should be anticipated in older, stemmy material. Calopo forage is not very palatable to cattle because taste and smell limit the intake, but animals are forced to eat it during the dry season when little green fodder is available. Its low palatibility, which is usually ascribed to the abundance of hairs on the stems and leaves, contributes to its persistence in mixed swards. The weight of 1000 seeds is 13–15 g.

Description A vigorous, creeping, twining or trailing herb, up to several m long, forming a tangled mass of foliage 30–50 cm deep, with densely



Calopogonium mucunoides Desv. – 1, flowering branch; 2, fruiting branch.

pilose stems with long spreading ferruginous hairs. Leaves trifoliolate, petiole up to 16 cm long, pilose; leaflets elliptical, ovate or rhomboid-ovate, (1.5–)4–10(–15) cm × (1–)2–5(–9) cm, the laterals oblique, adpressed pilose or pubescent on both surfaces. Inflorescence a slender raceme, up to 20 cm long, peduncle 0–17 cm long, ferruginous pilose; flowers in fascicles of 2–6, blue or purple; calyx campanulate, unequally 5-lobed; corolla with emarginate standard, about 1 cm long. Pod linear-oblongoid, 2–4 cm × 3.5–5 mm, straight or curved, softly pilose with coarse reddish-brown hairs, impressed between the seeds, 3–8 seeded. Seed compressed squarish, 2–3 mm long, yellowish or reddish-brown.

Growth and development Calopo grows rapidly and is able to cover the soil in 3–6 months after sowing and even sooner on newly cleared, fertile land. It forms a dense entangled sward in 4–5 months after sowing, but the plants are short-lived and may only persist for 1–2 years. When grown as a cover crop in plantation crops in a mixture with tropical kudzu and centro, calopo is the first to become established but also the first to be shaded out. Long-term persistence is through recruitment of new plants from seedlings. The root system is dense and rather shallow, its deepest roots reaching a depth of about 50 cm. Flowering in calopo is initiated by short days. It is self-pollinated and seeds freely.

Other botanical information Although widely grown for decades, no improved cultivars of calopo are known to exist. The name 'tortilla' is used to indicate seed of calopo sometimes harvested from naturalized stands in the Adelaide River area of the Northern Territory (Australia). It was at one time thought to have been a long-term locally adapted ecotype, but it is now believed to have come to the area as a contaminant in tropical kudzu seed from Queensland which had been sown in the late 1960s at the Tortilla Flats Research Farm. 'Tortilla' is likely to be similar to Queensland commercial material, which is rarely harvested and has never been assigned a cultivar name.

Ecology Calopo is grown from sea level to 2000 m altitude, but is best adapted to altitudes 300–1500 m. It is well suited to the hot humid tropics with an annual rainfall exceeding 1250 mm but not tolerant of frost. It is moderately drought-tolerant but may die out if the dry season is prolonged. Vigorous growth occurs on soils of all textures, even those with a low pH(H_2O) range of 4.5–5. Its self-seeding nature and twining growth habit make calopo well adapted to a range of ecological conditions. When grown for forage it can be used in a mixture of species, provided it does not become too dominant.

Calopo is poorly adapted to shade, showing a marked decline in top growth, root growth and nodulation with decreasing light intensities. This may be attributed to the 'non-plasticity' of leaves under shade as compared with other, shade-tolerant plants such as *Calopogonium caeruleum* (Benth.) Sauv., *Centrosema pubescens* and *Desmodium heterocarpon* (L.) DC. subsp. *heterocarpon* var. *ovalifolium* (Wallich ex Prain) Rugayah. Under low light intensities (< 20%) calopo leaves are reduced in size by 70% compared with leaves in full sunlight. In contrast, centro and *C. caeruleum* leaves are reduced by only 10–25%, while leaves of *Desmodium heterocarpon* subsp. *heterocarpon* var. *ovalifolium* are 20% larger under such a low light intensity.

Propagation and planting Calopo is usually propagated by seed, sown at 1–3 kg/ha. Seed is normally drilled in rows when sown into new plantations or broadcast in stands to be used for forage production. After seed is broadcast, the seed-bed may be rolled to improve establishment. Newly harvested seed usually has more than 75% hard seed. Mechanical scarification, soaking in concentrated sulphuric acid for 30 minutes, or soaking in hot water (75°C) for 3 minutes is recommended to enhance germination. Although calopo stems root at the nodes when in contact with moist soil the establishment of stem cuttings inserted directly into soil is generally poor. Use of pre and post-emergence herbicides or hand weeding promotes the establishment of calopo. As calopo nodulates promiscuously with native rhizobia, seeds are usually not inoculated. If inoculum is applied, then cowpea strains such as the Australian CB 756 are used. When planted as a cover crop in plantations it is usually sown in a mixture with other legumes such as *Calopogonium caeruleum*, *Centrosema pubescens* and *Pueraria phaseoloides* with 1–3 kg/ha of calopo in a total mixture of 10–15 kg/ha of legume seed. When sown for forage production, calopo has been successfully used in mixtures with stoloniferous grasses, such as molasses grass (*Melinis minutiflora* Beauv.) and Rhodes grass (*Chloris gayana* Kunth), and with tussock grasses such as setaria (*Setaria sphacelata* (Schumacher) Stapf & Hubbard ex M.B. Moss). Good results have been obtained from oversowing it into existing stands of pangola grass (*Digitaria eriantha* Steud.) which have been harrowed.

Husbandry Calopo grows vigorously, shedding a large amount of leaf litter onto the soil which smothers most weeds. Fertilizing acidic soils with ground dolomite and Mo increases yields. Application of P usually increases leaf size. The effect of calopo and associated legumes in improving soil fertility may last for 14–16 years. In an experiment in Malang, Indonesia, a green manure crop of calopo grown for 3 months contained about 65 kg/ha nitrogen in its leaves, shoots and roots. It was followed by a maize crop, which yielded 2.4 t/ha of grain, while a second maize crop following a well-fertilized maize crop had a grain yield of 1.4 t/ha. However, maize following *Mucuna pruriens* (L.) DC. cv. group Utilis or *Crotalaria juncea* L. gave significantly higher yields.

If calopo is grazed it is advisable to use rotational grazing with rest periods of 8–12 weeks if calopo growth is erect rather than prostrate. Regular slashing is needed when calopo is planted as cover crop in young oil palm and rubber plantations, to prevent the cover from overgrowing the trees.

Diseases and pests Calopo is susceptible to viruses in Costa Rica, Guatemala and Panama. Beetles and leaf-eating caterpillars have been observed on calopo in Malaysia, but they have not been a serious problem.

Harvesting Whether grazed or cut and fed, calopo is often refused by cattle although they eat it less reluctantly during the dry season. It is usually cut by hand and is seldom conserved as hay or silage.

Yield When pods are mature, peak dry matter yields of up to 14 t/ha can be obtained in a single cut. Lower yields of 4–6 t/ha per year are obtained when calopo is cut every 9–12 weeks. Seed yields of 200–300 kg/ha have been recorded.

Genetic resources Collections of calopo are held at the Centro Internacional de Agricultura Tropical (CIAT, Colombia) and the Australian Tropical Forage Genetic Resource Centre (ATFGRC, Australia).

Breeding There are no known breeding programmes on calopo.

Prospects Being one of the components of a widely adopted mixture of cover crops, calopo is likely to remain important in plantation agriculture. Its value as a green manure crop in intercropping systems and in rotations with annual crops still needs confirmation. Low palatability may explain why interest in calopo as a forage plant has faded during the last decade. However, this low palatability and resulting persistence may open up opportunities for incorporating calopo into forage systems as a way of improving soil fertility and the growth rate and quality of pastures.

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Chen Chin Peng & A. Aminah

Casuarina equisetifolia L.

Amoen. Acad. 4: 143 (1759).
CASUARINACEAE
$2n = 18$, (20)

Synonyms *Casuarina litorea* L. (1759), *C. equisetifolia* J.R. & G. Forster (1776).

Vernacular names Coast she-oak, ironwood, whistling pine (En). Beach she-oak (Am). Filao (Fr). Indonesia: cemara laut, eru. Malaysia: ru laut. Papua New Guinea: yar. Philippines: Australian pine, agoho. Burma (Myanmar): tin-yu. Cambodia: snga:w. Laos: pè:k namz, sôn th'ale:. Thailand: son-thale (general). Vietnam: c[aa]y phi lao.

Origin and geographic distribution *C. equisetifolia* has the widest natural distribution of all *Casuarina* species, occurring naturally along the tropical coastlines from northern Queensland and the Northern Territory in Australia, throughout the whole Malesian region to the Kra Isthmus (Thailand). To the east its natural range extends throughout Melanesia and Polynesia. It is doubtfully indigenous to the Mekong Delta in Vietnam and to Burma (Myanmar) and possibly also to Madagascar. It has also been introduced into a large number of countries and is now a common feature of the coastal landscape of most tropical and warm subtropical countries, where it is often naturalized.

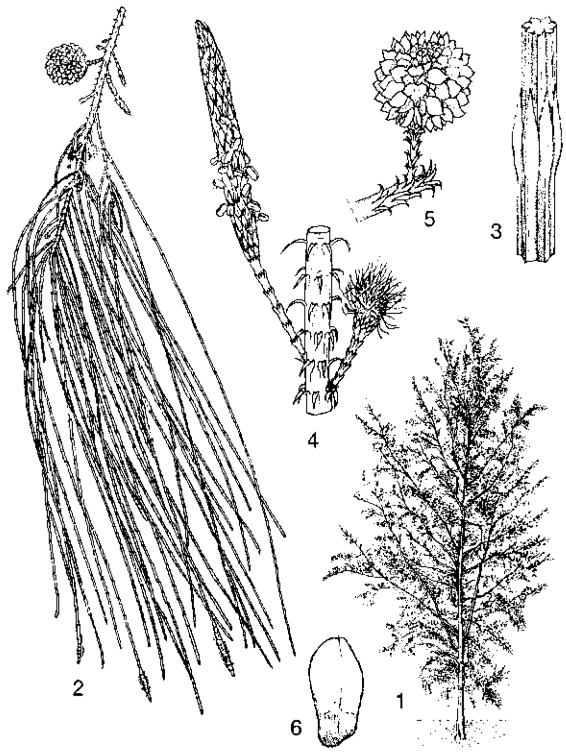
Uses The most common uses of *C. equisetifolia* are for coastal sand dune stabilization, shelterbelts, land reclamation and erosion control. It is a popular agroforestry tree in coastal and saline areas. In Sarawak it is protected because of its importance in controlling coastal erosion. Many ar-

eas of occurrence are susceptible to tropical cyclones or typhoons and *C. equisetifolia*'s general tolerance to strong winds has encouraged its use in protective plantings. A 3000 km long belt along the coast of southern China is planted to *C. equisetifolia* for this purpose.
The wood is highly regarded as a fuel. It burns even when green and produces high quality charcoal. The small branch litter is often collected for domestic fuel and is sometimes used to fuel pottery and brick kilns. Poles are popular as masts for fishing boats, piles, posts and tool handles. Sawn timber is only used for small items like roofing shingles. The wood is used to produce paper pulp using neutral sulphate and semi-chemical processes and as raw material for rayon fibres. In Egypt it is used to make chipboard.
The bark has been used for tanning and is still occasionally used by amateur tanners. Medicinal use is made of the roots to treat dysentery, diarrhoea and stomach ache. In West Malaysia, a decoction of the twigs is used for treating swellings and the powdered bark is used for treating facial pimples.

Production and international trade No statistics are available on production and trade.

Properties The bark of *C. equisetifolia* is astringent and contains 6–18% tannins. Tests of the chemical composition of the branchlets in Puerto Rico gave per 100 g dry matter: N 1.56 g, P 0.16 g, K 0.48 g, Ca 1.23 g, Mg 0.23 g, Na 3.28 g.
The wood is hard and heavy with an air-dry density of 900–1000 kg/m^3, sapwood being slightly heavier than heartwood. Green logs have a moisture content of 40–60%. The energy value of the wood is 24 000 kJ/kg and that of the charcoal exceeds 33 500 kJ/kg. The wood produces little ash and burns even when green. On sawn timber the rays are prominent on radial faces. The wood tends to warp and crack on drying.
The weight of 1000 seeds is 1.4–3.3 g.

Description Monoecious tree with a finely branched crown, 6–35 m tall, with trunk diameter up to 50 cm; bark light greyish-brown, smooth on young trunks, rough, thick, and furrowed on older trees; inner bark reddish and astringent; branchlets deciduous, drooping, needle-like, terete but with prominent angular ribs, 23–38 cm × 0.5–1 mm, greyish-green, articles 5–8 mm long, glabrous to densely pubescent. Leaves reduced to minute teeth, in whorls of 7–8 per node. Male flowers in a terminal, simple, elongated spike, 7–40 mm long, borne in whorls with 7.0–11.5 whorls per cm of spike. Female inflorescence on lateral woody branches, cylindrical, cone-shaped or globose, 10–24 mm long, 9–13 mm in diameter; bracteoles acute, more or less protruding from the surface of the cone. Fruit a samara, 6–8 mm long, 1-seeded, dull brown. Seed with epigeal germination.



Casuarina equisetifolia L. – 1, habit of young tree; 2, habit of flowering branch; 3, part of branchlet; 4, branch with male and female inflorescence; 5, infructescence (cone); 6, fruit (samara).

Growth and development *C. equisetifolia* has a life span of 40–50 years and displays fast early growth. Under favourable conditions early growth in height may exceed 3 m per year. At 10 years a height exceeding 10 m and a diameter of 20 cm may be reached.
Branching in *Casuarinaceae* is dimorphic. Most prominent are the green needle-twigs that are functional leaves with a limited life and determinate growth. With age they turn brown and are shed. The other type of branch is normal, woody, with indeterminate growth.
Tree form in wild populations is very variable, from crooked low-branching trees on exposed seashores to straight-stemmed forest trees with a narrowly conical crown in more sheltered situations and in plantations. *C. equisetifolia* coppices

only to a limited extent and only when cut young (3–4 years).

Although trees in natural stands are mostly monoecious, many introduced populations are dioecious. Pollination is by wind. Female cones mature about 18–20 weeks after flowering, and open shortly thereafter, releasing the small winged fruitlets.

C. equisetifolia forms large, long-lived, woody root nodules with several strains of the actinorhizal symbiont, *Frankia*, which enables it to fix atmospheric nitrogen. These root nodules can be prolific. Extrapolations from experimental data indicate that 90 kg/ha of atmospheric nitrogen can be fixed annually at a planting density of 2000 trees per ha. Uptake of other plant nutrients is enhanced by the presence of proteoid roots and associations with ectomycorrhizal and endomycorrhizal fungi. As in other actinorhizal plants, endomycorrhizal (VAM) infection occurs easily.

Other botanical information Linnaeus's publication of *C. equisetifolia* consists only of a name and a reference to a drawing by Rumphius. Unfortunately, the name contains a printing error (*equisefolia*) and many sources therefore cite J.R. & G. Forster as the original authors. Correction of the typographical error is allowed, however.

In *C. equisetifolia* two subspecies have been distinguished: subsp. *equisetifolia* is most common and most widely distributed; subsp. *incana* (Benth.) L.A.S. Johnson occurs exclusively along the coast of Queensland and northern New South Wales and on Vanuatu. It is a 6–12 m tall tree with densely pubescent immature branchlets with sometimes flat and wrinkled ribs.

Ecology *C. equisetifolia* is commonly confined to a narrow strip adjacent to sandy coasts, usually from sea level to 100 m altitude, but recorded to 600 m in Hawaii and 800 m in the Philippines. It is planted up to 1200 m altitude. It is found on sand dunes, in sands alongside estuaries behind foredunes and gentle slopes near the sea. It may be found at the leading edge of dune vegetation, subjected to salt spray and inundation with sea water at extremely high tides and where it may be the only woody species, growing over a ground cover of dune grasses and salt-tolerant broad-leaved herbs. It may also be part of the richer Indo-Pacific beach flora, in which it grows in association with *Barringtonia asiatica* (L.) Kurz, *Calophyllum inophyllum* L., *Heritiera littoralis* Aiton, *Hibiscus tiliaceus* L., *Thespesia populnea* Sol. ex Correa and *Pandanus* species. It requires much light. Seedlings do not grow in the shade of uniform *C. equisetifolia* stands and such stands are gradually replaced by mixed forest, with a single file of *C. equisetifolia* trees along the sea front.

The climate in its natural range is semi-arid to sub-humid and frost-free. Rainfall varies from 700–2000(–3500) mm per year. In most regions there is a distinct dry period of 4–6(–8) months, although this seasonality decreases towards the equator in South-East Asia and in the southern parts of its range in Australia. *C. equisetifolia* is intolerant of prolonged waterlogging. It can grow in semi-arid climates with annual rainfall of less than 350 mm where sea spray and high air humidity supplement rainfall. Mean minimum temperature of the coldest month ranges from 7°C–20°C, mean maximum temperature of the hottest month from 20°C–35°C.

Soils are invariably well-drained and rather coarse-textured, principally sands and sandy loams. The tree tolerates saline, calcareous and slightly alkaline soils and is very well adapted to soils of low fertility.

Propagation and planting Propagation is mainly by seed, although cuttings are increasingly used. Seed requires no pretreatment. Germination takes up to two weeks. In Thailand and India cuttings are made from small branchlets 10–15 cm long and 2 mm in diameter. Rooting is enhanced through use of the hormones indole-3-butyric acid (IBA) or indole-3-acetic acid (IAA). In southern China cuttings are taken from branchlets of 5 cm long and 1 mm in diameter and soaked in a solution of naphthalene-1-acetic acid (NAA) before being placed in polythene bags.

Inoculation of the seedlings with a pure culture of effective strains of *Frankia* is recommended when *C. equisetifolia* is introduced to a new area. This is done by applying a water suspension of the inoculant to the seedlings. Applying a solution of crushed nodules works less well. The availability of mycorrhizal fungi can be assured by adding soil collected from established stands to the potting medium. Early growth can be doubled as a response to inoculation.

Plantations can be established using containerized seedlings, bare-root seedlings or rooted cuttings. Plants are typically suitable for planting out when 25–30 cm tall, though in the desert climate of Egypt smaller seedlings are preferred. A density of 2500 plants per ha is commonly used, but some private farmers plant up to 8000–10 000 plants per ha. Young trees compete poorly with weeds, so weeding is important for 2 years after planting.

Husbandry *C. equisetifolia* is considered to be a poor self pruner. Pruning in plantations is necessary up to 2 m, to keep plantations accessible for general maintenance. Pruning may, however, allow infection with fungal pathogens, especially *Trichosporium vesiculosum*. *C. equisetifolia* is not fire-resistant and protection is necessary, even against light fires. Leaf litter from plantations is frequently removed for fuel; this depletes the soil's reserves of phosphorus and potassium.

Diseases and pests *C. equisetifolia* is only rarely attacked by diseases and pests except when grown under unfavourable conditions. The most serious disease threatening *C. equisetifolia* plantations is blister blight caused by the fungus *Trichosporium vesiculosum*. Infected trees exhibit symptoms of foliar wilt and cracking of the bark, where blisters develop enclosing a black powdery mass of spores. Bacterial wilt disease caused by *Pseudomonas solanacearum*, characterized by yellowing of the foliage followed by wilting and death, has been reported in China and India. Other potentially serious diseases include stem canker and dieback caused by *Phomopsis casuarinae* and pink disease (*Corticium salmonicolor*).
In the nursery and in newly-established plantations, seedlings are sometimes attacked by termites, crickets or rodents. Young trees may be seriously damaged by browsing animals.

Harvesting Rotation periods vary from 6–15 years when harvesting for fuelwood.

Yield On favourable sites, *C. equisetifolia* can reach an annual increment of 15 m^3/ha at 10 years. In India, plantations using 1–2 m × 1–2 m spacing on 6–15 year rotations yield 50–200 t of wood per ha. Dry weight of stems, branches and twigs per tree ranges from 15 to 25 kg at 3 years of age, depending on site quality. Up to 4 t/ha of litter and twigs may be harvested for fuel.

Genetic resources The Australian Tree Seed Centre of the Division of Forestry and Forest Products of the Commonwealth Scientific and Industrial Research Organization (CSIRO) has a collection of seed material collected from 65 sites in 21 countries. International trials to evaluate this material are under way on about 30 sites in 20 countries and are being coordinated by the Australian Tree Seed Centre. The large phenotypic variation displayed between populations can be exploited for tree improvement. The effectiveness of different *Frankia* strains varies greatly. *Frankia* collections are maintained by the Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM) in France, the CSIRO Division of Soils in Townsville, Australia and at the School of Forestry at Yale University, Cambridge, United States.

Breeding Considerable improvements in growth following conventional plant breeding and screening of élite trees followed by vegetative propagation are anticipated.

Prospects *C. equisetifolia* will remain of considerable importance for agroforestry and reclamation of unstable coastal ecosystems in tropical countries. Improvement by breeding and concurrent screening of *Frankia* and mycorrhiza strains for effectiveness will receive priority.

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S.J. Midgley & R. Sylvester

Casuarina junghuhniana Miquel

Plantae junghuhnianae 1: 7 (1851).
CASUARINACEAE
$2n = 18$

Synonyms *Casuarina montana* Junghuhn ex Miquel (1855).

Vernacular names Red-tipped ru, mountain ru (En). Indonesia: cemara gunung (Indonesian), adjaob, kasuari (Timor). Thailand: son-pradiphat.

Origin and geographic distribution *C. junghuhniana* is indigenous to Indonesia where it occurs in East Java and the Lesser Sunda Islands (Bali and Nusa Tenggara) from Bali to Timor and Wetar. It has been introduced to Kenya and Tanzania. A male, hybrid plant was introduced into Thailand in about 1900, and its progeny was taken from there to India in the early 1950s.

Uses *C. junghuhniana* is planted widely, especially in Indonesia, to improve soil fertility and rehabilitate degraded soils and as a wind-break. Branches and foliage are burnt and the ash is spread on village gardens in Timor. The wood is highly suitable for firewood and charcoal production. In Thailand, it is a popular source of construction piles and for fish traps. In Kenya and Tanzania farmers plant *C. junghuhniana* around fields for poles and firewood and as a live fence. The wood is a suitable source of raw material for kraft pulp. It can be used to make hardboard in a mixture with *Dipterocarpus* spp.

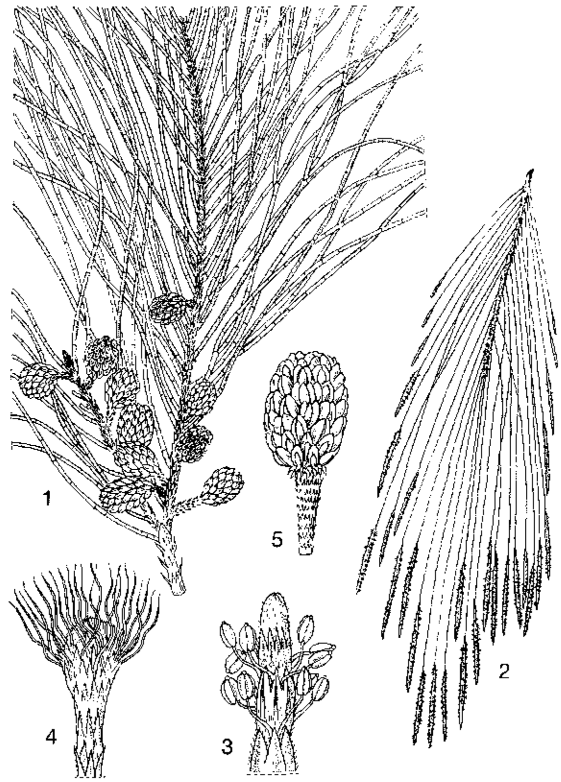
Although it is not a fodder, young trees are browsed by animals.

Production and international trade No statistics are available on wood production, international trade and areas planted to *C. junghuhniana*. Most plantings in Thailand and Kenya are scattered in small plots of a few hectares.

Properties Branchlets decompose slowly and provide good mulch. The air-dry density of the wood is 900–1000 kg/m^3, and that of charcoal is 650 kg/m^3. The energy value of the charcoal is 34 500 kJ/kg, which is among the highest for firewood species. Average durability of untreated wood is 4.5 years in direct contact with the ground. This can be increased to 15 years by treatment with a creosote preservative.

The weight of 1000 seeds is 0.6–1.0 g.

Description A fast-growing, dioecious tree, 15–25(–35) m tall; trunk diameter 30–50(–65) cm; crown somewhat open. Branching dimorphic with normal woody branches and determinate, deciduous branchlets; deciduous branchlets (switch twigs) numerous, articulate, internodes 10–15 mm long, greyish-green. Leaves reduced to tiny teeth, in whorls of 9–11(–13). Male inflorescence a cylindrical or slightly clavate spike, 3–8 cm long, borne on the apex of a deciduous branchlet; sheathing bracts hairy outside; lobes 10–11; bracteoles mucronate, 1.7–2.0 mm long; perianth lobes 0.7–1.7 mm long; filament 3.0–3.5 mm long. Female inflorescence in the axil of scale leaves on permanent



Casuarina junghuhniana Miquel – 1, habit of branch with fruits; 2, branch with male inflorescences; 3, detail male inflorescence; 4, female inflorescence; 5, infructescence (cone).

shoots, cone-shaped, ellipsoid, truncate, 1–2 cm long, reddish; bracts 18–20-seriate, broadly obtriangular; bracteoles oblong-obovate, rounded or very obtuse, thick, 5–6 mm × 2.5–3.0 mm. Fruit a samara, small, 2–3 mm wide and 4–5 mm long including wing. Seedling with epigeal germination.

Growth and development Mature seeds germinate readily without pretreatment. The germination rate is 50–60%, decreasing rapidly unless kept in dry, cool storage. The cotyledons are folded initially, later extending and becoming oblong. Under favourable conditions seedlings attain 25–30 cm in height within 3 months. As the main stem elongates, side branches develop from the upper axils of scale leaves. They are upright, giving the crown a slender, conical shape. Young trees continue to develop a conical crown; with age it tends to flatten.

Seedlings can attain 3 m growth in height per year during the first 2–3 years. In plantations with a controlled water regime in Thailand the *C.*

junghuhniana hybrid reaches 20 m in height and 15 cm in diameter in 5 years. In Markhanam, Tamil Nadu, India, hybrid trees reach a height of 5 m in 20 months.
Shoot growth tends to cease or to be less during the flowering period which coincides with the dry season. Like other *Casuarina* spp., *C. junghuhniana* is wind-pollinated.
C. junghuhniana fixes atmospheric nitrogen by nodulation with actinomycete bacteria of the genus *Frankia*. The nodules are woody and perennial and can form large masses in the root system. Mycorrhizal fungi further enhance its adaptability to poor soils.

Other botanical information *C. junghuhniana* is rather variable. In its easternmost area of distribution, 2 forms occur, locally known as black and white casuarina, respectively.
C. junghuhniana has coarse and fine branchlet variants. The forms with coarse branchlets may occur on exposed sites and are notable also for their rough, deeply-furrowed corky bark which is unusual for *Casuarina* spp. *C. junghuhniana* hybridizes readily with *C. equisetifolia* L. in cultivation, but not in the wild. The male hybrid introduced to Thailand has good form with straight stem and symmetrical conical crown. It is popular for commercial forestry and as an ornamental.

Ecology *C. junghuhniana* grows naturally on the slopes of volcanoes at altitudes of 1500–3100 m but also at lower altitudes in dry places. In eastern Indonesia, especially on Timor, it occurs from near sea level up to 550 m altitude.
Rainfall in the natural habitat is monsoonal, with a well-defined summer maximum and a reported annual range of 700–1500 mm. Mean maximum temperature of the hottest month ranges from 25–28°C, mean minimum temperature of the coldest month from 19–22°C. It is drought-tolerant and can survive prolonged waterlogging. Near Bangkok commercial plantations in salt-marsh areas are sometimes inundated with saline water. When trees reach a few metres in height they are fire resistant and sprout readily after being damaged by fire. *C. junghuhniana* grows on a wide range of soils, from light volcanic and sandy soils to heavy clays. It is tolerant of a wide pH range, from 2.8 in acidic clays to 8.0 in limestone-derived soils.

Propagation and planting Propagation is by seed, shoot cuttings or air layering. Seed is sown onto germination beds. Seedlings are pricked out into polythene bags when 3–5 cm tall. For mass propagation, shoot cuttings are more suitable than air layering. Young shoots 1–2 mm in diameter and 10–15 cm in length are rooted with the help of hormones, either indole-4-butyric acid (IBA), indole-4-acetic acid (IAA) or naphthalene-1-acetic acid (NAA). Under 50% shade, rooting takes 3–4 weeks.
Inoculation of the seedlings or cuttings with effective strains of *Frankia* is recommended when *C. junghuhniana* is introduced to a new area. Some *Frankia* strains of *C. equisetifolia* are effective on *C. junghuhniana*. When *C. junghuhniana* or *C. equisetifolia* are already being cultivated in an area, it is usually sufficient to mix topsoil collected from the plantations into the potting media. A spacing of 2 m × 2–3 m is used for commercial plantations for poles.

Husbandry Weeding is necessary only during the first few years, after which the trees shed large amounts of branchlets to form a thick and dense mat of litter that suppresses weeds.
C. junghuhniana is a poor self-pruner, and produces strong root suckers. Pruning in plantations up to a height of 2.0–2.5 m is often necessary to make the plantations more accessible for general maintenance. Trees respond well to coppicing and pollarding.

Diseases and pests A number of diseases are found associated with *C. junghuhniana*. Damping-off of seedlings in nurseries is caused by various fungi (*Phytophthora* sp., *Pythium* sp., *Fusarium* sp., *Sclerotium* sp. and *Rhizoctonia* sp.). Butt and heart rot, caused by *Ganoderma applanatum*, may infest tree trunks after damage by fire. *Schizophyllum commune* may cause decay of the sapwood.
Green branchlets are attacked by the *Acrididae* locust *Aularches miliaris* and insects of the family *Lymantriidae*. In dry areas subterranean termites can destroy young plants by eating their roots. In Thailand they are controlled by spreading a small quantity of a mixture of equal amounts of lime and salt in the planting hole.

Harvesting Plantation-grown trees can be harvested throughout the year. In Thailand a harvesting cycle of 5 years is used for poles and fuelwood planted at a spacing of 2 m × 2–3 m.

Yield In the highlands of Tanzania trees from a woodlot yielded 14.7 m^3 stacked wood at age 4.3 years, and those planted along contour strips in an agroforestry trial produced 180 kg air-dry fuelwood per tree at age 3.5 years. In general, a mean annual increment of 10–15 m^3/ha is obtainable.

Handling after harvest In Thailand felled trees are transformed to poles by removing side branches. The length of poles is cut proportionately to the diameter, i.e. 3 m pole length for 7.5 cm diameter, 4 m pole length for 10 cm in diameter. Off-cuts from stems or branches are excellent firewood for the pottery industry. No special handling is required if the products are marketed as poles, piles or firewood. The wood, however, has a tendency to split when sawn.

Genetic resources The Australian Tree Seed Centre, Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Forestry and Forest Products in Canberra has assembled germplasm from throughout the natural distribution of *C. junghuhniana* and from derived occurrences in Kenya and Tanzania. The Forestry Seed Centre in Kenya and the National Tree Seed Project in Tanzania collect and conserve seed from locally cultivated trees.

Breeding Activities on tree improvement work appear to be limited to a small progeny trial in southern China established with seed mainly from Kenya and Tanzania, and from a small number of trees from Timor. International provenance trials have been established to examine genetic variation.

Prospects Due to its fast growth, its nitrogen-fixing capacity, its wide adaptability, ease of propagation and excellent fuelwood quality, *C. junghuhniana* has the potential to be planted for a range of purposes in the semi-arid to humid tropics, under both lowland and highland conditions.

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K. Pinyopusarerk

Centrosema pubescens Benth.

Comm. legum. gen.: 55 (1837).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22$

Synonyms *Centrosema molle* Martius ex Benth. (1837).

Vernacular names Centro, butterfly pea (En). Flor de conchitas (Am). Indonesia: sentro. Philippines: dilang-butiki (Tagalog), lesu-kesu (Subanun). Thailand: thua-lai, thua-sentro. Vietnam: day trung ch[aa]u l[oo]ng.

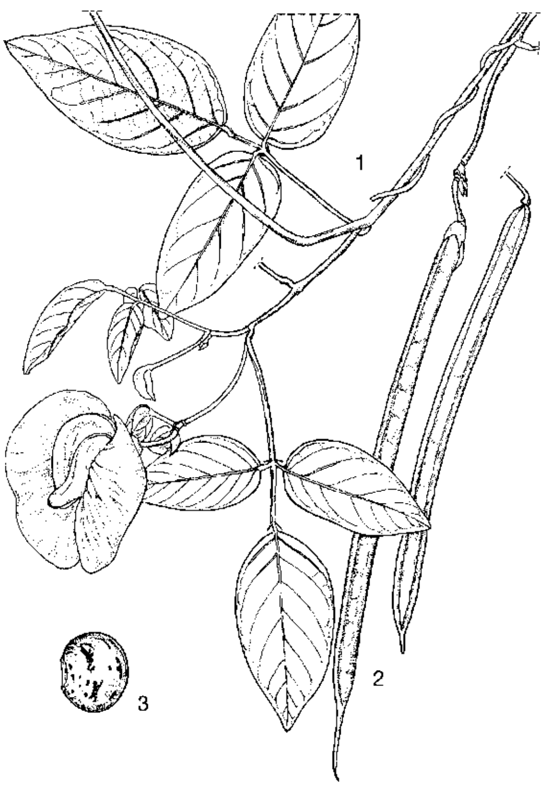
Origin and geographic distribution Originating in South and Central America, centro is now one of the most widely distributed of all legumes in the humid tropics. Centro was introduced to South-East Asia from tropical America in the 19th Century or earlier. It occurs naturalized in lowland Java.

Uses In 1922 centro was discovered in a heavily shaded rubber plantation in Central Java, and was quickly adopted as a green manure and ground cover in plantation crops in Java, Sumatra, Peninsular Malaysia and Sri Lanka. Since the 1950s, centro has been widely used as a plantation cover and pasture legume in South-East Asia, the Pacific Islands, the wet tropics of Australia and indeed much of the humid tropics worldwide.

Properties Centro is an efficient fixer of atmospheric nitrogen, with N concentrations generally ranging from 2.4–2.7(–3.2)%. The amount of nutrients temporarily immobilized in a centro cover can be high. Under intensively managed, well fertilized oil palm on a marine clay soil in Selangor, Malaysia, a centro cover produced 13.3 t/ha dry matter 20 months after planting, of which 5.4 t/ha was living biomass and 7.9 t/ha was litter. The nutrient content of the living biomass was per 100 g dry matter: N 2.51 g, P 0.17 g, K 1.92 g, Mg 0.23 g. Per 100 g dry matter the litter contained: N 3.18 g, P 0.12 g, K 0.36 g, Mg 0.38 g. Under comparable conditions on a sandstone-derived soil in Serdang,

Malaysia, the production 12 months after planting was 4.5 t/ha living biomass and 6.7 t/ha litter, containing per 100 g dry matter of living biomass: N 3.06 g, P 0.51 g, K 2.07 g, Mg 0.14 g and of litter: N 2.34 g, P 0.44 g, K 0.35 g, Mg 0.11 g. Centro is one of the most palatable tropical legumes.
The weight of 1000 seeds is about 25 g.

Description A vigorous, climbing, perennial herb; trailing runners have a tendency to root at the nodes if soil moisture is high, giving it a stoloniferous appearance; roots penetrating deeply; development of taproot and lateral roots is almost equal, although soil type exerts some influence. Stems leafy, arising from the main runners at 0.5–1.5 m intervals, climbing rather than trailing, slightly hairy, possibly becoming woody when older than 18 months. Leaves trifoliolate; leaflets elliptical, ovate-oblong or ovate-lanceolate, 1–7 cm × 0.5–4.5 cm, rounded at the base, rounded to sharp-acuminate at the apex, dark green, slightly hairy, especially on the lower surface; petiole up to 5.5 cm long, stipules 2–4 mm long, persistent. Flower cleistogamous, large, pale mauve with purple lines in the centre, borne in axillary racemes, 3–5 per raceme, subtended by 2 striate bracteoles; calyx tube campanulate, teeth unequal, 2 upper ones ovate-triangular 1.5–3 mm long; standard rounded, up to 3 cm in diameter, hairy on the outside, bright or pale lilac on either side of a median greenish-yellow band with numerous dark violet stripes or blotches. Pod linear, 4–17 cm × 6–7 mm, flattened, margins prominent, straight or slightly twisted, acuminate, dark brown when ripe, containing up to 20 seeds. Seed shortly oblongoid to squarish with rounded corners, 4–5 mm × 3–4 mm × 2 mm, brownish-black, with mottled darker blotches.



Centrosema pubescens Benth. – 1, flowering branch; 2, pods; 3, seed.

Growth and development Centro is notoriously slow to establish and requires good conditions and regular weeding during the establishment period, but when grown in a pure sward it forms a dense, compact cover 35–45 cm deep, 4–8 months after sowing. In mixtures it becomes fully established and vigorous by at least the 2nd year. In ungrazed mixtures with Guinea grass (*Panicum maximum* Jacq.) it forms an impenetrable vine canopy some 2 m high. In the commonly planted mixture with calopo (*Calopogonium mucunoides* Desv.) and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.) centro persists longest under the closing canopy of plantation crops and is comparable in persistence to *Calopogonium caeruleum* (Benth.) Sauv. In Australia common centro flowers in April and October, with main seed harvesting periods in June–July and November–December. Cultivar 'Belalto' flowers in June and has a main seed harvesting period in early August. Nodulation occurs with a range of rhizobia but optimal growth has been achieved with very few strains. Inoculation with an effective strain of *Bradyrhizobium* is therefore recommended. Estimates of atmospheric nitrogen fixation range from 120–270 kg/ha per year.

Other botanical information Commercially grown forms of *C. pubescens* represent only a small fraction of its diversity, and any statement on the commercial forms does not necessarily pertain to the species as a whole.
Two lines of centro are in commercial use: common centro and cultivar 'Belalto'. 'Belalto' is now identified as *C. schiedeanum* (comb. ined., syn.: *Clitoria schiedeana* Schlecht.) rather than as *C. pubescens* as was listed originally. It was selected by the Queensland Department of Primary Industries as an improvement over common centro because of its superior cool season growth, greater tolerance of pests and diseases, and its stronger

stoloniferous growth. Its origin is Costa Rica.

Ecology Centro is cultivated in the humid tropics up to an altitude of 600(–900) m. It prefers an annual rainfall of 1500 mm or more, but is also tolerant of lower rainfall, having persisted in pastures in Africa receiving an average annual rainfall of 800 mm. Centro tolerates some waterlogging when grazing is lenient and it will survive a dry season of 3–4 months, but is not adapted to prolonged drought. It is intolerant of low temperatures; growth is noticeably reduced when temperatures fall below 20°C and poor below 15°C. Frost of –3°C causes substantial leaf death, but plants may regrow from sheltered growing points near the ground. Centro is one of the shade-tolerant legumes and can persist under 80% shade. It will grow on a range of soils from sandy loams to clays. Acceptable growth may be obtained on relatively acid soils, provided extractable aluminium is less than 0.2 meq per 100 g soil. The pH range tolerated is about 4.5–8.0, but nodulation is poor towards the extremes of the range, the optimum pH being 5.5–6.0. Although centro is fairly tolerant of high Mn levels in the soil, low-pH-related Mn toxicity has been observed in acid soils, though this can be corrected by liming.

Centro combines well with other species in ground covers or mixed pastures under plantation crops. In the humid tropics the preferred legumes for fertile and infertile soils have traditionally been centro and stylo (*Stylosanthes guianensis* (Aublet) Swartz) respectively. However, when soil mineral deficiencies are corrected and seed is inoculated with an effective *Bradyrhizobium*, centro has been more productive than stylo on all land classes.

Propagation and planting Centro is propagated by seed. Hand-harvested seed has a high proportion of hard seed (up to 60%) and mechanical scarification is required. Seed rate is about 5 kg/ha. Since centro is somewhat slow to establish, careful seed-bed preparation and planting procedures are recommended. However, centro has been successfully sod-seeded directly into a rundown grass pasture, following heavy grazing and low slashing of the residual grass.

Husbandry When planted as a component of a soil cover in oil palm or rubber plantations, centro will persist for 3–6 years until the tree canopy closes. It contributes considerably to the nitrogen nutrition of trees. In an experiment in Malaysia comparing centro with grasses as cover crop under oil palm, the N levels of oil palm leaves were about 10% higher with centro than with grasses. Observations in northern Queensland showed that levels of soil N in regularly grazed, unfertilized mixed pastures of centro and Guinea grass hardly declined over a period of 16 years. Properly fertilized and carefully grazed grass/centro associations have been persistent, productive and competitive against weeds and timber regrowth. In mixtures with grasses, notably Guinea grass, centro tolerates rotational or continuous grazing, but in pure stands it is intolerant of grazing. Under acidic soil conditions, centro is more responsive to Mo, Ca, K and P than tropical kudzu which, in turn, is more responsive than stylo. Centro is more sensitive than stylo to soil P deficiency but is less sensitive to Cu and possibly S deficiencies.

Bioassays conducted in Taiwan revealed that banana growth is affected by phytotoxins from interplanted centro. The phenolic compound p-hydroxybenzoic acid in centro caused a growth inhibition similar to that produced by rhizosphere or plant extracts.

Diseases and pests Centro is relatively free of major diseases and pests, although some virus and bacterial diseases have been noted from time to time and seasonal infestations of *Cercospora* leaf spot and red spider mite (*Tetranychus* sp.) have been reported. In the humid tropics it is noticeable that the infestation of foliar blight (*Rhizoctonia solani*) may cause some dieback and that the attack of ladybird beetles (e.g. *Epilachna indica*) may affect plant growth and even cause complete defoliation. The damage can be severe when centro is grown in a pure sward, especially during the wet season. However, none of these have warranted commercial control measures.

Harvesting Centro has persisted for decades as plantation cover or in well-managed grazed associations with grasses, but it has not been very stable in cut-and-carry systems. When used as fodder centro is usually grazed, or it can be cut for stall feeding. It can be selectively overgrazed unless care is taken. Centro is usually consumed fresh but it can be ensiled or dried for hay or pellets.

Yield Biomass production of cover crops is rarely measured. Pure stands of centro have produced annual dry matter yields of up to 12 t/ha. In mixed pastures this is more likely to be about 3–4 t/ha per year. Standing dry matter yield of centro in grazed mixed pastures is unlikely to exceed 1 t/ha. Well managed grass/centro pastures have consistently supported stocking rates of 4 steers (of 250 kg liveweight) in the Malaysian wet tropics, producing about 500 kg/ha of liveweight gain per year. Seed production can reach more than 200 kg/ha.

Genetic resources Seed of centro has been sold for many decades in South-East Asia and other humid tropical areas. Large germplasm collections are held by the Australian Tropical Forage Genetic Resource Centre (ATFGRC, Australia), the Centro Nacional de Recursos Genéticos/Empresa Brasileira de Pesquisa Agropecuária (CENARGEN/EMBRAPA, Brazil) and the Centro Internacional de Agricultura Tropical (CIAT, Colombia).

Breeding Plant breeding programmes have been undertaken and improved cultivars have been released by the Queensland Department of Primary Industries (QDPI) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia and CIAT in Colombia. However, the most promising lines are beginning to emerge from plant collections in South and Central America.

Prospects Centro will continue to be an important component of cover crop mixtures for plantation crops, although its role as shade-tolerant component has been partly taken over by *Calopogonium caeruleum*. Centro is also a recommended legume in the 'Three Strata Forage System' in Bali, Indonesia. Except for the humid tropics of Australia and a few areas of Malaysia and the Philippines, the potential of centro as a component of grazed pastures has been largely unrealized.

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J.K. Teitzel & Chen Chin Peng

Chromolaena odorata (L.) R.M. King & H. Robinson

Phytologia 20: 204 (1970).

COMPOSITAE

$2n = 40$

Synonyms *Eupatorium odoratum* L. (1759), *E. conyzoides* Vahl (1794), *Osmia odorata* (L.) Schultz-Bip. (1866).

Vernacular names Siam weed, Christmas bush, goat weed (En). Jack in the bush (Am). Herbe du Laos, fausse ramie, fleurit-Noël (Fr). Indonesia: ki rinyu (Sundanese). Malaysia: Siam weed, pokok kapal terbang. Philippines: devil weed, gonoi, (hulo)hagonoy. Burma (Myanmar) : bi-zat, tawbizat, curse of Caylan. Cambodia: tontrien khaèt. Laos: hnha:z fàlangx (general), hnha:z khi:lo:z (Paklay), nroj pawm tshis (hmong). Thailand: sapsua, ya-suamop. Vietnam: c[os] hoi, c[os] Lao, y[ee]n-bach.

Origin and geographic distribution Siam weed originated in the humid tropics of the New World, where it occurs from southern Florida to northern Argentina. It has been introduced and is naturalized throughout humid, tropical Asia, from the Western Ghats in India throughout Indochina and Malesia to south-eastern Australia and the Mariana Islands in the east. It is found in the humid tropics of West and Central Africa and in south-eastern South Africa.

Uses Although, under certain conditions, Siam weed is one of the most noxious weeds in agriculture and range management, it is also used as a green manure and mulch crop. In Cambodia it is used as a green manure in the production of lowland rice, cassava and black pepper. In Nigeria its use as mulch in yam, cassava and coffee is subject of research. It is recommended for the control of *Imperata cylindrica* (L.) Raeuschel. In Asia and Africa a natural fallow of Siam weed is becoming gradually more common in semi-permanent food crop production, and many small farmers in e.g. Indonesia and Laos consider it a most useful fallow crop.

A protein extract from the leaves was in use as a poultry feed during the civil war in Nigeria. Siam weed is not palatable to cattle and large tracts of extensively managed pasture land have been abandoned because of uncontrollable Siam weed infestation.

Leaves of Siam weed are reported to be useful in controlling the weevil *Cylas formicarius* and the butterfly *Phtorimae operculella* in sweet potato, the nematode *Heterodera marioni* in black pepper, as well as nematodes in sugar cane and tomato.

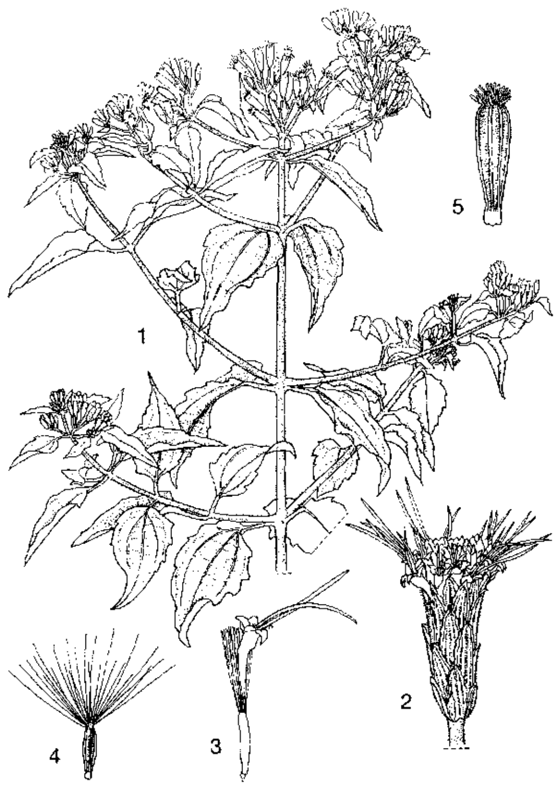
Siam weed is used as a medicine for intestinal pains, colds and cough in the Caribbean region; in Ivory coast, for healing wounds, as a purgative, a remedy against cough, malaria, smallpox and yellow fever. In Thailand, *C. odorata* is traditionally used to stop bleeding.

Properties At the end of the dry season a Siam weed fallow contains per 100 g dry matter: leaves: N 2.1–3.0 g, P 0.17–0.21 g, K 1.4–1.6 g, Ca 1.6–1.9 g, Mg 0.4–0.5 g; branches: N 0.2–0.4 g, P 0.02–0.03 g, K 0.6–0.8 g, Ca 0.3 g, Mg 0.2 g; litter: N 0.5–0.7 g, P 0.03–0.04 g, K 0.3–0.5 g, Ca 0.7–0.9 g, Mg 0.2 g.

Leaves and petioles have glandular dots emitting a strong pungent smell when crushed. Phenols and alkaloids in the plant, in particular in the leaves, have an allelopathic effect, inhibiting the germination of its own seeds and seedling development of other plants. Siam weed contains essential oils having an anti-bacterial activity on *Staphylococcus aureus* and *Escherichia coli*. Applied as a green manure in rice paddies, it may kill fish. It contains 4',5,6,7-tetramethoxyflavone, which enhances blood coagulation.

The weight of 1000 fresh achenes is about 0.25 g.

Description A spreading, much-branched, tangled, thicket-forming, perennial shrub, up to 3 m tall, scrambling up to 7 m. Root system rather superficial, upper part of the root growing horizontally and swollen, but taproot growing deep and massive. Stem profusely branched, herbaceous when young, tough and semi-woody when older, cylindrical, finely striate, yellowish, shortly hairy or nearly glabrous; branches slightly ridged longitudinally, pubescent. Leaves simple, opposite; petiole 1–3 cm long or more, glabrous or sparingly pubescent; blade ovate-triangular, conspicuously 3(–5)-veined, 5–14 cm × 2–8 cm, acuminate, margins toothed, dotted with glands, sparsely hispid-hairy to glabrous, often purple when young. Inflorescence a homogamous, 10–35-flowered head, arranged in corymbose clusters arising from the axils of upper leaves; peduncle 1–2 cm long; involucre cylindrical, 8–10 mm × 3–4 mm, bracts in 5 or 6 rows, closely overlapping, oblong, increasing in size upwards, up to 10 mm × 3 mm, straw-coloured to greenish; corolla tubular, 5 mm long,



Chromolaena odorata (L.) R.M. King & H. Robinson – 1, flowering branch; 2, flower head; 3, flower; 4, achene with pappus; 5, achene without pappus.

5-lobed, pale mauve, pale blue or whitish, protruding from the involucre; stigma with a long, exserted arm. Fruit a narrow achene, linear, angular, 3–5 mm long, brown or black, with short, white, stiff hairs along the edges; pappus white, consisting of rough bristles, 4–5 mm long. Seed minute.

Growth and development Viability of fresh seed ranges from 33–66%. After 2 years up to 40% of the seed still germinates. A small proportion of the seed germinates when mature, but most remains dormant. Seeds are photoblastic, but they may emerge when buried up to 3 cm deep. Emergence takes 4–12 days. During the first 3 months the seedlings stay rather small and mainly form leaves. Later, the length and biomass of the stem increase rapidly. Before growing downwards, the primary root forms a small, horizontal part, from which many secondary roots develop. During further growth it swells progressively and serves as a storage organ from which new shoots may sprout. Plants start branching after reaching a height of about 120 cm. The shoots of Siam weed bend over

due to their increasing weight. Consequently, apical dominance is broken and new shoots develop. The bent shoots die and form a thick, sagging mat in the vegetation which absorbs the light of plants in the understorey and hinders their vertical development by mechanical pressure.
Siam weed is a pioneer species, suppressing grasses in the succession from open space to forest, making it a noxious weed in rangelands. Its lifetime depends on the presence of woody species in the vegetation. In India and Ivory Coast Siam weed diminishes from the fifth year onwards, as tree species start shading it out. When shrubs and trees are absent the lifetime of Siam weed may exceed 15 years.
Siam weed flowers annually from the first year. Time of flower initiation and inflorescence development may differ among plants and even among branches of one plant. The central cyme of the inflorescence flowers slightly earlier than the peripheral ones. Pollination is by insects. Apomictic fruit development also occurs. The period from flower initiation to fertilization is about 1.5 months, from fertilization to seed dispersal takes another month. Flower initiation is rather complex: shorter daylengths, diminishing rainfall and falling temperatures seem decisive factors.
The number of seeds produced is often extremely high. Production of 100 000–180 000 seeds/m^2 has been recorded in natural stands of Siam weed. Seeds are dispersed mainly by wind, but dispersal by animals and humans are important as well. Vegetative growth stagnates during flowering and seed production. After flowering most leaves wither and fall. New leaves and shoots grow from the old leaf axils, while the dead terminal part of the stems with the old inflorescences drop off.

Other botanical information *C. odorata* has been excluded from the genus *Eupatorium* L.; it can be distinguished by its rather consistent pattern of many rows of bracts, giving a cylindrical appearance to the head, by the 3 prominent veins of the leaves, and by the pungent smell of crushed leaves. In Hawaii, the name *Eupatorium odoratum* is often used for *Ageratina adenophora* (Spreng.) R.M. King & H. Robertson. The name *Eupatorium conyzoides* Miller is a synonym of *Vernonia arborescens* Swartz, but is sometimes used erroneously for *C. odorata*.

Ecology The natural habitat of Siam weed includes forest clearings, river banks and borders between savanna and closed forest. It can be found from sea level up to 1000(–1500) m altitude. Minimum annual rainfall required is 1100 mm, with a dry season of up to 5 months, although it can be found sporadically at 700 mm annual rainfall. It is not found in temperate regions and a mean daily temperature of 25–30°C is optimal. Siam weed is heliophile. It needs light to germinate and is suppressed when shaded by other plants. It grows on a wide range of soils, but not on inundated sites. Through symbiosis with vesicular-arbuscular mycorrhizae it can grow well on soils poor in P. Under a Siam weed fallow the soil structure improves and the pH and biological activity of the soil increase.
It tolerates mechanical injuries caused by slashing and burning, as it is able to form new shoots on the swollen part of the root. However, frequent injuries deplete the plant's regenerative capacity.

Propagation and planting To date Siam weed has not been planted as a crop. It normally grows from seed, but can be propagated vegetatively, as the nodes of branches readily root when in contact with moist soil.

Husbandry Under humid tropical lowland conditions in Ivory Coast biomass production of a natural stand of Siam weed at the end of the dry season varied from 14.4 t/ha after 2 years to 21.7 t/ha after a 4 years fallow, supplying 70–140 kg N, 5–8 kg P, 109–125 kg K, 70–160 kg Ca and 30–50 kg Mg per ha. Regrowth of Siam weed after cropping is best when the impact of cultural practices during cropping is modest and the cropping period is limited to 1 or 2 seasons. Under humid tropical conditions a mulch of 8.5 t dry matter/ha, half of it composed of leaves and young shoots, will be decomposed in 38 days.
In trials in Cambodia a mulch of 20 t/ha of Siam weed increased rice yields from 1.5 t/ha to 2.8 t/ha. This increase was similar to that resulting from an application per ha of 30 kg N, 30 kg P and 30 kg K applied as chemical fertilizer. The combination of green manure with chemical fertilizer increased rice yield to 4.3 t/ha. Ploughing in the green manure or leaving it as mulch on the soil surface were equally effective. The Siam weed green manure repelled crabs from the rice field, but also killed the fish in the paddies.
Considerable increases in yield were also found in cassava. Mulching black pepper with Siam weed reduced the nematode infestation (*Heterodera marioni*) and secondary infection of *Pythium* spp. All the pepper vines in the untreated plots died within 3 years, but nearly all survived in the mulched plots.
In low input agriculture slashing and burning the fallow crop before planting and an early weeding

proved most appropriate to reduce the development of *Chromolaena* as a weed. In perennial cropping and forest plantations it can be controlled by repeated slashing and will eventually be shaded out when the canopy closes over. However, it hampers the establishment of a leguminous ground cover. In Malaysia it has been shown to depress the growth of rubber trees.

Siam weed is known to harbour parasites and pathogens injurious to crops, like grasshoppers (*Zonocerus variegatus*), weevils (*Aphis* spp.), nematodes (*Scutellonema bradys*) and microorganisms (*Cercospora* spp. causing leaf spot disease, *Fusarium oxysporum* and *Pseudomonas solanacearum*).

Diseases and pests Although many pathogens and insects have been found on Siam weed, they rarely do serious harm. Only the arctiid moth *Pareuchaetes pseudoinsulata* and the seed-feeding weevil *Apion brunneonigrum*, both oligophage insects originating from tropical America, are known to cause considerable damage to Siam weed. They have been introduced into several African and Asian countries for the biological control of this weedy plant, with varying degrees of success.

Prospects Due to its fast growth and nutrient accumulation and its copious litter production, Siam weed may play an important role as a fallow crop for restoration of soil fertility in cropping systems where shortening of the fallow period is inevitable. Used as a mulch it may contribute to the increase or maintenance of soil fertility and the improvement of the physical condition of the soil. Due to its rapid lateral spreading and superficial rooting, Siam weed also has good prospects for the control of soil erosion and *Imperata cylindrica*. However, more research is needed to incorporate Siam weed into semi-permanent cropping systems and to develop adequate measures to control its weediness in extensively managed crop production and rangeland systems.

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J.J.P. Slaats

Cordia alliodora (Ruiz & Pavon) Oken

Allg. Naturgesch. 3(2): 1098 (1841).

BORAGINACEAE

$2n$ = c. 72

Synonyms *Cerdana alliodora* Ruiz & Pavon (1799), *Cordia cerdana* (Ruiz & Pavon) Roemer & Schultes (1819), *Lithocardium alliodorum* (Ruiz & Pavon) Kuntze (1891).

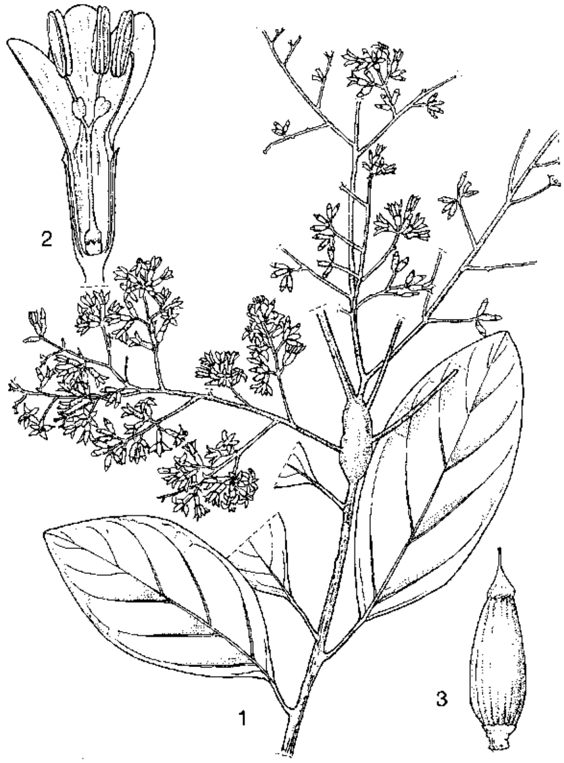
Vernacular names Cordia (general and trade name in the Americas), salmwood (trade name in the United Kingdom) (En). Spanish elm (Am). Bois soumis, chêne caparo, bois de rose (Fr). Laurel, cypre, capa prieto (Sp).

Origin and geographic distribution *C. alliodora* is indigenous to dry and wet forest from Mexico and the Antilles to Brazil and Bolivia. It is now widely distributed in tropical America from northern Argentina to central Mexico and in the Caribbean islands. It has been introduced to Africa, Asia (Nepal, Sabah and Sri Lanka) and the Pacific region (Hawaii, Solomon Islands, Vanuatu).

Uses *C. alliodora* produces high quality timber widely used where it occurs naturally. Because of its tall, straight stem, self-pruning habit and compact crown, combined with the ease with which it regenerates naturally on cleared sites, it is commonly grown in association with many agricultural crops and in numerous agroforestry systems, e.g. as shade tree in coffee and cocoa plantations and in pastures, often in combination with *Erythrina poeppigiana* (Walpers) O.F. Cook.
Its leaves and seeds have medicinal properties, the fruits are edible, if not very tasty, and its flowers are known to bee-keepers as a major source of nectar. The tree is planted as an ornamental because of its abundant, attractive, white, fragrant flowers.
The wood is used in construction, e.g. for doors, window frames, panelling, flooring, and for furniture, cabinet work, turnery, carving, scientific instruments, boats (including bridge decking), oars, sleepers, veneer, fuelwood and charcoal.

Properties Wood of *C. alliodora* is easy to season and work and produces an attractive finish (pale golden-brown to brown with darker streaks). It has dimensional stability when dry, satisfactory mechanical characteristics, and is moderately durable to fungus attack with good resistance to termites. Basic density of the wood shows wide variation, 380–520 kg/m^3 for natural forest samples from Central America. In Costa Rica, where it is found from tropical dry to tropical wet forest, basic density varies from 380–620 kg/m^3 in naturally regenerated trees. Trees grown under drier conditions have the highest values. The density of the wood of plantation-grown trees in Vanuatu ranges from 270–530 kg/m^3.
The weight of 1000 seeds is 15–50 g.

Description A large tree, up to 25(–40) m tall, with or without buttresses. Bark of young trees smooth and greenish, becoming greenish-black and sometimes narrowly fissured with age. Twigs stellate-pubescent when young, ending in obovoid



Cordia alliodora (Ruiz & Pavon) Oken – 1, flowering branch; 2, vertical section through flower; 3, fruit.

ant domatia. Leaves alternate, simple, deciduous, stellate-pubescent; petiole 0.5–3.5 cm long; blade elliptical to slightly obovate, up to 20.5 cm × 8.5 cm, glabrous to densely stellate-pubescent. Inflorescence terminal, usually arising from an obovoid ant domatium, paniculate, up to 25(–30) cm broad, branches usually densely stellate-pubescent; pedicel up to 1.5 mm long; flowers many, about 1 cm long and wide, white; calyx tubular, 4–6 mm long, grey-green, 10(–12)-ribbed, (4–)5(–6)-toothed, densely stellate hairy; corolla tubular, (4–)5(–6)-lobed, up to 14 mm long, white, tube up to 8.5 mm long, lobes oblong and rounded, spreading, up to 8.5 mm long; stamens (4–)5(–6), erect, white, lower part connate with corolla; pistil with 2-forked style, each fork ending in 2, clavate stigma lobes. Fruit an ellipsoid nutlet, 4.5–8 mm × 1–2.5 mm, completely enveloped by the persistent corolla and calyx, the wall thin and fibrous. Seedling with epigeal germination.

Growth and development Seedlings develop a strong taproot. Later, spreading roots also develop which may grow into buttresses. Flowering

may start when the trees are only 2 years old, but more commonly between 5–10 years after planting. Time of flowering and maturation of the fruit varies with locality; in Panama, flowering starts at the onset of the dry season. Lepidoptera are generally responsible for pollination. The mature fruit is shed with the withered flower still attached, which acts as a parachute during fruit fall, possibly assisting wind dispersal.
The bole is generally straight and cylindrical and often clear of branches 50–60% of the total tree height, even in open, uncrowded conditions.

Other botanical information The species is often incorrectly referred to as *Cordia alliodora* (Ruiz & Pavon) Cham. The genus contains about 300, mostly neotropical species and includes many useful timbers and some ornamentals with vivid, orange-red flowers. The flowers of *C. alliodora* vary from short-styled to forms with the stigma and anthers borne at about the same height, but individual plants have a constant ratio of anther and stigma height. The extent to which ant domatia are formed varies throughout the natural range. Domatia are is most prominent in Central America and north-western South America and almost absent in the West Indies and southern South America.
The crushed leaves and the inner bark have an odour of garlic ('alliodora').

Ecology *C. alliodora* is a pioneer plant, found in a wide range of habitats from sea level up to 1000(–2000) m. Optimal growth occurs where mean annual rainfall exceeds 2000 mm and the mean annual temperature is about 24°C. It is also common in drier areas with only 750 mm rainfall, but growth is slower and form of stem and crown poorer. It is a strong light-demander that readily colonizes exposed soils. Plantations of *C. alliodora* exposed to hurricanes and cyclones have shown above-average resistance to stem break and wind throw.
A range of soil types is tolerated. Fertile, freely-drained conditions are preferred. Growth on degraded soils and on sites with poor drainage is reduced. *C. alliodora* is particularly suitable for calcareous soils in the more humid tropics.

Propagation and planting *C. alliodora* is readily propagated by seed or by stem cuttings. Timing of seed collection is important to ensure a high germination rate, generally up to 80%. Shaking of branches to allow mature seed with a high viability to drop is the best method. Viability of fresh seed decreases rapidly under natural conditions; dried to below 10% moisture it may be stored at 2°C for up to 10 years. Seed germinates in 5–20 days.
Vegetative propagation is possible. Stumps are the type of planting stock generally used due to the ease and cheapness of the technique and the robust planting material produced. Seedlings, however, are known to have a more rapid early growth and may be used in cases where rapid canopy closure is required. Direct sowing and wildlings are sometimes used in plantation establishment, although more intense weed control is then generally necessary. Choice of provenance is important.
In plantations a planting density of 4–5 m × 4–5 m is recommended. If a narrower spacing is used, thinning after 3–4 years is needed. In agroforestry spacing is adjusted to the associated crops. In coffee plantations in Costa Rica the optimum density of *C. alliodora* appears to be 100 mature trees/ha. The number of trees counted in agroforestry plots in Costa Rica ranges from 70–290/ha. Diameter increment in these plots was related to the associated crops and increased in the order pasture, sugar cane, coffee and cocoa.

Husbandry Regular weeding is crucial in the early stages of establishment. Organic matter accumulation in a cocoa plantation in Costa Rica with *C. alliodora* planted at 6 m × 6 m amounted to 87–110 t/ha in 10 years and the trees had a mean annual increment of 7.4 m^3/ha. *C. alliodora* reduces the yield of cocoa, but the income generated from the timber compensates for this yield reduction.
Farmers in Central and South America rely mostly on natural regeneration of *C. alliodora* for shade trees, but increased use of herbicides may reduce the number of regenerating trees. Young to middle-aged trees coppice readily and suckers are sometimes abundant.

Diseases and pests The rust fungus *Puccinia cordiae* is economically damaging to *C. alliodora* in its natural range. Other diseases noted to cause damage are a root disease caused by *Phellinus noxius* and a stem canker caused by *Corticium salmonicolor* in Vanuatu.

Yield On suitable sites, with good management, annual growth of 2 m in height and 2 cm in diameter may be obtained during the first 10 years. Dimensions of 30–40 m height and 40–55 cm diameter at breast height are predicted for rotations of 20–25 years. In a 34-year-old plantation the mean annual increment of the *C. alliodora* trees was 8.8–20.3 m^3/ha; however, up to 36% of this volume was lost due to buttresses, stem irregularities, heart rot, forking, and inefficient wood extraction.

Genetic resources Wide variation in morphology and performance is observed in the natural populations of *C. alliodora*. Provenance trials in Central America revealed that germination is more rapid and seedling growth faster for provenances from the Pacific watershed which experience a more pronounced dry season. However, growth rates of Atlantic provenances are superior within two years after planting, after initial slow development.

Breeding The results of provenance trials are stimulating increased activities in the field of selection and breeding, e.g. in Vanuatu. *C. alliodora* is known to have a high degree of self-incompatibility. Other *Cordia* species are known to be either dioecious or heterostylous with associated self-incompatibility.

Prospects The use of *C. alliodora* in exotic plantings and agroforestry shows promise due to its rapid growth, good stem form and fine wood. Its success in Central America bodes for good in South-East Asia. Further research on its use in silvopastoral systems is needed, especially with regard to resistance to trampling. The relation between wood quality, growth and provenance also needs to be evaluated further.

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P.E. Neil & A.C.J. van Leeuwen

Crotalaria micans Link

Enum. pl. hort. berol. 2: 228 (1822).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 16$

Synonyms *Crotalaria anagyroides* Kunth (1824).

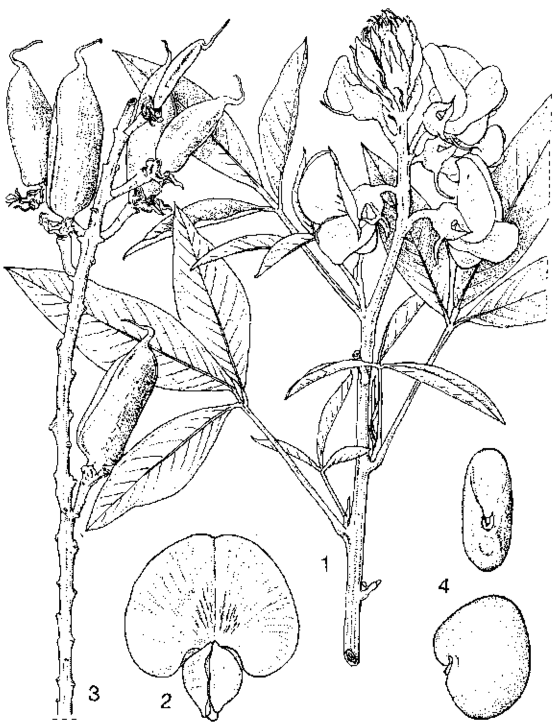
Vernacular names Caracas rattlebox (Am). Thailand: hinghai. Vietnam: s[uj]c s[aj]c cao, s[uj]c s[aj]c soc.

Origin and geographic distribution *C. micans* originated from Central and South America. It has been introduced into many tropical and subtropical countries, including those in Malesia, where it also naturalized locally.

Uses In Central and South America, Indo-China, Indonesia, Malaysia, and Sri Lanka, *C. micans* is grown as a green manure and cover crop, for instance in plantations of coffee, tea, tobacco and rice. Young shoots and leaves are used as fodder for cattle. It is widely grown as an ornamental.

Properties Unlike many other *Crotalaria* spp., *C. micans* is reported to be highly palatable and non-toxic to cattle. Young vegetative material contains per 100 g dry matter: crude protein 23 g, crude fibre 28 g, ash 7.2 g, ether extract 2.2 g, non-fibre extract 39.6 g, Ca 0.57 g, P 0.28 g. Tests in Colombia indicated per 100 g dry matter: N 3.6 g, K 2.0 g, Ca 2.1 g, Mg 0.3 g.
The weight of 1000 seeds is 18 g.

Botany Shrub up to 4 m tall; young branches angular, appressed pubescent. Leaves trifoliolate; petiole 3–5 cm long, longitudinally grooved above; stipules linear, 0.5–7 mm long, caducous; leaflets oblong-lanceolate to narrowly elliptic, 4–10 cm × 1–4.5 cm, apex acute to acuminate or obtuse, base cuneate, lower surface and midrib above puberulous, upper surface glabrous, lateral leaflets slightly smaller than the terminal one. Inflorescence a rather dense, 15–30-flowered raceme, 15–30 cm long, terminal, often leaf opposed; bracts linear, about 1 cm long, very early caducous; pedicel 5–9 mm long; bracteoles similar to bracts but smaller, very early caducous, inserted just above the middle part of the pedicel; flowers bisexual, 5-merous; calyx 8–13 mm long, appressed puberulous, tube campanulate, 5–6 mm long, bilabiate and 5-lobed, lobes longer than the tube, upper lobes triangular-acuminate, often coherent at the tips with the lateral lobes and woolly on the inside of the margins; corolla 14–18 mm long, yellow, purplish-veined; standard ovate-circular to slightly reniform, 13–14 mm × 18–21 mm,



Crotalaria micans Link – 1, flowering branch; 2, flower; 3, fruiting branch; 4, seeds.

glabrous; wings oblong, 12–15 mm long, claws 3–4 mm long; keel 13–15 mm long, abruptly rounded a little below the middle, with a slightly incurved, untwisted beak; stamens 10, monadelphous, anthers dimorphic, 5 anthers basifixed, with filaments 3–6.5 mm long, 5 anthers dorsifixed, with filaments 4–9.5 mm long; style 8–11 mm long, curved, persistent, pubescent. Fruit an inflated, short-stipitate pod, subcylindrical, 3–4 cm × 1 cm, appressed puberulous, brown, dehiscent, with 16–20 seeds. Seed unequal-sided heart-shaped, about 4.5 mm × 3.5 mm, fine papillate, yellowish-brown.

Early growth of *C. micans* is fast, giving it a competitive advantage over most weeds. It can cover the soil in 3 weeks after germination and may reach 2.5 m after 3 months and 3.5 m after 6 months. In Bogor, Indonesia, the first seeds mature 7 months after sowing. *C. micans* forms root nodules with *Bradyrhizobium* spp. and fixes nitrogen.

C. micans is characterized by terminal inflorescences on which the large flowers are grouped tightly with prominent, long curled bracts and bracteoles.

Ecology *C. micans* is tolerant of a wide range of climatic and soil conditions. It grows best in lowland areas, but is generally grown up to 1600 m altitude. In Java, it is found up to 1800 m altitude, and in Colombia even as high as 2600 m. Full sunlight is required for good seed production. Seed production is poor at high elevations.

Agronomy *C. micans* is propagated by seed. When broadcast, a seed rate of 20–35 kg/ha is used; 6–12 kg/ha is adequate for sowing rows 0.9–1.5 m apart. In Java it is sown at the onset of the drier season in May–June. In established tea plantations it is sown immediately after pruning. Once established it will reseed itself.

In Java fungal diseases are reported caused by the fungi *Corticium salmonicolor* and *Sclerotium rolfsii*. The dadap fungus (*Septobasidium bogoriense*), which also affects *Erythrina* spp. grown as shade trees, grows on the base of the stem, making it susceptible to other diseases. *C. micans* is a host of *Lasiodiplodia theobromae* affecting both cocoa and tea. The crotalaria bug (*Ragmus importunatas)* living on the underside of leaves and on the tips of branches causes leaves to turn yellow. The damage can be so serious that the cover crop has to be removed. It also attacks several Asian *Crotalaria* spp., but not *C. pallida* Aiton or *C. trichotoma* Bojer.

C. micans can be cut repeatedly, provided it is not cut too low and a few leaves per stem are left. It is easily incorporated into the soil as the lower stem does not start to lignify until 4 months after planting. Decomposition is rapid: in tests in Colombia, 40% of a crop was decomposed after 1 month and 60% after 2 months. However, in tea plantations in Java it is recommended to incorporate it into the soil 6 weeks before tea is planted.

From Java, yields of 40 t/ha fresh material 4 months after planting are reported, containing about 150 kg nitrogen, while in the southern United States, 6 months after planting 4.5 t/ha dry matter containing 100 kg nitrogen has been reached.

Genetic resources and breeding A germplasm collection of *Crotalaria* L. is being maintained by the United States Department of Agriculture, including material of *C. micans*. It is unlikely that any substantial breeding programme exists.

Prospects *C. micans* is a useful multipurpose crop that can be grown for erosion control and for either green manure or fodder.

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C. Niyomdham

Crotalaria pallida Aiton

Hort. kew. 3: 20 (1789).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 16$

Synonyms *Crotalaria mucronata* Desv. (1814), *C. striata* DC. (1825), *C. siamica* Williams (1905).

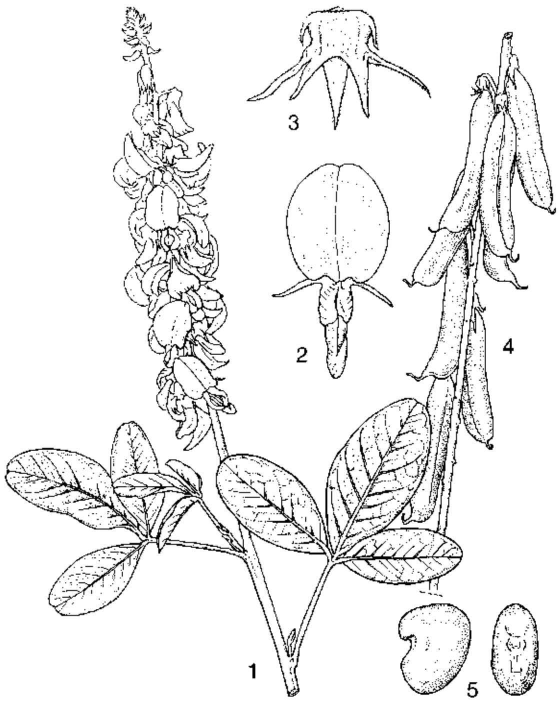
Vernacular names Smooth rattlebox, salts rattlebox (Am). Indonesia: kekecrekan (Sundanese), orok-orok (Javanese), telpok (Madurese). Malaysia: giring-giring, rang-rang. Philippines: gorung-gorung, kolong-kolong, tambarisa. Cambodia: chângrô:ng sva:, dâng höt khmaôch, sandaèk kû:öy. Laos: hingx ha:y. Thailand: hinghai, honghai. Vietnam: l[uj]c l[aj]c ba l[as] tr[of]n, c[aa]y mu[oox]ng tr[af], c[af] ph[ee] r[uw]ng.

Origin and geographic distribution *C. pallida* is probably a native of tropical Africa, but its natural distribution is obscured by widespread cultivation and subsequent pantropical naturalization. In Asia it is common in India and Sri Lanka and throughout South-East Asia.

Uses *C. pallida* is used as a ground cover and a green manure crop throughout the humid tropics, though on a limited scale. In tea, rubber and coconut plantations in Sri Lanka and South-East Asia, and in cocoa plantations in West Africa, it is used as a green manure and planted in the interrows to reduce erosion. It is one of the oldest green manure crops in Indonesia, but lost popularity because of its susceptibility to diseases and pests. *C. pallida* replaced the more toxic *Crotalaria spectabilis* Roth in the south-eastern United States and was grown extensively for soil sanitation and as a green manure crop until the 1960s. It also has some value as a forage crop. However, its use is no longer recommended as the seed occasionally gets mixed into fodder grains, causing poisoning.
In West Java, a fermented product ('dage'), was formerly made from the seeds. Seeds were boiled for two hours, wrapped in banana leaves and left to ferment for several days to remove poisonous components. In Cambodia the flowers are used as a vegetable. In Indo-China a kind of coffee is prepared from roasted seed. In Vietnam, the roots are sometimes chewed with betel-nut.
In traditional medicine, *C. pallida* is used to treat urinary problems. A poultice made of the roots is applied to painful swelling of joints, and an extract of the leaves is taken as a vermifuge. In Laos the plant is used to reduce fever.

Properties Tests in Java and Sri Lanka indicated 4.2 g N in above-ground parts per 100 g dry matter; in Florida 2.8 g N was found.
Seeds of many *Crotalaria* spp., including *C. pallida*, contain a number of pyrrolizidine alkaloids, such as mucronatine and monocrotaline which affect the liver and may kill birds and mammals. They are particularly insidious toxins, as their effects may only become apparent weeks or months after the animal has stopped eating the seeds. In *C. pallida* the concentrations are low and toxic effects have only been observed when chicks were fed the seeds for several weeks. Leaves contain an alkaloid poisonous to goats; dried leaves are not toxic. A lectin from *C. pallida*, which specifically agglutinates type A erythrocytes, is used in cytochemical research. The flavonoids apigenin and vitexin have been isolated from the bark and the leaves. The weight of 1000 seeds is about 5 g.

Botany An erect, well-branched annual or short-lived perennial herb, up to 1.5(–3) m tall. Stem stout, puberulent, with slender longitudinal grooves; branches densely appressed hairy. Leaves trifoliolate; stipules filiform, up to 3 mm long, caducous or absent; petiole 2–8.5 cm long; leaflets variable, elliptical to obovate, 3–13 cm × 2–5(–7) cm, obtuse, often emarginate, sometimes apiculate, glabrous above, thinly appressed puberulous beneath. Inflorescence a terminal, short-



Crotalaria pallida Aiton – 1, flowering branch; 2, flower; 3, calyx; 4, fruiting branch; 5, seeds.

ly pedunculate raceme, 15–40 cm long, 20–30-flowered; bracts linear, up to 5 mm long, caducous; bracteoles inserted at the base of the calyx, filiform, 1–3 mm long; pedicel 4 mm long; calyx deflexed, tubular, 6–8 mm long, appressed puberulous, with 5 unequal lobes; corolla about 1.5 cm long, yellow, often reddish-brown veined; standard elliptical, 11 mm × 8 mm; wings oblong-lanceolate, 8 mm × 3 mm; keel shallowly rounded, 11 mm × 4 mm, with narrow, slightly projecting beak. Pod shortly stipitate, subcylindrical, 3–5 cm × 6–8 mm, 30–40-seeded, glabrescent, yellowish when mature. Seed heart-shaped, 3 mm × 2 mm, shiny, mottled ochre and dark grey-green or brown.

C. pallida is cleistogamous and the percentage of outcrossing is usually small. Germination is quick, but initial growth is slow. After one month, 3 leaves and a well branched and nodulated root system have developed. In subtropical southern Brazil flowering starts about 160 days after sowing and the first mature seeds are released from the pods two months later.

Two varieties of *C. pallida* are sometimes recognized: var. *pallida* with elliptical leaflets, widest in the middle, about 6–13 cm long, acute or rounded at the apex, and var. *obovata* (G. Don) Polhill with elliptical-obovate to obovate leaflets, widest at a point 0.6–0.8 of the length from the base to the apex, about 3–7 cm long, rounded or retuse at the apex. Var. *obovata* tends to occur in wetter locations. Intermediate forms are reported from Thailand.

Ecology *C. pallida* occurs naturally on river banks, edges of lakes, extending into woodland, grassland and waste places from 0–1000 m altitude and may be planted to 1800 m. It is light-demanding and shade strongly retards development. It grows in a wide range of annual rainfall conditions, from 850 mm to over 3000 mm and occurs occasionally in rather dry locations. The average annual temperature varies from 16–26°C. Tests in Florida showed satisfactory growth on a wide range of soils, except on peat soils that developed under coarse grass. In West Africa it is considered well suited to sandy soils. In Thailand it is found in the tidal zone, growing in association with *Avicennia sphaerocarpa* Stapf ex Ridley and *Ipomoea pes-caprae* (L.) R. Br. It also occurs in open, secondary thickets with *Bambusa bambos* (L.) Voss, *Chromolaena odorata* (L.) R.M. King & Robinson and *Lantana camara* L.

Agronomy Fresh seed of *C. pallida* has a higher germination rate than stored seed. In India germination was found to be improved by treatment with hot water. However, other reports indicate less favourable results and even damage of seed. A seed rate of 10–20(–30) kg/ha is required. In Bogor, Indonesia, *C. pallida* sown in rows 50 cm apart covered the soil after three months. A few weedings were required. Plants have to be topped when about 30 cm tall to promote branching. *C. pallida* should be cut at least 20–25 cm above the ground to ensure good regrowth. It can be cut 3–4 times before it dies out, generally after 1.5–2 years.

In Sri Lanka yields of 13.5 t/ha of above-ground green material have been obtained in 6 months, and 23 t/ha in 4 cuts in a little over a year, while annual yields of up to 5.2 t/ha and 10.2 t/ha above-ground air-dry matter are reported from Florida and southern Brazil respectively.

C. pallida is susceptible to the root-knot nematodes *Meloidogyne incognita* and *M. javanica*. It is one of the alternative hosts of *Maruca testulalis*, which is a pest in cowpea (*Vigna unguiculata* (L.) Walp.). It also acts as a vector for the 'kette' virus affecting cardamom (*Elettaria cardamomum* (L.) Maton). During dry periods, flea-beetles may cause severe defoliation. The bug *Ragmus importunatas* causes leaf fall at the beginning of the rainy season in Java. Other insects causing damage are the beetle *Longitarsus* sp. and the caterpillar *Utetheisa lotrix*.

Genetic resources and breeding The Southern Regional Plant Introduction Station of the United States Department of Agriculture, Griffin, Georgia holds 26 accessions of *C. pallida* from 19 countries. Around 1960 cv. Giant Striata was the most popular cultivar in the south-eastern United States. About 90% of the seed sold in North Carolina was of this cultivar.

Prospects *C. pallida* retains some importance as a cover, green manure and fodder crop in the south-eastern United States. In South-East Asia it will probably remain of minor importance only, as species more resistant to diseases and pests are available.

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N.O. Aguilar

Crotalaria spectabilis Roth

Nov. pl. sp.: 341 (1821).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 16$

Synonyms *Crotalaria sericea* Retzius (1788), non Burm.f. (1768).

Vernacular names Showy rattlebox, showy crotalaria (En). Thailand: mahing men (northern).

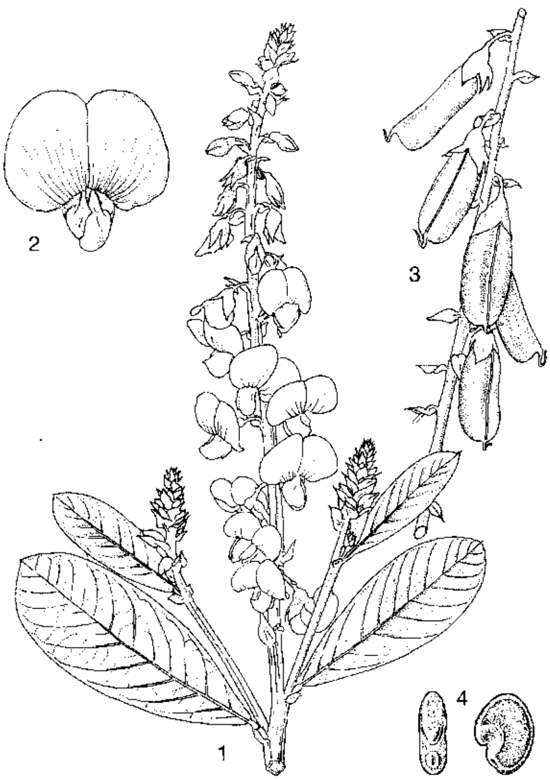
Origin and geographic distribution *C. spectabilis* probably originated in tropical Asia, but is now distributed pantropically. It is also cultivated throughout the tropics, including South-East Asia and in the south-eastern United States.

Uses *C. spectabilis* is used as a green manure and for erosion control in the tropics and in the United States. Its use as fodder has ceased because of its toxicity. It is a spectacular ornamental, which flowers for long periods. A fairly strong fibre is extracted from the stem. In India, plants are used in the treatment of scabies and impetigo.

Properties The seed and other above-ground parts contain the pyrrolizidine alkaloid monocrotaline, which lowers blood pressure and is toxic to farm animals and probably also to root-knot nematodes (*Meloidogyne* spp.). Because of its bitterness the green material is avoided by farm animals. In Brazil, leaves contained per 100 g dry matter: N 4.0 g, K 1.2 g, Ca 1.1 g, Mg 0.4 g. The weight of 1000 seeds is 15 g.

Botany Erect, much-branched annual herb, up to 2 m tall. Stem and branches angular, grooved, subglabrous. Leaves simple; stipules persistent, obliquely oblong-ovate, acuminate, 3–10 mm × 2–8 mm; petiole 2–8 mm long; blade oblanceolate to obovate, (5–)8–14 cm × 3–8 cm, upper surface glabrous, lower surface appressed pubescent. Inflorescence a rather lax, many-flowered raceme, 15–50 cm long; bracts persistent, cordate, 10–20 mm × 5–10 mm, acute or acuminate; pedicel 8–13 mm long; bracteoles lanceolate, 1–2 mm long; calyx campanulate, 11–14 mm long, with 5 unequal lobes which are longer than the tube, glabrous; corolla yellow; standard orbicular, about 20 mm in diameter; wings obovate-oblong, 9–18 mm × 5–9 mm; keel 10–14 mm × 4–9 mm, rounded about the middle, with a short, incurved, twisted beak; stamens 10, monadelphous; anthers dimorphic, with 5 long, basifixed anthers on a short filament alternating with 5 rounded, dorsifixed anthers on a long filament; ovary narrowly oblong, glabrous. Fruit a broadly clavate-oblong pod, 4–5 cm × 1.5–2.5 cm, glabrous, brown to dark brown when mature, 20–24-seeded. Seed unequal-sided heart-shaped, about 3.5 mm × 4 mm, with the radicular side strongly incurved, brown.

C. spectabilis is grown as an annual with a life cycle of 4–6 months. It develops an extensive root system that may reach to a depth of 120 cm. It nodulates with slow-growing *Bradyrhizobium*



Crotalaria spectabilis Roth – 1, flowering branch; 2, flower; 3, fruiting branch; 4, seeds.

spp. Flowering starts about 2 months after germination.

Ecology *C. spectabilis* is a plant of the tropics and subtropics, requiring an annual rainfall of 900–2800 mm and a mean annual temperature of 12–28°C. It is drought-tolerant. It occurs in open locations along forest margins and as a weed in cultivated fields, from sea level up to 1500 m altitude, on a wide range of soils, including heavy soils, with a pH range of 4.8–8.0.

Agronomy *C. spectabilis* is propagated by seed. A seed rate of 15–20 kg/ha is recommended in the United States, and of 90 kg/ha for broadcasting in Brazil. Seed should not be sown deeper than 5 cm. Germination is rapid and can be complete 5–6 days after sowing. A crop of *C. spectabilis* is easy to incorporate into the soil, as the lower part of the stem hardly lignifies. It should be ploughed in about 2 months before the following crop is sown or planted. This allows about 70% of the organic matter to decompose and release its nutrients.

Tests on poor sandy soils in Florida found that *C. spectabilis* had a dry matter production of 10–11 t/ha in 5 months, containing 170 kg nitrogen, slightly lower than *Cajanus cajan* (L.) Millsp. cv. Norman and *Indigofera hirsuta* L. The beneficial effect of *C. spectabilis* on the succeeding crop results not only from the increased nitrogen content of the soil but also from its effect on nematodes. The numbers of root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) and of the sting nematode (*Belonolaimus longicaudatus*) in the soil are greatly reduced by a crop of *C. spectabilis*. The reduction in root-knot nematodes has been shown to last until the harvest of a subsequent highly susceptible crop of cowpea (*Vigna unguiculata* (L.) Walp.). Reports on the effect on the lesion nematode (*Pratylenchus brachyurus*) are contradictory; its numbers increased slightly in Florida, but were reduced in experiments in Nigeria.

When grown for seed, several caterpillars may attack the young pods. They may be very destructive, causing complete failure of the seed crop. Preventive use of insecticides is recommended. The fungus *Alternaria cassiae* has been tested as control agent for *C. spectabilis* where it has become weedy. Effective control in the field was achieved by spraying twice with a solution containing spores of the fungus.

Genetic resources and breeding Germplasm collections of *Crotalaria* spp. are maintained by the United States Department of Agriculture, including material of *C. spectabilis*. It is unlikely that any substantial breeding programmes exist.

Prospects Its high growth rate and effective control of root-knot and sting nematodes make *C. spectabilis* a very useful green manure crop, deserving more attention in South-East Asia. Its effect on nematodes and potential as a trap crop for root-knot nematodes should be studied further.

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C. Niyomdham

Crotalaria trichotoma Bojer

Ann. sc. nat. Series 2. Vol. 4: 265 (1835).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 16$

Synonyms *Crotalaria zanzibarica* Benth. (1843), *C. usaramoensis* Baker f. (1914).

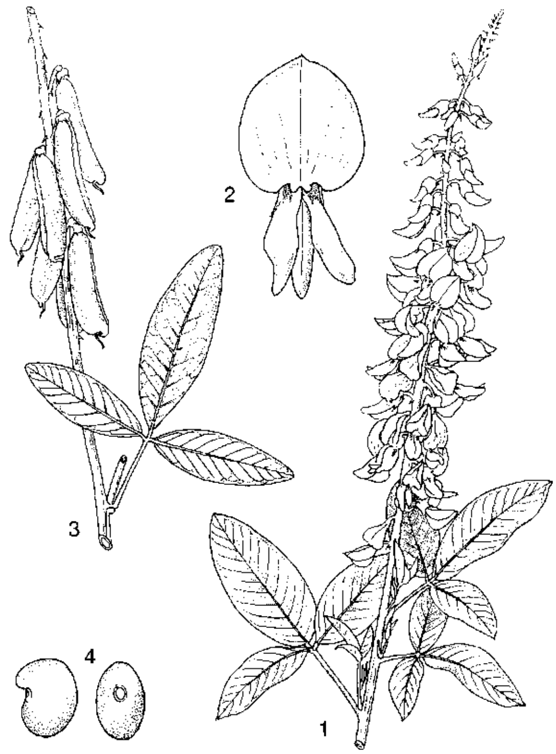
Vernacular names Curare pea (En). West Indian rattlebox (Am). Indonesia: geger sore (Sundanese).

Origin and geographic distribution *C. trichotoma* originates from the coastal regions of Tanzania and northern Mozambique. It was introduced into Java in 1916 by the Botanic Garden in Bogor. It was soon taken into cultivation and spread through Java and Sumatra, where it occasionally escapes from cultivation, but does not seem to naturalize. It is now distributed throughout the humid tropics and sometimes naturalizes (e.g. in Taiwan and Vietnam).

Uses Because of its quick growth and good production of green matter *C. trichotoma* is grown as a green manure and cover crop in tea, coffee, rubber and citrus plantations. It is especially grown in locations where *C. micans* Link is severely attacked by *Ragmus* bugs or where a lower-growing cover is preferred. In Indonesia it has been tested as an intercrop in maize and as a green manure crop in vegetables. In Argentina, Central America and Angola it is grown for fodder, often in mixed swards with grasses.

Properties The leaves and stems are very nutritious and are readily eaten by cattle and horses. Although poisonous alkaloids have been found in many other *Crotalaria* spp., *C. trichotoma* appears to be free of them. Its bark contains fibre, but this is of poor quality, unsuitable for making bags, possibly adequate for cordage.

Botany Erect annual or short-lived perennial herb, up to 2.7 m tall, deep rooted, base often woody, upper part of stem well branched. Stem



Crotalaria trichotoma Bojer – 1, flowering branch; 2, flower; 3, fruiting branch; 4, seeds.

ribbed, appressed puberulous. Leaves trifoliolate, without stipules; petiole 2–5 cm long; leaflets lanceolate to elliptical-oblong, 4–14 cm × 1–4 cm, base acuminate, apex acute or rounded, glabrous or rarely puberulous above, appressed puberulous below. Inflorescence a terminal raceme, 30–40 (–90) cm long; flowers many, closely arranged; pedicel 4–8 mm long; bracts linear-caudate, 2–4 mm long; bracteoles inserted at the base of the calyx or rarely on upper part of pedicel, linear, 1–1.5(–2.5) mm long; calyx becoming truncate at base and deflexed against the pedicel, 4–6 mm long, glabrous or thinly appressed puberulous, the 5 lobes reduced to small, widely spaced teeth; standard obovate-elliptical or suborbicular, 10–13 mm wide, yellow, reddish-purple veined, glabrous outside; wings and keel about equal in size, wings with a dark mask at the base, keel 12–13 mm long, rounded about the middle, with a slightly incurved, sharp, untwisted beak; stamens 10, all joined, sheath open at least at the base, anthers dimorphic, 5 large ones alternating with 5 short ones; ovary stipitate. Pod shortly stipitate, subcylindrical, inflated, (30–)35–45 mm × 7–11 mm, black when ripe, appressed puberulous, 50–70-seeded. Seed obliquely heart-shaped, 2–3 mm long, smooth, orange-buff or terracotta.

C. trichotoma is self-incompatible and tests indicate that its flowers are pollinated by insects before they open, suggesting that it is cleistogamous and self-compatible. In the literature *C. trichotoma* is better known by its synonymous names. It resembles *C. pallida* Aiton, in which the wings are shorter than the keel and lack the basal dark colouration.

Ecology The natural habitat of *C. trichotoma* is grassy sites in coastal forest clearings, bushland, *Brachystegia* woodland, grasslands, roadsides and cultivated fields, up to an altitude of 1800 m. In Java and Sri Lanka it is cultivated up to 1500 m altitude. On degraded and compacted soils it performs better than most other green manure crops. It is fairly tolerant of drought.

Agronomy *C. trichotoma* is propagated by seed. Direct sowing at a rate of 2.5–3.5 kg/ha in strips about 0.3–1 m apart is most common. Sowing should not be done under very wet conditions. Two weedings are generally required before it covers the ground, which occurs after 3–4 months. Once established, *C. trichotoma* propagates abundantly by self-seeding. It produces a large amount of green matter but is rather short-lived and does not tolerate frequent heavy lopping. Cutting should be done at a height of 45–60 cm above the ground, always leaving a few leaves. Cutting at lower levels results in very poor regrowth. Green manure yields are generally slightly lower than from *C. micans*; a yield of 5 t/ha, obtained 5 weeks after a previous harvest is reported from Bogor. A soil cover may contain about 25 t/ha fresh organic matter 6 months after planting. Little organic matter accumulation takes place thereafter, unless the plants are cut.

C. trichotoma is sometimes severely attacked by the fungus *Parodiella spegazzinii*, which covers the upper surface of the leaves with a black soot-like layer. The affected leaves curl upwards and whole plantations can be destroyed. *C. trichotoma* is occasionally ravaged by *Helopeltis antonii* and – less severely – by *Deiopeia pulchella*. It is resistant to *Ragmus importunatas* bugs, but may act as a host plant for the legume pod borer (*Maruca testulalis*) and the lima bean pod borer (*Etiella zinckenella*).

Genetic resources and breeding Germplasm collections of *Crotalaria* spp. are maintained by the United States Department of Agriculture, including material of *C. trichotoma*. It is unlikely that any substantial breeding programmes exist.

Prospects *C. trichotoma* is a very suitable green manure crop in plantation crops on poor, compacted soils and where other, more productive crops cannot be grown because of disease and pest problems. More research is urgently needed, especially on its economics and its incorporation in cropping systems with annual crops.

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L.P.A. Oyen

Cyamopsis tetragonoloba (L.) Taubert

Engler & Prantl, Natürl. Pflanzenfam. 3(3): 259 (1894).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 14$

Synonyms *Cyamopsis psoraloides* (Lamk) DC. (1825).

Vernacular names Guar, cluster bean, Siam bean (En). Cyamopse à quatre ailes (Fr). Malaysia: kottavarai (Malayalam, Tamil). Burma (Myanmar): pè-walee, walee-pè. Thailand: thua-kua (central).

Origin and geographic distribution Guar is a cultigen of uncertain origin. It has been speculated that guar originated in north-western India and Pakistan from *Cyamopsis senegalensis* Guill. & Perr. The latter species, which occurs from Senegal to the Arabian Peninsula, is occasionally used as a fodder and may have been taken by Arabian traders to India as fodder for horses, which were one of their main trading commodities.
Guar was taken to Indonesia, Malaysia, and the Philippines around 1915. It is now grown in many parts of the drier tropics and subtropics. Introduced into the United States in 1903, it was developed into an industrial gum-producing crop during the second World War.

Uses Traditionally, the main use of guar is as a green manure and cover crop, and as a shade plant for ginger and turmeric. Sweet and tender young pods are consumed as a vegetable in north-western and southern India. They are also eaten as snacks after drying and frying. Mature seeds have been eaten as a pulse during periods of food shortage. Guar is grown as a fresh or dry forage crop and as a feed-grain crop.
Guar seed is an important source of the industrial vegetable gum galactomannan, which has a thickening property 5–8 times stronger than starch. It is used as a thickener and stabilizer in foods such as salad dressings, ice cream, yoghurt, tinned vegetables and bakery items, and in the preparation of cheese and reconstituted tobacco. Industrially, guar gum is used to strengthen cloth and paper, as a filtering agent in the mining industry and as an additive to drilling fluids in oil-well drilling. The seedcake, a by-product of guar gum extraction, is an important source of animal feed, having a protein content of about 40%.
Extracts from guar seed are being tested as a medicine against non-insulin-dependent diabetes and against hyper-cholesteremia. Traditionally, leaves are eaten to cure night blindness, while pods are used as a laxative.

Production and international trade The main area of production of guar as a green manure and fodder crop is north-western India and Pakistan. The main producers of guar for gum are India, Pakistan and the United States. Limited and fragmented information indicates that the annual production of guar seed in India for the period 1970–1975 was 510 000 t, which increased to 940 000 t in 1976. Pakistan produced 160 000 t in 1974. Annual production in the United States fluctuates strongly, from 35 000 t in 1976 to only 7000 t in 1978, averaging about 15 000 t. In 1987, world trade of guar gum stood at about 125 000 t. The United States is the main importer of guar gum supplied by India and Pakistan and imported about 45 000 t in 1994 at a price of 0.5 US$/kg.

Properties Green pods contain per 100 g fresh material: water 82 g, protein 4 g, fat 0.2 g, carbohydrates 10 g, fibre 2.5 g, ash 1.5 g, Ca 0.1 g, P 0.25 g, Fe 6 mg, vitamin A 330 IU, vitamin C 50 mg. They contain 40–70 mg hydrocyanic acid per 100 g, which is removed by thorough boiling. The seed consists of 14–16% testa, 38–45(–50)% endosperm and 40–46% cotyledons. Dry seed contains per 100 g: moisture 10 g, protein 30 g, fat 2.5 g, carbohydrates 41 g, crude fibre 13 g, ash 3 g. The proximate composition of guar green forage is per 100 g: moisture 81 g, crude protein 3 g, digestible protein 2.5 g, ether extract 0.4 g, crude fibre 4.4 g, N-free extract 8 g, ash 3.3 g, Ca 0.6 g, P 0.07 g.
The galactomannan gum, which makes up 47–68(–85)% of the endosperm, consists of chains of D-mannopyranosyl units to which D-galactopyranosyl units are attached at every second unit. In cold water it forms a gel of exceptionally high viscosity at low concentrations. The viscosity depends on temperature and concentration. Maximum viscosity is achieved at 25–40°C. Viscosity increases proportionally with concentration to about 0.5%. At higher concentrations it increases more slowly. Solutions are stable over a very wide pH range (pH 1–10) and a wide range of salt concentrations. With borate ions hydrated guar gum forms a cohesive, structured gel. Commercial guar gum is 78–82% galactomannan with some protein and other endosperm admixtures. In 1974 the United States Food and Drug Administration affirmed the 'generally recognized as safe status' (GRAS) of guar gum, with specific limits.
The weight of 1000 seeds is 26–47 g.

Description A robust, bushy, erect, annual herb, 20–100 cm tall in improved cultivars, up to 3

Cyamopsis tetragonoloba (L.) Taubert – 1, flowering and fruiting branch; 2, flower; 3, staminal tube with pistil.

m in landraces. Root system well developed laterally. Stems and branches angular, grooved, appressed pubescent with white, forked hairs, sometimes glaucous; some cultivars remain unbranched. Leaves alternate, trifoliolate; leaflets elliptical to ovate, terminal one 8–12 cm long, lateral ones 5–8 cm long; rachis 3–7 cm long, pulvinate; margins toothed, the length of the teeth less than 1/10 of the breadth of the leaflet, which usually exceeds 1 cm. Inflorescence a dense, axillary raceme with 5–30 flowers; flowers up to 9 mm long; calyx hairy, ending in 5 unequal teeth, carinal tooth longest; petals creamy white on emergence, changing through pink to light purple, standard orbicular, wings and keel oblong; stamens 10, filaments united into a staminal tube, anthers apiculate. Pod 6–12-seeded, 4–12 cm long, in stiff erect clusters, pubescent or glabrous, straight to slightly curved, beaked, with a single ridge at one suture and two ridges at the other. Seed hard, flinty, flattened, ovoid, about 5 mm long, white, grey or black. Seedling with epigeal germination.

Growth and development After germination, about 3 simple leaves emerge, followed by compound leaves. Under controlled conditions, short daylength and high temperature delay the appearance of trifoliolate leaves and flowering may start before the first compound leaf appears. In branching cultivars most of the initial branching takes place near the stem base. Non-branching types have larger leaves than branched ones. Guar is a quantitative short-day plant, but cultivars in which flowering is not affected by daylength have been developed. Profuse and continuous flowering may start about one month after establishment. Flowers are cleistogamous, but in some cultivars natural crossing may be as high as 9%. Pod formation starts 45–55 days after sowing and peaks after 75–80 days. Seeds ripen 110–160 days after sowing.

Guar produces clusters of nitrogen-fixing nodules with *Bradyrhizobium* strains. Nodulation may start early, the first nodules becoming visible 1 week after germination.

Other botanical information *Cyamopsis* DC. is a small genus of 3 species and is closely related to the genus *Indigofera* L. All species have a diploid chromosome number of 14. The 2 wild species are African (*C. serrata* Schinz) or mainly African (*C. senegalensis*).

Numerous cultivars of guar have been developed. In general, branched types are more suitable for seed production, while erect, single-stem types that produce larger and more fleshy pods are preferred in vegetable production. In India three main types are sometimes recognized: 'Deshi', a mostly rainfed seed crop, 1.2–1.5 m tall; 'Pardeshi', mainly grown for its green pods, 1.5–1.8 m tall; and 'Sotiaguvar', mostly grown for fodder and green manure, 2.5–3.5 m tall. 'Sofia' is a multipurpose cultivar from Gujarat, grown as a green manure and shade plant and for its green pods, 'Durgapura Safed' is a successful cultivar for forage and grain production. 'Brooks' was the first cultivar released in the United States, moderately resistant to the main diseases (*Alternaria* leaf spot and bacterial blight). However, its resistance to bacterial blight tends to break down under heavy infestation, as is the case with 'Kinman' released in 1974. 'Mills' (early maturing), 'Esser' (late maturing) and 'Hall' (full season) were released in between 1965 and 1975, 'Lewis' (intermediate) and 'Santa Cruz' (full season) in 1985. These are all higher yielding than older cultivars and were more resistant to bacterial blight when released.

The American cultivars and 'Pusa Sadabahar' and

'Pusa Naubahar' from India are daylength neutral; most other cultivars are photosensitive.

Ecology Guar is a hardy, drought-tolerant legume. It grows in a wide range of environments from the sub-humid to semi-arid conditions in the tropics and subtropics with (300–)500–800(–1500) mm of rainfall. The main production of guar for seed occurs where annual rainfall is less than 800 mm. In areas with higher rainfall, vegetative growth is greater, but seed quality is inferior, making guar more suitable as a green manure and fodder crop. Guar prefers a very hot climate. Mean monthly maxima in northern India may reach 35–40°C, though in southern India extremes are lower. Optimum soil temperature for root development is 25–30°C. Guar is cultivated up to 900 m altitude. It is highly susceptible to frost. The optimum temperature for germination is about 30°C. At 20°C, germination is retarded, at still lower temperatures the rate of germination is reduced. It can grow in most soils, but thrives in well-drained alluvial and sandy-loam soils of pH 7.0–8.0. Waterlogging is not tolerated. On heavy soils, guar should be grown on ridges to maintain root aeration. In an experiment using irrigation water with equal amounts of NaCl and $CaCl_2$, salinity levels up to 8.8 dS/m did not affect germination, early growth or grain yields.

Propagation and planting Guar is propagated by seed. Scarifying the seed by mechanical means or by treating it with sulphuric acid tends to give more rapid and more uniform germination. However, under humid conditions germination is generally good without scarification.

For green manure production, seed is broadcast at a rate of 35–45 kg in India, versus 22–35 kg/ha in the United States.

In northern India, vegetable guar is generally grown twice per year, the first crop is sown after the start of the rainy season in June–July, the second crop is sown in February–March at the start of the hot season, and is grown under irrigation. In southern India, vegetable guar is grown throughout the year. In vegetable production, seeds are generally sown in raised beds, 5–7 cm deep at 45–60 cm × 22–30 cm or dibbled at 60 cm × 30–60 cm. The seed rate used ranges from 3–12 kg per ha.

For grain production in India, sowing is done in March–April under irrigation, while rainfed guar is sown soon after the onset of the monsoon rains in June–July. Seed is often broadcast, though sowing in rows gives higher yields. Spacing between rows varies from 30–60 cm, within-row spacing from 15–30 cm. Seed rates range from 10–15 kg/ha, but 12–25 kg/ha is also reported.

For grain production in the United States, guar is sown in rows 60 cm or 90–110 cm apart, at 10–30 cm within rows, using seed rates of 4–7 kg/ha. The recommended depth of sowing is 2.5–5 cm. Differences in seed rates reflect cultivar type and growing conditions rather than seed size.

Guar responds well to inoculation with rhizobium, which can improve nodulation by as much as 36%. Group E (cowpea) or Group PE inoculant are as good as specific guar inoculants.

Husbandry In India, especially in dry areas, such as Gujarat, guar is often grown as an intercrop with other annuals such as pearl millet, sorghum, maize or cotton. It is also grown as a cover crop between young rubber or young coconut trees. As a sole crop it is grown in rotation with maize, sorghum, cotton, wheat and vegetables.

Guar plants cannot withstand much weed competition and inter-row weeding by chemical or mechanical means is needed. At least 2 mechanical weedings are normally required. In the United States the application of pre-emergence herbicides is recommended. Trifluralin and profluralin have been found to be non-toxic to guar. Alternatively, EPTC, chlorthal, naptalam or linuron can be used. Precautions should be taken if these herbicides are to be used when intercropping is practised. When grown as a vegetable, weeding is done manually.

The fertilizer requirements of guar are dependent on soil fertility. On fertile soils or soils well-fertilized in the previous season, guar hardly responds to fertilizer application. Otherwise, application of 30–50 kg/ha of P_2O_5 and 10–15 kg/ha of K_2O is recommended.

Although guar is adapted to rainfed agriculture, it responds well to irrigation. It has the ability to cease growth during dry weather and to sprout when rain resumes.

Diseases and pests Internationally, bacterial blight, caused by *Xanthomonas cyamopsidis* and leaf spot caused by the fungus *Alternaria cucumerina* var. *cyamopsidis* are the main diseases of guar. Bacterial blight is seed-borne and infected seedlings are often killed rapidly. In older plants the disease develops from transparent, oily leaf spots coalescing into brown, angular, necrotic lesions. Infection spreads systemically throughout the plant and can kill it at any stage of development. The cultivars 'Brooks', 'Hall', and 'Mills', which were originally resistant, are now affected by a highly virulent strain. Soaking the seed in hot water at 56°C for 10 minutes will eliminate seed-borne infection. *Alternaria* leaf spot develops between flowering and pod set. It causes defoliation, especially during periods of high rainfall and humidity. Dithane and cupramar give excellent control of this disease. A mildew, caused by *Oidiopsis taurica*, is widespread and causes some damage, especially during periods of humid weather.

Guar is relatively free of pests. The midge *Contarinia texana* causes damage in the United States and has caused yield losses of 20–30%. Effective, economical chemical control is possible. A gall midge (*Asphondilia* sp.) occurs in India and the United States and may cause limited damage late in the growing season.

Harvesting The best time for harvesting guar for fodder is during flowering and early pod formation. In India pods are often picked for home consumption before the fodder is harvested. In some regions guar is grazed, usually after frost, to reduce the risk of bloat in ruminants. It takes about 4–6 weeks from the onset of natural defoliation for guar to dry sufficiently to allow mechanical harvesting. The pods of most cultivars do not shatter. Moist conditions during this stage may cause the seed to weather and blacken. In India most harvesting is done manually and often starts when the stalks are still green. Subsequently, the plants are put in loose stacks, for rapid drying. This system avoids weathering of the seed, but harvesting too early will reduce the yield and the gum content. In the United States frost often kills the maturing crop, initiating rapid drying. Alternatively, desiccants such as paraquat may be used to promote drying. Harvesting is carried out with an adjusted standard combine harvester.

When grown for green pods, harvesting occurs 50–80 days after sowing, with the tender pods being picked every 2–3 days for several weeks.

Yield As a rainfed forage or green manure crop, average yields in India are 8–12 t/ha, 10–12 weeks after sowing. Under irrigation, average yields are 16–20 t/ha. A green manure crop adds about 50 kg fixed nitrogen to the soil. Yield increments of crops following guar can be very high. Increases in wheat yield of 1500 kg/ha on light soils and 500 kg/ha on heavy soils are reported from India, while yield increases in cotton from 450–540 kg/ha are reported. In an experiment in the United States barley yield increased from 3.2 t/ha to 5.1 t/ha, 0.8 t/ha more than after other green manure crops.

Dry grain yield under rainfed conditions in India and the United States ranges from 350–1000 kg/ha, depending on rainfall and time of sowing. Under experimental conditions it rarely exceeds 1300 kg/ha. Yield can be more than doubled under irrigation. Under experimental conditions in the United States yields of over 3 t/ha have been obtained with 'Kinman' and 'Esser', in Zimbabwe over 3.5 t/ha with 'Mills' and 'Hall'.

Average yield of green pods is about 2000 kg/ha for a premonsoon crop and 2500–3000 kg/ha for a monsoon crop. Experimentally, yields of over 9000 kg/ha have been obtained with 'Pusa Mausami'.

Handling after harvest Guar gum is prepared from the seed by dry milling. In a multi-stage grinding and sifting process, the testa and cotyledons are removed to obtain 'splits'. Food-grade guar gum is made by grinding splits to a fine particle size. Most seed is milled to guar gum in the country of production.

Guar gum can be purified by autoclaving a mixture of the gum in water to obtain a 0.8% dispersion, followed by gradual addition of ethanol to a concentration of 40% and repeated centrifugation to precipitate the pure galactomannan.

The purified gum can be chemically changed to adjust its gel-making and water-binding characteristics to specific applications.

Genetic resources The National Bureau of Plant Genetic Resources, New Delhi, India and the Agricultural Research Institute, Lyallpur, Pakistan have representative collections of guar accessions. In the United States, the Texas Agricultural Experiment Station, Vernon, Texas and the Oklahoma State University, Stillwater, Oklahoma maintain collections. In addition to these actively used collections, the entire plant collection of 1300 accessions of 33 cultivars and local forms is stored at the National Seed Storage Laboratory, Fort Collins, Colorado.

Breeding Selection and breeding in guar in the United States aims at increased seed production and disease resistance, while in India cultivars have been selected for seed, vegetable, and multipurpose use. The American cultivars are derived from a very small number of introductions from India, leaving the genetic variability largely unutilized. An improved technique for controlled pollination of guar has been developed in India. Male sterility has been found, with pollen fertility probably being monogenically dominant over sterility.

Recent research has concentrated heavily on increasing grain yield. This was justified by the strong and growing market for guar gum and the increasing number of its applications. Development of determined cultivars with a compressed flowering phase and improved tolerance of temporary waterlogging have been suggested to increase its adaptability. Despite the crop's good prospects, research on guar all but stopped in the United States around 1985.

Prospects Although a few improved multipurpose cultivars have been developed in India, few efforts have been made to develop the green manure, cover crop, vegetable and forage aspects. These aspects would be most important in the drier parts of South-East Asia. There, it could become more important, being one of the few green manure and cover crops providing a useful by-product. Development of disease tolerance under humid conditions and agronomic research to incorporate it in a wider range of crop production systems would be urgently required.

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L.J. Wong & C. Parmar

Dactyladenia barteri (Hook.f. ex Oliver) G.T. Prance & F. White

Brittonia 31: 484 (1979).

CHRYSOBALANACEAE

$2n = 22$

Synonyms *Griffonia barteri* Hook.f. ex Oliver (1871), *Acioa barteri* (Hook.f. ex Oliver) Engler (1899).

Vernacular names Monkey fruit (En).

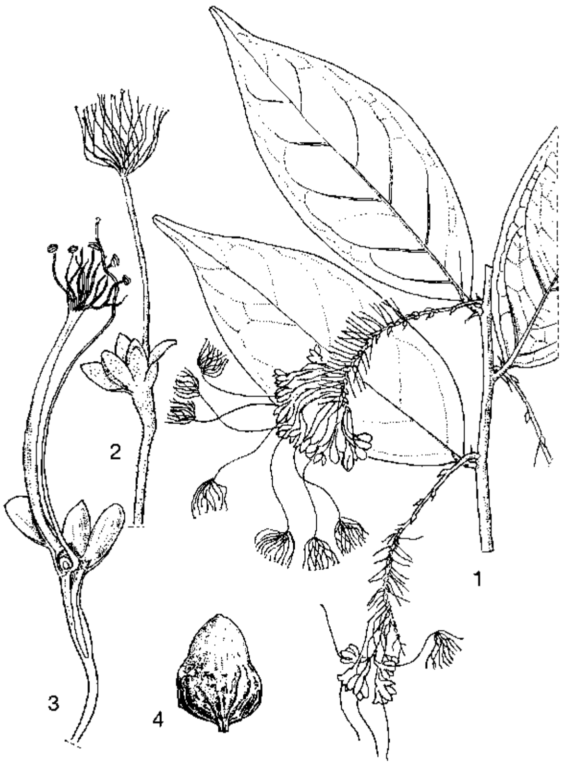
Origin and geographic distribution *Dactyladenia barteri* is endemic to West and Central Africa from Sierra Leone to Cameroon and Gabon. Its occurrence in Kivu in Zaire is uncertain.

Uses *D. barteri* is widely used in south-eastern Nigeria as a fallow crop, producing large amounts of litter and recycling appreciable quantities of nutrients through its deep root system. The dense canopy also aids in weed suppression. In farmers' fields, it is either planted or protected in natural regrowth. Leaves are used for fodder. Stems provide good quality poles for staking crops and for construction work.

In Nigeria and Liberia the bark and roots are used medicinally as a purgative and against a variety of ailments.

Properties The leaves of *D. barteri* grown on acidic sandy soil contain per 100 g oven-dry matter: N 1.7 g, P 0.08 g, K 0.77 g, Ca 0.57 g, Mg 0.25 g, Cu 1.2 mg, Zn 0.8 mg. The dark red wood of *D. barteri* is hard and durable and resistant to termite attack.

Botany Climbing shrub or small tree, up to 12 m tall; bole fluted, often multiple, crooked, up to 25(–40) cm in diameter; bark brittle, slash thin and watery-white, turning reddish; crown dense, spreading. Young shoots dark red, covered with whitish, arachnoid tomentum, early caducous; branches more or less scandent, slender, hispid, very quickly glabrescent when young, with numerous lenticels when old. Leaves alternate, simple; stipules often attached near the base of the petiole, linear, 4–6 mm long; petiole 3–4 mm long; blade elliptical-oblong to ovate, 7–13(–15) cm × 3–5.5(–7) cm, dark glossy green, turning reddish-brown when senescent, base acuminate, sometimes broadly acuminate and somewhat asymmetrical, apex acuminate; lateral veins in 4–6 pairs, some circular glands often present on the underside of the blade near the base and the apex. Inflorescence a terminal or axillary raceme, single or sometimes in pairs, 3–4(–12) cm long, puberulous, many flowered; peduncle up to 1(–4) cm long; bracts elliptical-lanceolate, 2–4 mm long, tricuspi-



Dactyladenia barteri (Hook.f. ex Oliver) G.T. Prance & F. White – 1, flowering branch; 2, flower; 3, section through flower; 4, fruit.

date, often with circular glands; pedicel articulated, portion below articulation 6–10 mm long, long persistent, bearing 2 alternate, lanceolate bracteoles 1–1.5 mm long; upper portion 5–15 mm long; flowers bisexual, zygomorphic; receptacle tubular, 4–6 mm long, puberulous; sepals 5, 4–5 mm long, puberulous outside; petals 5, oblong-obovoid, 4–5 mm long, white, caducous; stamens 15–20, (15–)25(–30) mm long, ligulately connate for most of their length, far exserted; pistil with 1-locular ovary, a filiform style slightly longer than the stamens, and a 3-lobed stigma. Fruit a single-seeded drupe, compressed-ovoid, 2.5 cm × 3.5 cm × 5.0 cm, green, surface often ferruginous-tomentose, apex often slightly tuberculate. Seedling with epigeal germination.

The root system is deep, but its lateral expansion in the top layer of the soil is limited. On an ultisol in south-eastern Nigeria, for instance, about 50% of the roots of less than 2 mm in diameter occurred in the top 20 cm of the soil near the stem, whereas at a distance of 120 cm from the tree base this percentage dropped sharply. In Nigeria and Ghana, *D. barteri* flowers usually during the dry season, between October and February. Fruits mature at the beginning of the rainy season, between March and May. *D. barteri* is open-pollinated, the main pollinators being red ants.

Ecology *D. barteri* occurs in lowland forest up to 300 m altitude with at least 1200 mm rainfall per year, where the mean minimum temperature of the coldest month is about 20°C and mean maximum temperature of the hottest month about 34°C. In the forest–savanna transition zone, it is found along river banks, sometimes on the inland side of mangrove forest. It is well-adapted to leached, acid and infertile soils and can survive occasional flooding. Established trees are fire-resistant.

Agronomy Propagation is mainly by seed. Occasionally, stakes are used as cuttings in live fence systems. Juvenile stem cuttings will also root quickly. Seed germinates readily. It can be stored for up to 6 months at 15°C when treated with copper sulphate. Direct sowing is possible, but seedlings survive better when raised in nursery bags before planting out. In traditional cropping systems, *D. barteri* is retained, planted scattered, or in hedgerows. Established trees coppice well, even after pollarding or burning. In south-eastern Nigeria it is planted in hedgerows in a traditional alley cropping system with inter-hedgerow spacing of 2–3 m in fallow systems with 1–2 years of cropping followed by 3–4 years of fallow. Following the fallow period, the shrubs are underbrushed and burned and stems cut to a height of 10–20 cm. Some stems are left uncut for live staking of white yam (*Dioscorea rotundata* Poiret). Crops are then interplanted in the alleys.

Planted at 4 m × 4 m spacing, *D. barteri* can produce per ha 6 t dry prunings (leaves and small branches), 4 t twigs and 9 t wood within 8 months, with a nutrient yield of the prunings of 85 kg N, 5 kg P, 43 kg K, 18 kg Ca and 46 kg Mg. In an alley-cropping experiment, *D. barteri* planted in rows 4 m apart at a within-row spacing of 50 cm produced 3.5 t/ha oven-dry litter and 1.4 t/ha dry wood when pruned 22 months after planting. The nutrient content of the prunings was: 65 kg N, 6 kg P, 41 kg K, 33 kg Ca and 13 kg Mg. The prunings have a high C/N ratio (28:1 – 36:1), lignin (47.6%) and polyphenols (4.1%) content and decompose slowly in the soil, making good mulch material. The mulch has little direct effect on soil nitrogen. Nitrogen immobilization by decomposing *D. barteri* leaves is counteracted by increased mineralization of soil organic matter under the mulch. The decomposition rate of the mulch is very low. After 100 days as little as 20% may have decomposed, after 6 months about 50%.

Genetic resources and breeding The genus *Dactyladenia* Welwitsch comprises about 27 species. It has been suggested that *D. lehmbachii* (Engl.) Prance & F. White and *D. pallescens* (Baill.) Prance & F. White, which flower in the same period, may cross-pollinate with *D. barteri*. There is potential for genetic improvement of *D. barteri* to enhance coppicing, growth and biomass yield.

Prospects *D. barteri* has shown promise as a mulch and alley crop in experiments at the International Institute of Tropical Agriculture (IITA) in Nigeria. There is a need to evaluate its potential in other regions of the tropics with high rainfall and acid soils, in agroforestry systems to promote sustained crop production on highly weathered soils. Already in use at the IITA as a test tree in alley cropping systems on poor acid soils, it may contribute to the development of such systems in South-East Asia as well. Provenance evaluation and variability studies are needed to reveal the amount of exploitable genetic variation which may exist within *D. barteri*.

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D.O. Ladipo & B.T. Kang

Derris microphylla (Miquel) B.D. Jackson

Index kewensis 1: 332 (1893).

LEGUMINOSAE – PAPILIONOIDEAE

$2n$ = unknown

Synonyms *Brachypterum microphyllum* Miquel (1861), *Derris dalbergioides* Baker (1878), *Deguelia microphylla* (Miquel) Valeton (1904).

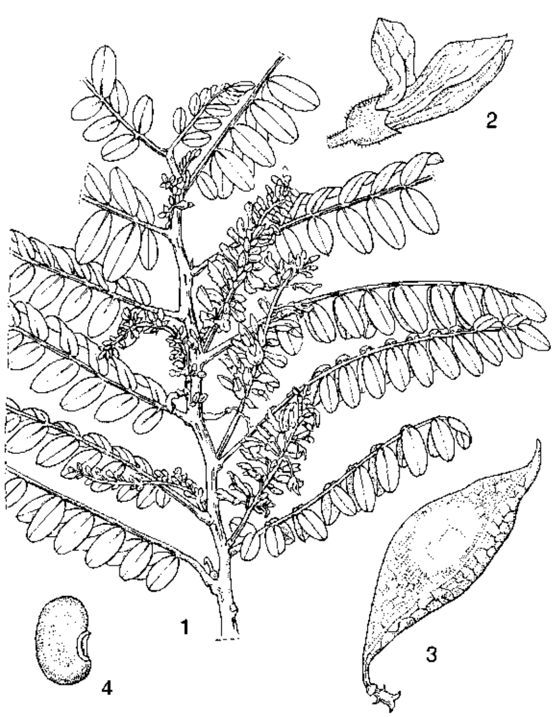
Vernacular names Vetch tree (En). Indonesia: kayu retak (Palembang). Malaysia: daun berayai, batai, betek (Peninsular). Thailand: khangten (south-eastern), di-ngu, fantae (peninsular).

Origin and geographic distribution *D. microphylla* occurs naturally in Sumatra, Peninsular Malaysia, Thailand, Burma (Myanmar) and possibly in Indo-China. Its natural occurrence in Java, where it is often planted, is uncertain.

Uses In Java, *D. microphylla* is occasionally grown as a shade tree in cocoa, coffee and tea plantations especially on poor soils. It is also used as green manure. The wood is used as building material and as firewood. In Malaysia a poultice of roots or bark is used to treat itch. Its abundant purple flowers make it a distinctive ornamental tree.

Properties Many *Derris* species contain rotenone and related compounds, which have insecticidal and piscicidal properties. It is unlikely that *D. microphylla* contains exploitable quantities of these compounds. All parts produce a foetid smell when crushed.

Botany Tree with several ascending branches and umbrella-shaped, feathery crown, 5–20 m tall; bark light-grey to brown, slightly fissured. Branchlets, petioles and buds golden-brown silky, glabrescent. Leaves imparipinnate, petiole and rachis 9–20 cm long; petiolule 1–2 mm long; leaflets 19–43, elliptical-oblong, 1.5–3.2 cm × 0.8–1.2 cm, rounded-emarginate at both ends, both surfaces thinly appressed brown hairy, glaucous below. Inflorescence an axillary raceme, 2–13 cm long, 1–3 together; flowers 7–8 mm long; pedicel 0.5–1.5 cm long; calyx campanulate; corolla dark-red to violet; standard 9 mm × 7 mm, bearing 2 glands at base; stamens 10, monadelphous, 1 stamen free at top and bottom but adnate to stamen



Derris microphylla (Miquel) B.D. Jackson – 1, flowering branch; 2, flower; 3, pod; 4, seed.

tube in centre. Pod flat, in outline elliptical to linear-lanceolate, 2.5–7 cm × 1.2–1.7 cm, 1–2(–5)-seeded, indehiscent, narrowed at both ends, glabrous to puberulous, leaf-like along dorsal suture with a 1–2 mm wide wing. Seed 6 mm × 3 mm, brown-green.

D. microphylla does not grow very fast and does not produce large amounts of green matter. The root system, which is superficial, produces large numbers of root nodules and, when damaged, large numbers of saplings. In Java, *D. microphylla* flowers in August–January.

D. microphylla is classified in section *Brachypterum* (Wight & Arnott) Benth. of the genus *Derris* Lour.; this section is sometimes considered a separate genus and in that case the correct name of the species is *Brachypterum microphyllum* Miquel.

Ecology In Java and Peninsular Malaysia, *D. microphylla* occurs from 200–1200 m altitude. It is tolerant of strong winds. To provide shade in plantations it is mostly planted on soils too poor for *Leucaena leucocephala* (Lamk) de Wit or *Paraserianthes falcataria* (L.) Nielsen.

Agronomy Propagation by seed and by cuttings is easy. For firewood and timber use the recommended planting distance is about 3 m × 3 m, gradually thinned out to a final spacing after 10 years of 10 m × 10 m. Experiences with *D. microphylla* grown as a shade tree in tree crops are mixed. Early reports, especially from tea plantations, indicate positive results, later reports from coffee and cocoa plantations draw attention to its slower growth, more superficial root system and lower production of organic matter resulting in poorer growth of the main crop than is the case with shade trees like *Paraserianthes falcataria* and *Erythrina subumbrans* (Hassk.) Merrill. However, it requires little maintenance, and pruning and pollarding are well tolerated. *D. microphylla* is attacked by the fungi *Ganoderma pseudoferreum*, *Rosellinia* and *Ustulina zonata* which affect its root system, and by several bagworm species. It is resistant to most borers. In the mid 1940s large numbers of trees died in West Java of unknown causes.

D. microphylla is a suitable tree for filling in gaps for soil protection in mature tree plantations, where it is easier to establish than most other trees.

Genetic resources and breeding A small collection of *Derris* germplasm including material of *D. microphylla* is being maintained at the National Germplasm Repository, Miami, United States.

Prospects *D. microphylla* may continue to play a role as a shade tree in tree crops on poor soils. On more fertile soils *Paraserianthes falcataria* and *Leucaena leucocephala* generally give better results. It remains a useful tree for filling in gaps in plantations, where it is difficult to establish other trees.

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K. Thothathri & Rugayah

Desmodium adscendens (Swartz) DC.

Prodr. 2: 332 (1825).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22$

Synonyms *Hedysarum adscendens* Swartz (1788), *Desmodium oxalidifolium* G. Don (1832), *D. trifoliastrum* Miquel (1855).

Vernacular names Tick clover, sweetheart (Dominica), adscendens (South America) (En). Zarzabacoa galana (Am). Philippines: pega pega. Vietnam: bai ngai.

Origin and geographic distribution *D. adscendens* occurs naturally in tropical Africa and South America. It has been introduced throughout South and South-East Asia and Melanesia.

Uses In South-East Asia and tropical Africa, *D. adscendens* is used as cover crop in tea, coffee and oil-palm plantations. In Zanzibar and mainland Tanzania it is used as a cover crop in clove plantations and has been tested as a forage legume in coconut stands. In Brazil, it provides forage for all stock, especially for horses. In Dominica in the Caribbean it is said to provide a useful medicine against gonorrhoea, in Zaire against stomachache.

Properties In Brazilian analyses the composition of 100 g dry matter was: crude protein 10.5 g, ether extract 3.4 g, nitrogen free extract 49.8 g, crude fibre 31.4 g, Ca 0.92 g, and P 0.13 g. The digestibility of organic matter was 64.9%. When harvested at mid-bloom stage, the composition of 100 g dry matter was: crude protein 14.7 g, ether extract 2.7 g, nitrogen free extract 39.7 g, crude fibre 34.8 g. The estimated digestible protein content was 2.5–2.7 g, the energy value 2200–2300 kJ/kg.

Botany A creeping or ascending perennial herb or low shrub, up to 1 m long, taproot diffuse. Stem terete, often rooting near the base, striate, densely soft hairy, glabrescent. Leaves trifoliolate; stipules obliquely ovate-lanceolate with long attenuate apex, up to 1 cm × 3 mm, persistent; petiole 1–3 cm long, rachis up to 1 cm long, both pilose; leaflets elliptical-obovate, terminal leaflet (1.5–) 2–4(–5.5) cm × 1–3 cm, lateral leaflets smaller, cuneate to rounded at base, margin entire, obtuse and emarginate at apex, upper surface glabrous to

Desmodium adscendens (Swartz) DC. – 1, habit of flowering and fruiting plant-part; 2, pod.

sparsely pubescent, lower surface sparsely to densely soft pilose, lateral nerves rather distinct and not reaching the margin, 4–7 on either side of the midrib. Inflorescence a terminal or axillary raceme, 4–20 cm long, lax-flowered; flowers usually in pairs; bracts ovate with a long-acuminate apex, 4–6(–11) mm × 1.5–2.5 mm, densely pubescent, early caducous; pedicel slender, up to 2 cm long in fruit, densely covered with mixed, spreading, hooked and straight hairs less than 1 mm long; bracteoles absent; calyx 2.5–3.0 mm long, covered with persistent, patent, long hairs especially on the 5 teeth and with minute straight or hooked hairs; corolla white or purple to violet; standard broadly obovate or orbicular, 4.5–5.5 mm × 4.0–4.5 mm, rounded or retuse at the apex, shortly clawed; wings nearly obovate, about 4 mm × 2 mm, obtuse at the apex, auriculate at the base, shortly clawed; keel-petals 4.5–5.0 mm long, incurved, subacute at the apex, distinctly long-clawed, claw 2–3 mm long; stamens diadelphous; pistil 5.0–5.5 mm long, densely short-hairy on the ovary, style glabrous, stigma minutely capitate.

Pod narrowly oblong, 1.0–2.5 cm × 3–4 mm, 3–6-jointed, dehiscent along the lower sutures, rarely shortly (1–2 mm) stipitate, slightly swollen on the seed, densely covered with very short, spreading, hooked hairs. Seed flattened, ellipsoid, 2.5–5.0 mm × 1.5 mm.
Several varieties and forms have been distinguished in the taxonomic literature on the basis of size and thickness of leaflets and on degree of hairiness. Because many intermediate forms occur as well, *D. adscendens* is best considered as a rather variable species, of which the extreme forms do not deserve separate taxonomic recognition.

Ecology *D. ascendens* occurs in damp swamp forest and other humid, locations like stream banks and bunds of rice fields, provided that they are shady. In equatorial regions it is found from 200–1000 m altitude. In Java, it flowers year-round. In the subtropics it flowers late in the growing season.

Agronomy *D. adscendens* is usually propagated by seed, but propagation by stem cuttings is also possible. Planted at 1 m × 1 m spacing, it forms a permanent ground cover. It loses its leaves after flowering during the dry season, and some stems may die. Growth starts again with the onset of the rains. In Brazil, 3–4 cuts per year can be taken for forage. It has been tested in Colombia, and in Florida it was found to be resistant to root-knot nematodes.

Genetic resources and breeding Small numbers of *D. adscendens* accessions are included in the *Desmodium* collections of the Centro Agronómico de Agricultura Tropical (CIAT), Colombia and of the United States Department of Agriculture (USDA) in Florida.

Prospects *D. adscendens* may continue to play a role as a green manure and cover crop. Its resistance to root-knot nematodes may prove useful in *Desmodium* breeding programmes.

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C.C. Wong & P.K. Eng

Eichhornia crassipes (Martius) Solms

A. DC., Mon. Phan. 4: 527 (1883).
PONTEDERIACEAE
$2n = 32$

Synonyms *Pontederia crassipes* Martius (1823), *Eichhornia speciosa* Kunth (1843).

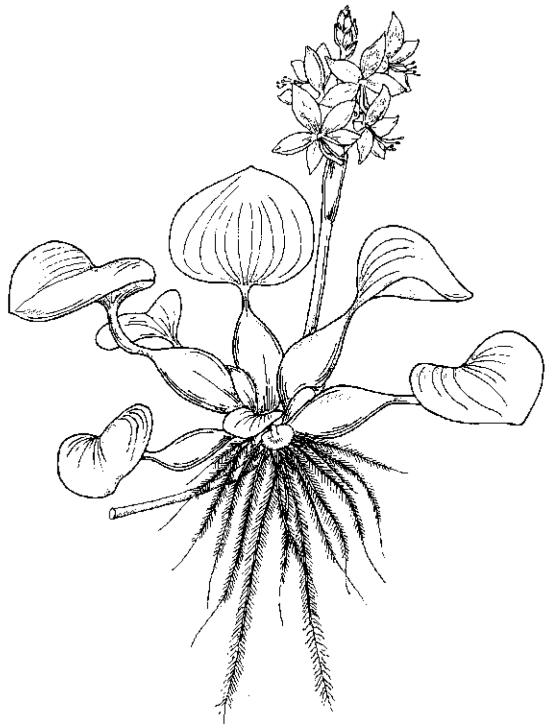
Vernacular names Water hyacinth (En). Jacinthe d'eau (Fr). Indonesia: eceng gondok (general, Sundanese), kembang bopong (Javanese), kelipuk (Palembang). Malaysia: keladi bunting, kemeling telur, bunga jamban. Philippines: water lily. Burma (Myanmar): beda-bin, ye-padauk. Cambodia: kâmplaôk. Laos: tôb po:ng. Thailand: phaktop-chawa. Vietnam: l[uj]c b[if]nh, b[ef]o nh[aaj]t b[ar]n.

Origin and geographic distribution Water hyacinth is native to tropical South America. During the latter half of the 19th Century it spread beyond its original habitat as an ornamental and subsequently became naturalized in tropical and subtropical areas around the world. It was first introduced into South-East Asia in 1894 to the Bogor Botanical Garden in Java, from where it spread over the Indonesian Archipelago. It was introduced into Singapore from Hong Kong in 1903 by the Chinese. The plant arrived in the Philippines in 1912. From Bangkok, where it was introduced from Java, water hyacinth spread over the Chao Phraya delta and along the Mekong river and adjacent regions in Vietnam, Cambodia and Laos, where it was already causing concern in 1908. Water hyacinth was first reported from Papua New Guinea in 1962.

Uses Water hyacinth is considered one of the world's most troublesome weeds because of its rapid growth and formation of dense, impenetrable mats of vegetation which hinder navigation and fishing, obstruct irrigation and drainage of farm land and crowd out other plants. To decrease the costs of water hyacinth control and the negative effects of chemical control, various studies have been carried out on possible ways of using it. However, it is difficult to harvest and process large masses with a very high water content (90–96%) in an economical way. The simplest and most practical routine use of water hyacinth is as green manure, compost and mulch for soil improvement. It is sometimes used as a fodder, and in South and South-East Asia it is common to see water buffaloes grazing it. It is further used in fish traps, where fish are trapped in nets under small clusters of water hyacinth, and to produce paper and biogas by means of anaerobic fermentation. In biogas production the high moisture content in the plants is an advantage, because moisture is needed for the fermentation process. One hectare of water hyacinth produces about 70 000 m^3 of biogas, one kg of dry material producing about 370 l. Increasing attention is being given to its potential as a water-clearing agent. The roots trap large amounts of dispersed organic and inorganic particles and efficiently remove minerals, including several heavy metals and radio-active elements. The feasibility of using water hyacinth as a substrate for mushroom cultivation is being studied. In some countries in the temperate zones water hyacinth is cultivated as an indoor plant. In Indonesia a home industry has been established producing handicrafts such as lady handbags, slippers, hats, and vests from the elongated dried petioles of water hyacinth.

Properties The different organic constituents in water hyacinth are nutritionally comparable to those of any other forage. The protein content varies from 7.4–18.1% on a dry weight basis. The concentration of the basic elements is in the same range as in terrestrial forage plants whereas those of iron, sodium, potassium and calcium are relatively high. Per 100 g dry matter the proximate composition is: Fe 0.3 g, Na 0.4 g, K 4.6 g, Ca 1.3 g. The nitrogen and phosphorous concentration as well as the concentrations of heavy metals are directly correlated with the concentrations in the water. It is advisable to mix water hyacinth with other fodders, because it can contain high levels of K and Cl and its P levels are often inadequate.

Description Perennial herb, 30–60 cm tall, rarely taller, floating free or rooting in the mud of shallow waters. Root system mainly composed of adventitious roots (blackish with age) originating from the rhizome and bearing many laterals; rhizome consisting of several nodes and internodes, each node with a leaf, and emitting stolons. Leaves consist of a petiole, a thin part between petiole and blade, called isthmus, and a blade; petiole elongated (when plants are rooted in the soil or growing in dense stands) or forming a bulbous float; blade broadly ovate or rhomboid with an almost cordate base. Inflorescence a long-peduncled, axillary spike subtended by two bracts, with 5–35 spirally arranged flowers, usually simultaneously expanding and withering; flowers zygomorphic, with a perianth of 6 pale-purple segments; the posterior segment largest, about 3 cm long, with a bright yellow, blue-bordered median blotch; stamens 6, variable in length; ovary superior, conical, trilocular with numerous ovules, style terminated by an almost capitate stigma at medium height between the anthers of long and short filaments. Fruit a dehiscent capsule containing a variable number of seeds. Seed ovoid, 1 mm x 0.5 mm, ribbed.



Eichhornia crassipes (Martius) Solms – habit of flowering plant.

Growth and development Propagation is mainly by vegetative means, i.e. through stolons. Only where it occurs in seasonally dry habitats is multiplication by seed important. Under favourable conditions growth is very rapid. The area under plant cover may double within a period of 6–15 days. In general, water hyacinth flowers profusely, both under long- and short-day conditions. Flowers of water hyacinth are tristylous, the most common form, also in South-East Asia, has 3 long and 3 short stamens and an intermediate style. Other forms, which are mostly absent outside the Amazon basin, have either 3 long and 3 intermediate stamens and a short style or a long style and 3 intermediate and 3 short stamens. In the natural habitat, pollination is carried out by pollen-collecting and nectar-collecting bees. Most effective pollination occurs between flowers of different style length, but fertilization by pollen from the same form occasionally occurs. In areas where water hyacinth has been introduced, pollinators are generally absent and some self-pollination may occur. In South-East Asia fruits are seldom produced if pollination is not carried out artificially. The fruits usually mature under water and in general a period of 20 days is necessary for the production of ripe seed. When the fruit bursts upon maturity, seeds will sink to the bottom of the water. The seed-coat acts as a physical barrier to germination. However, if the seed-coat is cracked, for example by alternate drying and wetting, germination may occur soon after shedding. On the other hand, there are reports of seeds remaining dormant for a period of about 20 years. Seedlings produce 2–3 ligulate leaves in 10 days and 7–8 ligulate plus 1–3 spatulate leaves in 30 days.

Ecology Water hyacinth thrives in various fresh-water habitats, ranging from shallow ponds, marshes, and small streams to large lakes and rivers. However, strong wave movements will unfavourably affect its growth. When ponds or floodplains dry out, water hyacinth dies rapidly. It is heliophilous and grows best under high light intensity. The present geographic distribution ranges from the Equator to nearly 38°N and 38°S which demonstrates its tolerance of various temperature regimes. Air temperatures may be as low as 1°C and as high as 40°C. Leaves are killed by frost, but plants survive until the rhizomes are frozen. Water hyacinth occurs in water having a wide range of pH values, but dense vegetations are mainly found in water with a pH near 7. Although the chemical composition of the water may vary to a large extent, the salt tolerance of water hyacinth is relatively low.

Diseases and pests In general, water hyacinth is very little affected by diseases and pests outside its natural habitat. However, fungi and arthropods that can be used as biological means of weed control have been identified. Of the few host-specific virulent pathogens, only the fungus *Cercospora rodmanii*, a native of Florida, has been found suitable for large-scale field application. Various arthropods have been collected in its original habitat in South America and the most promising agents for biological control are the curculionid weevils *Neochetina eichhorniae* and *N. bruchi*, and the stem-boring pyralid moth *Sameodes albiguttalis*. These insects have already been put to practical use and have become established in new habitats following their introduction. They cannot control water hyacinth by themselves, so additional control measures remain needed. Apart from the above-mentioned biological means of control, water hyacinth can be removed physically (manually or mechanically) or killed with herbicides. It should be taken into consideration that chemical control may bring about risks to the environment. The herbicide most commonly used against water hyacinth is 2,4-D (2–5 kg/ha).

Genetic resources and breeding No substantial germplasm collections are known to be maintained.

Prospects Water hyacinth is the subject of extensive research, which bodes well for the development of new applications. Its operational use in the treatment of waste water including sewage effluent, removing both dispersed particles and heavy metals is likely to develop further. Attempts are also being made to combine the water treatment potential of water hyacinth with biogas production. Its role as a green manure, mulch and fodder plant will remain important, mainly in conjunction with its control as a weed.

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A.H. Pieterse

Erythrina fusca Loureiro

Fl. Cochinch.: 427 (1790).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 42$

Synonyms *Erythrina glauca* Willd. (1801), *E. ovalifolia* Roxb. (1832), *E. atrosanguinea* Ridley (1911).

Vernacular names Purple coral-tree, coral bean, swamp immortelle (En). Bucayo (Am). Bois immortelle, immortelle blanc (Fr). Indonesia: cangkring (Javanese, Sundanese), rase, kane (southern Sulawesi). Malaysia: dedap, dadap. Papua New Guinea: maor (Lamekot), vatamida (Ugana). Philippines: anii (Tagalog), korung-korung (Bisaya). Cambodia: roluöhs phâ-'aông. Laos: th'o:ng hla:ng. Thailand: thonglang nam, thonglong (central). Vietnam: v[oo]ng d[oo]ng (Ho Chi Minh City), v[oo]ng gai (Quang Nam), c[aa]y son dong (Annamese).

Origin and geographic distribution *E. fusca* is the most widespread species in the genus *Erythrina* L. occurring wild in both the Old and New World tropics. In Asia and Oceania it occurs along coasts and rivers from India to the Philippines, New Guinea and Polynesia; in Africa in Madagascar, the Mascarene Islands, the Comoro Islands and Pemba Island, but not in continental Africa; in Central and South America in the West Indies, throughout the Amazon basin, and along the coast of Brazil, Colombia, up to Honduras and Guatemala. It is now planted throughout the humid tropics.

Uses *E. fusca* is widely planted as a shade tree in cocoa and coffee plantations in Central and South America and, less frequently, in South-East Asia. In Sumatra and Central America, pepper and vanilla vines are commonly planted with *E. fusca* as live stakes. In Costa Rica, *E. fusca* is occasionally used in live fences, though much less commonly than *E. berteroana* Urban and other *Erythrina* spp. In Central America it is used as a source of fodder.

The young leaves are eaten as a vegetable in Java and Bali, the flowers in Guatemala. In Indonesia the bark is used for poulticing fresh wounds, and bark or root decoctions against beri-beri. Like many *Erythrina* spp. it is often planted for ornamental purposes.

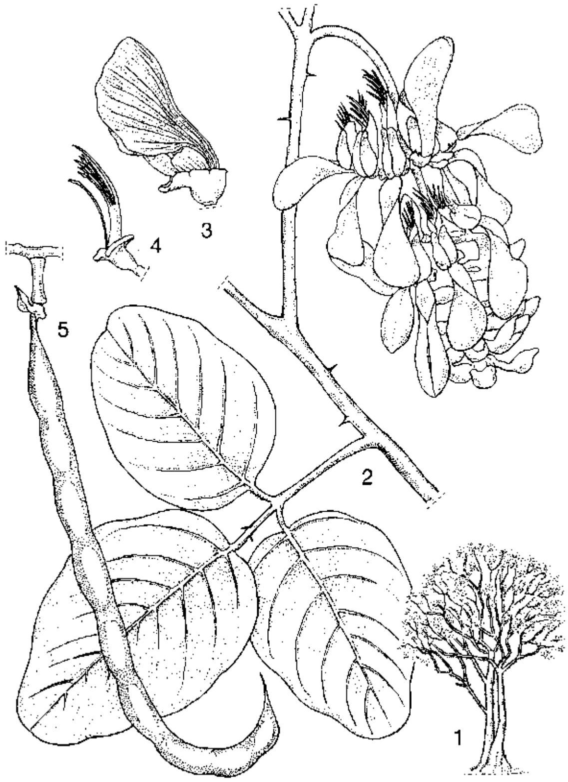
Properties The edible portion of the leaves contains per 100 g dry matter: 20–22 g crude protein; in vitro digestibility ranges from 30–55%. The mineral content of the leaves per 100 g dry matter is: N 3.2 g, P 0.15 g, K 1.0 g, Ca 1.3 g, Mg 0.5 g.

As in other *Erythrina* spp., the seed contains very small amounts of free amino acids and large amounts of alkaloids. In *E. fusca*, only the amino acid histidine occurs in fairly large amounts (0.6–1.0%), which is characteristic of the species. The only common *Erythrina* alkaloids found in *E. fusca* are erysotrine, erythraline, erysodine, erysovine and erysopine. Ant-repellent compounds in the nectar have been reported.

The weight of 1000 seeds is 200–700 g.

The wood is soft with a moderately coarse texture and an unattractive, straight grain. Growth rings are absent, axial and radial parenchyma fairly abundant. The colour of the wood is white to yellow, without differentiation between the heartwood and the sapwood. The average air-dry density ranges from 250–300 kg/m^3.

Description A medium to large, spreading tree, 10–15(–26) m tall, crown rounded; trunk short, spiny (spines 1–2 cm long), much branched, sometimes buttressed to 2 m; bark brownish-grey or olive-brown, flaky. Branches spreading, spiny; branchlets stout, spineless or aculeate. Leaves alternate, trifoliolate; stipules and stipels orbicular, caducous; petiole up to 25 cm long, sometimes sparsely prickly; rachis up to 5 cm long, petiolule up to 1.5 cm; leaflets ovate to elliptical, 2.5–20 cm × 1.5–15 cm, subcoriaceous, rounded or subacute at both ends, pale green above, glaucous or greyish-green beneath, glabrous to velvety hairy. Inflorescence racemose, terminal, appearing when leaves are present, with pale brick-red or salmon (seldom white) flowers in fascicles scattered along the rachis, covered with deciduous, ferruginous hairs, mostly unarmed; peduncle up to 13 cm long; rachis 8–30 cm long; pedicel up to 2 cm long; bracts and bracteoles ovate, up to 2.5 mm × 2 mm, deciduous; calyx asymmetrical, broadly campanulate, about 1.5 cm long, lacerate or subentire but with a 0.5–1.5 mm long spur on the keel side, pubescent; standard rounded-rhombic, 4–7 cm ×



Erythrina fusca Loureiro – 1, habit; 2, flowering branch; 3, flower; 4, flower (petals removed); 5, pod.

3.5–6 cm, reflexed, orange or scarlet, broadly folded down the middle, claw 9 mm long; keel slightly longer than the wings, both about half the length of the standard; stamens 10, 4–6 cm long, 1 free, 9 united in lower half into staminal tube; pistil 4–6 cm long, ovary densely pubescent. Fruit a woody, linear, compressed pod, 14–33 cm × 14–18 mm, dehiscent, slightly constricted between the 3–15 seeds, stipe stout, 1.5 cm long, beak 2 cm long, velvety ferruginously hairy when young, later glabrescent. Seed oblong-ellipsoid, 12–18 mm × 5–8 mm, dark brown or black.

Growth and development Young plants nodulate well under natural conditions. Trees flower when in leaf, and flowers are frequently visited and pollinated by birds. Fruits mature in approximately two months.

Other botanical information Trees nearly devoid of spines exist and have also been bred. Hybridization is frequent where several *Erythrina* species co-occur.

Ecology *E. fusca* is found from sea level up to 2000 m altitude, within a wide range of rainfall patterns, from 1200 mm to over 3000 mm annually, with or without a seasonal distribution. Average daily temperatures range from 16–24°C at the higher elevations to over 26°C in the lowlands. It seems to prefer littoral locations with badly drained soils like swamps and stream banks and upland riverine marshes. In low-lying freshwater swamps *E. fusca* attains huge dimensions and sometimes develops almost pure stands. In an experiment in Cauca, Colombia, on an acid soil of pH 4.3 and an aluminium saturation of 80%, it showed better growth than *Samanea saman* (Jacq.) Merrill and *Delonix regia* (Bojer ex Hook.) Rafinesque, which are considered tolerant of such conditions.

Seeds of *E. fusca* float in water and are dispersed by ocean currents. They have been found on the beaches of cays of the Great Barrier Reef of Australia. *E. fusca* and *E. variegata* L. were among the first species to colonize Krakatau Island (Indonesia), only a few years after the cataclysmic eruption in 1883.

Propagation and planting When used as a shade or nurse tree, *E. fusca* is propagated by large cuttings, about 2 m long and 6–10 cm in diameter. Rooting success is excellent, provided soil moisture is close to field capacity. Cuttings start sprouting in 2–4 weeks. *E. fusca* can also be propagated easily by seed. Fresh seed has a germination rate of 80–95%. In Costa Rica, trees supporting black pepper vines are planted at a density of 1600 trees/ha.

Husbandry Established trees withstand regular pruning very well. They start sprouting rapidly and develop strong shoots. In Mexico, when shading cocoa, *E. fusca* is managed under a moderate regime of pruning. Trees are partially pollarded once every 1–2 years, leaving a few branches per tree to regulate light influx to the crop. In the per-humid, tropical lowlands of Costa Rica, on alluvial soil, a 6-month pollarding cycle is used for trees supporting black pepper vines (*Piper nigrum* L.). Annual dry matter production from prunings of 1600 trees/ha (without natural litter fall) is 3.4 t/ha, corresponding to an N application of 124 kg/ha.

In Bahia, Brazil, it was observed that cocoa trees planted near *E. fusca* produced more pods than those growing further away from the shade trees. Increased litter fall in plantations with *E. fusca* added to the available amounts of N and P in the system, while daily evapotranspiration was reduced from 90 l/tree in unshaded cocoa trees to 40 l/tree in shaded trees on sunny days. On overcast days, the reduction was about 40%, from 45 l/tree to 26 l/tree.

Diseases and pests Under conditions of high relative humidity the bark of *E. fusca* may be attacked by fungi such as *Calostibe striipora*.
In pepper plantations in Sumatra, stakes of *Erythrina* spp. are frequently attacked by stem-borers. The damaged stakes may fall over and the pepper will not produce fruits properly. Two species of borer insects have been found, a stem-borer (*Batocera* sp.) and a ring-borer (family Lecanidae).
In alley cropping, *Erythrina* spp. may act as a host to diseases and pests of the associated crops. In Peru, the use of *Erythrina* spp. in alley cropping has already been discouraged due to an increase of shoot and fruit borers. In India, an increased number of root-knot nematodes (*Meloidogyne incognita*) has been observed in cardamom plantations with *E. fusca*.

Genetic resources A collection of *Erythrina* spp. of over 70 entries has been established at the Waimea Arboretum in Haleiwa, Hawaii. The Tropical Agricultural Center for Research and Training (CATIE) in Turrialba, Costa Rica, maintains a collection of 28 species of *Erythrina*. Both collections include *E. fusca*.

Breeding A breeding and selection programme is in progress at CATIE. Cultivars are being selected for absence of spines, branching habit, biomass characteristics for livestock fodder and capacity to retain their leaves during the dry period.

Prospects *E. fusca* may be of special interest in the development of agroforestry systems for the per-humid tropics, due to its adaptability, ease of propagation from cuttings, ability to withstand regular pruning, and the rapid sprouting and development of shoots. However, diseases and pests should be monitored closely, as they may affect both *E. fusca* and the associated crops. The feasibility of using it as a nurse tree for other tree species in reforestation projects in the tropics is an alternative to be explored.

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R.O. Russo & N.T. Baguinon

Erythrina poeppigiana (Walpers) O.F. Cook

Bull. U.S. Dept. Agric. Div. Bot. 25: 57 (1901).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 42$

Synonyms *Erythrina micropteryx* Poeppig ex Walpers (1850), *Micropteryx poeppigiana* Walpers (1850).

Vernacular names Mountain immortelle, coral tree (En). Bois immortelle (Fr). Poró gigante, bucayo gigante (Sp). Indonesia: dadap. Similar vernacular names often refer to other *Erythrina* spp. as well.

Origin and geographic distribution *E. poeppigiana* occurs naturally in South America, from Venezuela and Panama in the north, throughout the Andean foothills of Colombia, Ecuador, Peru and Bolivia to the western parts of the Amazon basin in the south. It is now extensively planted and naturalized in Central America and the Caribbean. It has been introduced into the humid tropics of the Old World, including South-East Asia.

Uses *E. poeppigiana* is one of the most commonly planted shade trees in cocoa, coffee and pepper plantations in Central America, often planted in combination with the agroforestry tree *Cordia alliodora* (Ruiz & Pavon) Oken. It is valued for its high production of green manure and mulch, the ease with which shade can be adjusted to the requirements of the main crop and its ability to tolerate regular coppicing for many years. It is used occasionally as a shade tree in Indonesia.
It is used less frequently in live fences and as a

shade and forage tree in pastures, e.g. in association with *Cynodon plectostachyus* (K. Schum.) Pilger, *C. nlemfuensis* Vanderyst and *Pennisetum purpureum* Schumach. Leaves are cut for fodder for cattle and goats. Pigs are reported to suffer from hair loss when fed with *E. poeppigiana* loppings.

Seeds and leaves are reportedly used medicinally in the countries of origin. Seeds also yield a fish poison. Like several other *Erythrina* spp., trees are often grown as ornamentals for their bright orange-red flowers. In Colombia, the flowers are eaten in salads and soups.

The wood is of very limited value, even making only poor quality firewood. It is used occasionally for poles and posts, sometimes for vegetable crates, pulp or particle board. Lopped branches have no value as wood.

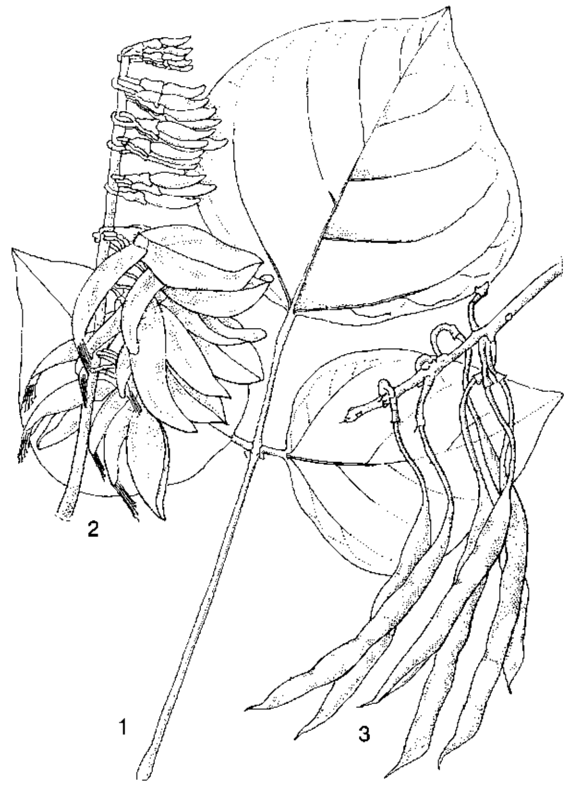
Properties The edible biomass contains per 100 g dry matter (22–)27–34 g crude protein with an in vitro digestibility of 50–80%. Mineral content of prunings per 100 g dry matter is: leaves: N 3.1 g, P 0.24 g, K 1.3 g, Ca 1.6 g, Mg 0.5 g; branches: N 1.2 g, P 0.15 g, K 1.3 g, Ca 1.25 g, Mg 0.4 g. Fallen leaves contain per 100 g dry matter: N 2.2–2.6 g, P 0.14–0.15 g, K 0.5–0.6 g, Ca 1.9–2.2 g, Mg 0.5–0.7 g. Branches in natural litter contain per 100 g dry matter: N 1.3 g, P 0.1 g, K 0.7 g, Ca 2.0 g, Mg 0.7 g. Mineral content is influenced by the pruning regime. Frequent pruning increases the proportion of leaves and the N content of the loppings.

Like other *Erythrina* spp., *E. poeppigiana* contains curare-like alkaloids with a muscle relaxant or paralysing action and uncommon, non-protein amino acids assumed to have insecticidal properties. The alkaloids have been subject of extensive pharmaceutical tests. Species can be identified by the alkaloid profile of the seeds. *E. poeppigiana* contains erysotrine and its derivatives erythratidine and erythroidine. These alkaloids are not poisonous to ruminants in the quantities present in normal rations.

The wood is characterized by abundant thin-walled, axial and radial parenchyma. It is soft, light in weight (specific gravity 250 kg/m^3), whitish to yellowish. Heartwood can not be distinguished from sapwood. Large vessels, the prominent rays and parenchyma bands are easily visible using a hand lens.

The seed weight of 100 seeds is 15–30 g.

Description A sometimes multi-stemmed, deciduous, often spiny tree with spreading crown, up to 25 m tall and 1.2 m in trunk diameter; when cultivated it is generally kept small, by cutting the



Erythrina poeppigiana (Walpers) O.F. Cook – 1, leaf; 2, inflorescence; 3, infructescence.

stem to 2–2.5 m. Bark greenish-brown to grey-brown, nearly smooth or slightly furrowed, warty or spiny. Twigs stout, spiny, light green and puberulous when young, becoming greenish-grey, with raised leaf scars. Leaves alternate, trifoliolate, thin-chartaceous, often scabrous beneath, glabrescent; petiole 10–40 cm long; rachis up to 30 cm long, with cup-like stipellar, nectar-producing glands at the base of lateral leaflets; petiolules up to 1.5 cm long; leaflets ovate to rhombic, terminal one 8–30 cm × 5–30 cm. Inflorescence an axillary raceme, borne horizontally at distal end of shoots, densely and finely tomentellous; peduncle 4–8 cm long; rachis 7–40 cm long; pedicel 0.5–1.2 cm long, very finely tomentellous or puberulent; bracts and bracteoles ovate, up to 1.3 mm × 0.8 mm; calyx campanulate, 5–10 mm long and wide, orange to reddish at the top, entire but with 2 mm long spur on keel side; standard elliptical, 3–5 cm × 1.5–2.5 cm, bright orange, erecto-patent or slightly recurved, claw 1.5 mm long; wings spatulate to obovate, 7–14 mm × 3–6 mm; keel falcate, 3–5 cm × 0.5–1 cm; stamens 10, 1 free, 9 tubular connate at base, 3–5 cm long, separate for 0.5–1 cm; pistil up to 5 cm long, with linear, puberulent ovary and filiform style. Pod 13–25 cm × 1–1.5 cm, chartaceous, not constricted between seeds, stipe 3–4 cm long, beak 4–8 mm. Seed oblongoid to ellipsoid to slightly reniform, 10–17 mm × 5–7 mm, glossy-brown, without markings.

Growth and development Mature seed germinates readily. The germination rate is 60–90%, decreasing with storage time. Under favourable conditions, seedlings attain 60–85 cm height and a basal diameter of 2–3 cm in 4 months. In 6 months, trees can attain a height of 4–5 m and develop a crown of 3–4 m diameter with up to 15 branches.

The growth of the tree follows the architectural model of Attim. The main and lateral shoots display indeterminate growth. Most mature trees shed their leaves early in the dry season. Leaf abscission is generally followed by flowering. Flowers open acropetally on newly formed lateral inflorescences at the distal ends of shoots. Fruits develop on leafless trees, maturing in about 2 months, and new shoots emerge during or after fruit maturation. However, this development may be asynchronous within the crown of large trees; on upper branches leaves may abscise and flowers may develop, while lower branches retain their leaves. Trees in some areas shed their leaves again at the end of the wet season, but this leaf fall is not followed by a flush of flowers. Where a dry season is absent, trees are never bare and flower when in leaf. Near the equator trees may flower twice a year. The processes of leaf and flower development seem to be controlled by internal moisture conditions. The increased availability of moisture immediately after leaf fall has been suggested as a stimulus for flowering.

E. poeppigiana is capable of atmospheric nitrogen fixation by nodulation with *Bradyrhizobium*. Successful inoculation has been obtained with strain CIAT 71. Nodulation starts early and plantlets may contain up to 80 nodules 3 months after sowing. Nodules are 1.5–10 mm in diameter, spherical and clustered on the central root system at the point of emergence of lateral roots. They occur only in the top 10–12 cm of the soil, mainly in the area under the crown of the tree. The biomass of the root nodules varies from 80–250 mg dry matter per dm^3 soil and is largest close to the stem.

Pollarding affects nitrogen fixation of the trees. Some of the root nodules and part of the root system disintegrate after the tree has been pruned. New roots and nodules form when the development of new foliage is well under way.

Other botanical information The species of *Erythrina* L. can, as far as is known, all be intercrossed to produce fertile hybrids.

E. poeppigiana is pollinated by many non-specialized perching or sparrow-like birds. The amount of nectar in the flowers may reach 50 μg per flower and is so great that insects would visit too few flowers to be effective distributors of pollen.

Ecology In cultivation, *E. poeppigiana* can adapt to a wide range of conditions. It is found from (0–)500–1500(–2000) m above sea level in the tropics with annual rainfall ranging from 1200–3000 mm, with a period of up to 6 months of reduced rainfall. Average annual temperatures may vary from 18–28°C. Above 2000 m altitude, trees become blanketed with epiphytes and stunted, but may survive up to 2400 m.

It will grow on a wide range of soils, from heavy clay to medium loam, ranging from acid to alkaline, but very acid soils are not tolerated.

Trees are resistant to fire, including controlled burning.

Propagation *E. poeppigiana* is sometimes propagated by seed, suckers or air layering, but farmers usually propagate it by large stem cuttings, 2–2.5 m long and 8–12 cm in diameter, readily obtainable from 2-year-old branches. Sprouting starts within a month after planting, and in 4–6 months the new trees start shading coffee seedlings. Rooting success varies from 70–90%. Methods of in vitro propagation are being developed.

Husbandry Established shade trees in coffee or cocoa plantations are normally completely or partially pollarded once or twice a year. Timing and intensity of pruning can be adjusted to prevailing conditions and the requirements of the associated crop. In coffee plantations, trees are usually pruned prior to flowering and again before ripening of the crop, or at the beginning of the long and the short rainy seasons. Additional pruning is sometimes carried out during prolonged periods of extremely cloudy weather. To maintain a low shade canopy the calloused trunk tip is sawn off every 5–6 years. Trees tolerate pollarding well and can be treated this way for many years.

E. poeppigiana produces large quantities of prunings and litter. Planted at a density of 280 trees per ha in a coffee plantation under experimental conditions in Costa Rica, pollarding once a year produced 18.5 t dry matter per ha of prunings and

4.3 t dry matter per ha of natural litter. Of the prunings 3.2 t were leaves, 15.2 t were branches. When pollarded twice a year, annual dry matter production fell to 11.8 t/ha of prunings and 1.9 t/ha of natural litter. Three prunings per year resulted in an annual dry matter production of 7.9 t/ha of prunings, consisting of 4.3 t of leaves and 3.5 t of branches. No natural litter fall occurred under the latter pruning system, as the life span of leaves exceeds 4 months. Prolonging the pruning interval thus results in a greatly increased production of branch wood and a gradual decrease in the production of leaves. Leaf production of the associated coffee crop is also larger than in coffee grown without shade. In cocoa plantations with a similar density of *E. poeppigiana* comparable amounts of prunings and litter are found.

The amounts of nutrients recycled in the prunings are considerable and mostly match fertilizer recommendations for intensively managed coffee. In the pollarding experiment mentioned, annual pollarding resulted in contributions per ha of 330 kg N, 32 kg P, 156 kg K, 319 kg Ca, 86 kg Mg. When pollarding three times per year annual contributions per ha were: 173 kg N, 14 kg P, 119 kg K, 94 kg Ca, 27 kg Mg. Amounts for pollarding twice a year were intermediate. Although considerable amounts of nutrients are recycled, large quantities are immobilized in the stems as well. The total amount of available P in the soil and the litter layer may actually diminish under *E. poeppigiana*. However, when trees are pollarded 2 or 3 times per year, most of the stored nutrients are recycled. It was found that most of the nitrogen recycled was taken up from the soil. N balance studies indicate that up to 60 kg atmospheric N per ha may be assimilated annually, even when the crop receives mineral N fertilizer. This is comparable to several other woody legumes, but less than the quantities reached by *Leucaena leucocephala* (Lamk) de Wit.

There is little information on the durability of the mulch layer. Studies indicate that 50% of the organic matter decomposes within 1 month and 75% in 6 months. The decomposition of organic material may cause the pH to decline in certain soils, which may result in increased leaching of K, Ca and Mg.

The high production of organic matter in prunings results in an increase in soil organic matter. In a ten-year experiment with *E. poeppigiana* and cocoa, the soil organic matter increased from a relatively high initial amount of 200 t/ha to 240 t/ha. This contributes to very low levels of leaching of minerals, comparable to those in natural or planted forests.

Neither the intensity nor the effects of the shade of *E. poeppigiana* have ever been measured systematically and directly.

In long-term trials with maize (*Zea mays* L.), grown in the rainy season, followed by a dry season crop of common bean (*Phaseolus vulgaris* L.), both crops showed considerable yield increases in response to an annual mulch of 20 t/ha of *E. poeppigiana* prunings. The N utilization by the crops was somewhat less efficient than with mineral N fertilizer. The cut-and-carry mulch system was superior to an alley-cropping system with the same crops. The yield advantages were smaller in the alley-cropping system. An economic analysis of the systems showed the cut-and-carry system to be more profitable in spite of the high labour requirements. Cassava (*Manihot esculenta* Crantz) yields could not be maintained, either in the mulch system or in the alley-cropping system.

E. poeppigiana has been tested as shade and forage tree with a number of grasses, e.g. king grass (a hybrid of *Pennisetum purpureum* and *P. glaucum* (L.) R. Br.) and *Cynodon nlemfuensis*. Yields of the grasses were not reduced and sometimes even increased under *E. poeppigiana*. The protein content increased. However, after a few years, yields started to decline because of the large loss of nutrients caused by removing cut grass and *E. poeppigiana* loppings. Leaves of *E. poeppigiana* are readily accepted by livestock and may increase the amount of feed ingested and milk produced.

Diseases and pests *E. poeppigiana* is not seriously affected by diseases or pests. It is termite resistant even when regularly pollarded.

Genetic resources The Nitrogen Fixing Tree project maintains a collection of 28 species and about 75 accessions of species commonly used in Costa Rica at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba. Another large collection of species of *Erythrina* is maintained in the Waimea Arboretum, Haleiwa, Hawaii.

Breeding At CATIE, Turrialba, selections have been made on the basis of desirable characteristics such as absence of spines, branching habit, capacity to retain leaves during the dry season and value as forage crop. Selection trials are still in progress. As the selections used in Central America seem to be derived from a very limited number of introductions, there is ample scope for including genetic materials from the regions of origin.

Prospects Its fast growth, ability to produce large amounts of biomass and to fix atmospheric nitrogen, ease of propagation from cuttings, excellent response to pruning and high content of crude protein mean that *E. poeppigiana* has excellent potential for various agroforestry practices not only in Central America but throughout the humid tropics. It plays a central role in agroforestry and alley-cropping research work at CATIE, Turrialba, Costa Rica. Besides its role as shade tree, it fits in well in alley cropping with annual crops and pasture grasses. Its productivity and the good digestibility of its protein make it a promising forage crop. The low value of the wood is compensated by other qualities.

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L.P.A. Oyen

Erythrina subumbrans (Hassk.) Merrill

Philip. J. Sci. Bot. 5: 113 (1910).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 42$

Synonyms *Erythrina lithosperma* Miquel (1855), *Hypaphorus subumbrans* Hassk. (1858), *Erythrina hypaphorus* Boerl. (1899).

Vernacular names December tree (En). Indonesia: dadap duri (general), dadap rangrang (Sundanese), dadap ri (Javanese) (armed forms); dadap minyak (general), dadap lesang (Sundanese), dadap lenga (Javanese) (thornless forms). Malaysia: dedap batik, cengkering. Papua New Guinea: dadap. Philippines: dap-dap (Tagalog), rarang (Bikol), anii (Bisaya). Burma (Myanmar): ye-katit. Laos: th'o:ng hla:ng. Thailand: thonglang-pa (northern), thong-lang (central).

Origin and geographic distribution *E. subumbrans* occurs naturally from India and Sri Lanka, throughout South-East Asia (except New Guinea) to Fiji and Samoa. Now it is distributed throughout the tropics.

Uses *E. subumbrans* was one of the most widely planted shade trees for coffee and other crops in Indonesia, until large numbers of trees were destroyed by a root disease in the late 19th Century. It is still planted on a smaller scale in Indonesia for shade in cocoa, coffee and tea plantations, and as live support for betel (*Piper betle* L.), pepper (*Piper nigrum* L.) and vanilla (*Vanilla planifolia* H.C. Andrews) vines. In Malaysia, it is used as a shade tree for coffee and tea; in Western Samoa, as a shade tree for cocoa and taro (*Colocasia esculenta* (L.) Schott) and as a live support for yams (*Dioscorea* spp.). In Burma (Myanmar) and India, it is often grown to support betel and pepper vines. In Sri Lanka, it is the most common shade tree for tea and cocoa.

Very young leaves are steamed and eaten in salads in Java.

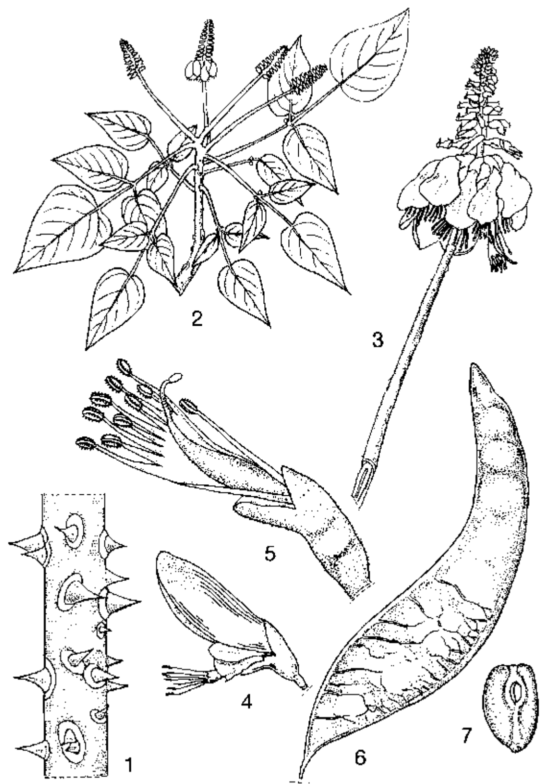
The leaves are a good and palatable fodder but if eaten by rabbits it can cause sterility and death. In Western Samoa, an addition of 5% leucaena meal and 5% dried and ground dadap meal to the starter diets of chicken improved their gains in weight.

Bark and leaves are used medicinally, sometimes mixed with parts of other plants. A decoction of the bark is taken to treat spleen afflictions in the Philippines. In Indonesia pounded young leaves are used as a poultice for women soon after giving birth and against headache; juice of leaves is used as an eye-wash and a decoction of the leaves is

given for coughs.
The wood is utilized in canoe and raft building. In Papua New Guinea, trees are planted near villages for their showy red flowers, while in certain districts (e.g. Morobe) they are used in ritual ceremonies.

Properties Loppings of *E. subumbrans* provide a quickly decomposing green manure, containing per 100 g dry matter: N 1.5–3 g, P 0.2–0.35 g, K 1–2 g. Flowers contain large quantities of nectar and are a major source of food for birds during the dry season in East Java. Seeds contain the curare-like alkaloids erysoline, erysopine and erythratine.
The wood of *E. subumbrans* is soft and light, with an air-dry density ranging from 335–385 kg/m^3. The sapwood is not differentiated from the heartwood, which is light straw-coloured. Texture is coarse and uneven due to the presence of broad rays and abundant confluent parenchyma conspicuous to the naked eye. Grain is straight, shallowly interlocked or spiral. Growth rings are absent. Vessels are about 310 μm in diameter, few, solitary, in radial groups of 2 to 3.

Description A deciduous, medium-sized tree, 5–25 m tall, trunk reaching 60 cm in diameter; crown spreading; bark whitish; trunk and branches armed with stout prickles, in cultivation mostly unarmed. Leaves alternate, trifoliolate; stipules orbicular, small, caducous; rachis 10–21 cm long, inclusive of the petiole of 8–16 cm which is thickened at the base; petiolule up to 7 mm long; stipels 2, below the lateral leaflets, stipitate, cup-like, glandular, 2 mm long; leaflets ovate-triangular-rhomboid, terminal one largest and 8–16 cm × 6–14 cm, base rounded or cordate, apex acuminate, glabrous. Inflorescence racemose, in the upper leaf axils, 5–23 cm long, brownish-tomentose; flowers many, arranged in groups of 3; peduncle terete, robust, 3–15 cm long, pubescent; pedicel 2–3 mm long, in fruit up to 6 mm; calyx campanulate, 1–1.5 cm long, splitting open up to halfway down, tomentose, yellow-green; petals 5, red; standard broadly elliptical, shortly clawed, 2.5–4 cm × 2–3 cm, scarlet, at base inside with numerous white stripes; wings as long as the keel or slightly longer, about 1.5 cm long, pale red with a blackish upper margin; stamens 10, 3–3.5 cm long, monadelphous but vexillary stamen slightly shorter than other ones and only connate for the lower 0.5–1 cm, pinkish red; pistil with hairy ovary. Pod flat, curved, 10–15 cm long, on a slender stalk 3–4.5 cm long, lower part seedless and 2–2.5 cm wide, upper part thicker, 1–1.5 cm wide and 1–5-



Erythrina subumbrans (Hassk.) Merrill – 1, part of prickly branch; 2, flowering branch; 3, inflorescence; 4, flower; 5, flower (petals removed); 6, pod; 7, seed.

seeded, septate between the seeds, dehiscent. Seed ellipsoid, 7–18 mm × 5–11 mm, smooth, dull black.

Growth and development *E. subumbrans* forms large numbers of effective root nodules. In Singapore it flowers from October to December during the height of the wet season. In Java, flowering and fruiting occur almost throughout the year, with peaks in February–March and October–November. Thornless forms generally produce fewer flowers and fruits than the armed, wild ones. As in other *Erythrina* spp., the red, odourless, nectar-rich flowers are so constructed that cross-pollination is universal. Pollination is by birds which feed on the abundant nectar.
Some of the leaves are shed during the dry season. However, in Java, trees are never completely leafless. Pruning before the start of the dry season can prevent leaves being shed during the dry season. Cultivated thornless forms may reach an age of 40–50 years but often die earlier because of dis-

eases and pests.

Other botanical information Most *Erythrina* spp. are ecologically separated, even when occurring in the same geographical region. Hybrids, however, occur frequently in cultivation, as there appear to be no barriers to interspecific hybridization. An unarmed hybrid between *E. subumbrans* and *E. variegata* L., named 'dadap Solo', probably originated near Surakarta in Java, and is widely planted. It is shorter than other unarmed forms of *E. subumbrans*, has a denser crown and rarely produces viable seed.
The necklace-shaped pods of *E. subumbrans* are highly characteristic and can be used to identify the species.

Ecology *E. subumbrans* occurs at low and medium altitudes, from (0–)300–1500 m, in moist valleys, near streams, in open locations and secondary forest. It requires a high annual rainfall with a maximum of 4 months with less than 100 mm rainfall, and a mean annual temperature above 22°C. It is reported, however, to occur gregariously on the Ijen plateau in East Java, in open grassland in stony or sandy, occasionally dry places; elsewhere it is widely dispersed. The trees are fairly tolerant of wind, unless branches have been damaged by borers. Seeds are dispersed by water and occasionally by birds.

Propagation and planting *E. subumbrans* grows easily from large cuttings, even if they are 25 cm in diameter. It can be propagated by seed, but seedlings of thornless trees are generally armed. The spacings employed depend on the spacing of the main crop, pruning regime, and growth rate of the trees. In Western Samoa, a spacing of 1.5 m × 1.5 m is used in cocoa, 2 m × 2 m when planted as a shade for taro.

Husbandry Pruning and pollarding are very well tolerated. In tea plantations in Sri Lanka it is customary to pollard twice a year. In coffee and tea plantations in Java, pruning is generally done once a year. The frequency of lopping depends on the requirements of the main crop, the labour supply and the growth rate of the trees and can be up to 4 times per year. However, mortality may occur if pruning is followed by a prolonged dry spell. Where *E. subumbrans* is pruned, it is sometimes used as a medium level shade tree, interplanted with taller shade trees like *Paraserianthes falcataria* (L.) Nielsen or *Grevillea robusta* Cunn. ex R. Br. Elsewhere, *E. subumbrans* is not pruned and is used for high shade, interplanted with *Leucaena leucocephala* (Lamk) de Wit providing low shade. In Western Samoa, yam vines planted in a circle around an *E. subumbrans* tree are allowed to cover the canopy and suppress its growth.

Diseases and pests At the end of the 19th Century in Java, *E. subumbrans* was heavily attacked by a root disease, which locally destroyed all trees and prevented its further planting. Little has been published about this disease, its cause and importance today.
The fungus *Septobasidium bogoriense* often grows on the bark. It does not cause direct damage, but keeps the bark moist, creating favourable conditions for pathogenic fungi like *Corticium salmonicolor*, *Fomes* spp., and *Ustulina zonata*.
Several boring insects attack the wood and bark of branches, often causing them to break and making them susceptible to rot. The leaves of *E. subumbrans* are damaged by many insects and defoliation is common. Normally, the trees recover rapidly.

Prospects Where *E. subumbrans* is not too seriously affected by diseases and pests, it is one of the best shade and live support trees for a wide range of crops. It is fast growing, fixes atmospheric nitrogen, provides easily decomposing litter and its shade can be well adjusted to the requirements of the main crop. A programme for the selection of disease-tolerant cultivars would be well justified. Its neat appearance makes it a good ornamental and amenity tree.

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Umi Kalsom Yusuf

Erythrina variegata L.

Herb. Amb.: 10 (1754); Amoen. acad. 4: 122 (1759).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 42, 44$

Synonyms *Erythrina indica* Lamk (1786), *E. orientalis* (L.) Murr. (1787), *E. variegata* L. var. *orientalis* (L.) Merrill (1917).

Vernacular names Indian coral tree, variegated coral tree (En). Indian coral bean (Florida), tiger's claw (Am). Arbreau corail, arbre immortel (F). Indonesia: dadap blendung (Sundanese), dadap ayam, (Javanese), dede bineh (Madurese). Malaysia: dedap, cengkering. Papua New Guinea: balbal (Kuanua, Pala), valval (Lamekot), banban (Ugana). Philippines: karapdap (Tagalog), andorogat (Bikol), bagbag (Ilokano). Burma (Myanmar): penglay-kathit. Cambodia: roluöhs ba:y. Laos: (do:k) kho, th'o:ng ba:nz. Thailand: thong baan, thong phueak (northern), thong laang laai (central). Vietnam: c[aa]y v[oo]ng nem, h[af]i d[oof]ng b[if] (Annamese), dan ro, (Thuân Hai).

Origin and geographic distribution *E. variegata* is a native of the coastal forests from East Africa, the Indian Ocean Islands, from India, throughout South-East Asia, to the Pacific Islands and the Northern Territory and Queensland in Australia. It has been in cultivation throughout the tropics for so long that its original dispersal as a beach species is now obscure.

Uses In India, Malaysia and Indonesia *E. variegata* is used as live support for betel (*Piper betle* L.), black pepper (*Piper nigrum* L.), vanilla (*Vanilla planifolia* H.C. Andrews) and yam (*Dioscorea* spp.) vines. When planted as a live fence the more prickly forms are best. In southern India, it is occasionally grown as a shade tree for cocoa and coffee; in Java it is not recommended for this purpose as it is leafless for up to a few months per year. A columnar cultivar is planted in hedges as a windbreak. The leaves are used as green manure and to a limited extent as fodder.

Boiled leaves are eaten as a pot-herb. The raw seeds are poisonous but may be eaten after boiling or roasting.

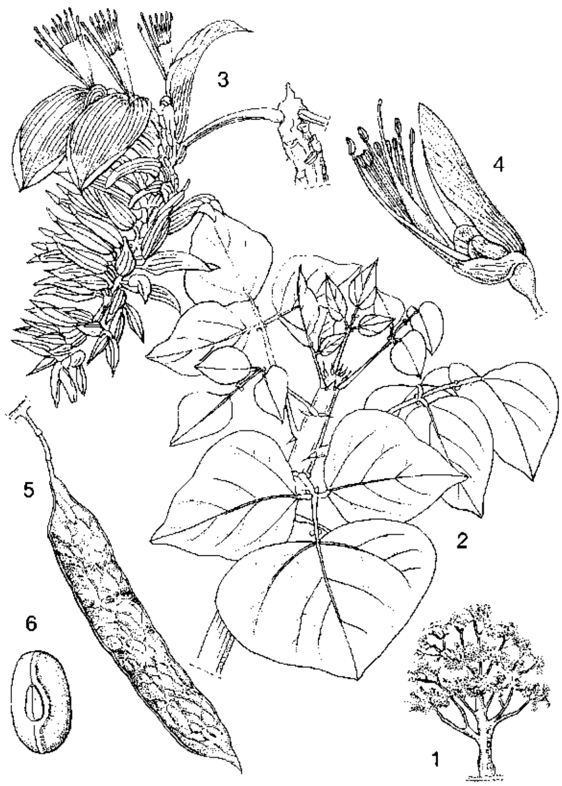
The leaves and bark are widely used as cures in many South-East Asian countries. The bark is used as an antipyretic in Burma (Myanmar), in decoction to treat liver problems in China and intermittent fever in Indonesia. A decoction of the bark and leaves is used to treat dysentery in Indonesia; sweetened, it is considered a good expectorant. A decoction of the leaves may also be used to treat mastitis. The bark has also been used to treat rheumatism and to relieve asthma and coughs. The roots and leaves are often employed to alleviate fever in the Philippines. Crushed seeds are used to treat cancer and abscesses in Indo-China, and are boiled in a little water as a remedy for snake bites in Malaysia. In India, the root and bark are called 'paribhadra', one of the reputed drugs of Ayurvedic medicine.

The wood is of little use, even as firewood, but can be turned into packing-cases. In New Britain, it is used for spears and shields. The wood has been tested as a source of pulp for the paper industry. The fibre is acceptable for pulping, having good length, high flexibility and slenderness ratio and low Runkel's ratio. The light, spongy wood is used in Cambodia as floats for fishing-nets. *E. variegata* is also planted as an ornamental tree, the leaves of the variegated forms and the flowers being very showy. In New Britain, blackened dried leaves are worn for their scent.

Properties Leaves of *E. variegata* contain per 100 g dry matter 1.5 g N, 1.5 g K, and 0.15 g P. Leaves and seeds have narcotic properties. Alkaloids are present in low concentrations. Seeds contain hypaphorine, erysodine, and erysopine, the leaves and bark the poison erythrinine, acting on the nervous system. Saponins are present in leaves, bark and seeds. Hydrocyanic acid has been found in the leaves, stems, roots, and fruits. The seed contains 0.75% of the free amino acid histidine, an amount only paralleled by *E. fusca* Loureiro.

The wood is white and soft, spongy, fibrous and darker towards the centre. Growth rings are visible. The density of the wood is 300 kg/m^3.

Description Deciduous tree, 3–27 m tall with fluted bole and much branched crown; trunk and



Erythrina variegata L. – *1, habit; 2, leafy branch; 3, inflorescence; 4, flower; 5, pod; 6, seed.*

branches thick and sappy, armed with large, scattered prickles; bark grey or grey-green, furrowed; young shoots stellate pubescent at first, later glabrous; flowering branches often leafless; in cultivation tree often unarmed. Leaves alternate, trifoliolate; stipules lanceolate, 1–1.5 cm long, caducous; petiole 2–28 cm long, unarmed; rachis 10–12 cm long; petiolule up to 1.5 cm long, at base with globose glandular stipels; leaflets ovate to broadly rhomboid, usually wider than long, 4–25 cm × 5–30 cm, terminal one largest, base rounded or slightly cordate, apex acuminate, entire or sometimes shallowly lobed, thinly coriaceous, green or sometimes strikingly variegated light green and yellow, glabrescent. Inflorescence an axillary, dense raceme 10–40 cm long, ferruginous tomentose, lateral near the top of branchlets; peduncle 7–25 cm long; pedicel up to 1.5 cm long; flowers in groups of 3 scattered along the rachis, large, bright red (occasionally white); calyx eventually deeply spathaceous, 2–4 cm long, glabrescent, red; standard ovate-elliptical, 5–8 cm × 2.5–3.5 cm, more than twice as long as wide, shortly clawed, longitudinally conduplicate, recurved, bright red without white veins; wings and keel subequal, 1.5–2.5 cm long, red; stamens 10, monadelphous, 5–7 cm long, vexillar stamen basally connate with the tube for 1 cm, red; pistil with pubescent ovary and glabrous style. Pod sausage-shaped or long cylindrical, 10–45 cm × 2–3 cm, 1–13-seeded, slightly constricted between the seeds, glabrescent, distinctly veined and exocarp bursting irregularly, indehiscent. Seed ellipsoid to reniform, 6–20 mm × 5–12 mm, smooth, glossy black, purplish or purplish red-brown.

Growth and development *E. variegata* can live to about 100 years. Unpruned trees may attain a height of 15–20 m in 8–10 years. Subsequently, the growth rate slows down, but the main stem continues to increase in diameter. *E. variegata* forms root nodules and fixes atmospheric nitrogen with *Bradyrhizobium* bacteria. In general, rooting is superficial, with most roots in the upper 30 cm of the soil; older trees, however, root deeper.

Other botanical information *E. variegata* has the typical 'bird flowers' of *Erythrina* spp.: scentless, strong and elastic to withstand birds hopping about and poking into the flowers. The flowers in the drooping inflorescences are upturned, which prevents the copious nectar from running out. The flowers remain open for 2–3 days, but stop secreting nectar after the morning of the first day.

Forms with variegated leaves have been classified as botanical varieties; subclassification of the species, however, seems most appropriate at the cultivar level. A cultivar with a columnar habit has been selected. It possibly originated in New Caledonia, from where it spread to other tropical and warm temperate areas, including Hawaii and Florida. It was released in the United States in 1985 as cv. Tropic Coral.

Ecology *E. variegata* is adapted to coastal forests, but is frequently cultivated inland, up to 1200 m altitude. Annual rainfall should exceed 1250 mm. The mean minimum temperature should be about 20°C, the mean maximum temperature about 32°C. As in *E. fusca*, the seeds float and are dispersed by ocean currents.

Propagation and planting *E. variegata* is usually propagated from large cuttings, 2–3 m long and 5–8 cm in diameter, to ensure that new shoots are above grazing height and to allow fast early growth. Branch cuttings with the terminal bud are sometimes used in India to obtain tall, straight-stemmed trees. Propagation by seed is also possible. Seed germinates in 8–10 days, attaining a transplantable height of 30–50 cm in 8–10 weeks.

In India, a spacing of 8–10 m is used when planting *E. variegata* for shade in coffee plantations; spacing of live stakes for betel and pepper is 2–3 m × 2 m.

Husbandry When trees are used to support vines, side branches are lopped at intervals of 6–8 weeks, the foliage being used as green manure or fodder. When planted for shade, lower branches are removed immediately after establishment and only a few high branches are allowed to grow. Subsequently, the trees are pollarded once per year in the middle of the rainy season.

Diseases and pests In Hawaii the trees are attacked by powdery mildew (*Oidium* sp.), Chinese rose beetle (*Adoretus sinicus*), mealy bugs (*Phenacoccus* spp.), mites (*Tetranychus cinnabarinus* and *Polyphagotarsonemus latus*). Like other *Erythrina* spp., it is a potential host of the fruit-piercing moth (*Othreis fullonia*), the hibiscus snow scale (*Pinnaspis strachani*), and the carob moth (*Ectomyelois ceratoniae*) as well as of their predators. In India, larvae of the beetle *Raphipodus* damage the roots.

Yield Yields depend on the pruning system. In India, trees used as support for betel vines yield 15–50 kg fodder per year; shade trees in coffee plantations produce about 100 kg fodder and 25–40 kg wood per year.

Genetic resources and breeding *E. variegata* is included in the *Erythrina* germplasm collection at Waimea, Hawaii. No breeding programmes are known to exist.

Prospects *E. variegata* is useful as a live fence and source of fodder. It is also a handsome ornamental. It may be used as raw material for the pulp wood industry. Its medicinal value needs further investigation.

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B. Na-songkhla

Eucalyptus camaldulensis Dehnh.

Cat. pl. horti camald., 2nd ed.: 6, 20 (1832).

MYRTACEAE

$2n = 22$

Synonyms *Eucalyptus rostrata* Schlechtendal (1847).

Vernacular names River red gum, Murray red gum, red gum (En). Indonesia: ekaliptus. Cambodia: pré:ng khchâl' slök sâ:. Thailand: yukhalip. Vietnam: b[aj]ch d[af]n [us]c.

Origin and geographic distribution *E. camaldulensis* is the most widely distributed eucalypt. Its natural distribution area covers most of the Australian mainland, ranging from 12°48'S in the tropical Northern Territory to 38°15'S in cool, temperate Victoria. *E. camaldulensis* is planted in many tropical and subtropical countries and is probably the world's most widely planted tree in arid and semi-arid lands. It is naturalized in many areas.

Uses *E. camaldulensis* is one of the main forestry species for seasonally dry sites in South-East Asia. It is widely planted for shade, shelter and amenity purposes and as a source of nectar to produce high quality honey. Wood of planted *E. camaldulensis* is used mainly for firewood, charcoal, poles, posts and paper pulp. It is also used for hardboard, fibreboard and particle board. Logs may be sawn for construction timber (especially for bridges, wharves and ships), railway sleepers, furniture, flooring and packing cases, although the quality is sometimes poor. The bole has potential as a substrate for shiitake mushroom (*Lentinus edodes*) cultivation and yields a gum which can be used as a dye. Some tropical provenances produce eucalypt oil suitable for medicinal purposes.

Production and international trade In addition to extensive but largely unrecorded small-scale plantings worldwide for fuelwood, shade and shelter, over 500 000 ha of plantations had been established by the mid-1970s, mainly in the Mediterranean region using provenances from southern Australia. This figure has now probably doubled due to better adapted provenances from northern Australia being planted in tropical areas.

Wood production for domestic consumption is substantial. Wood chips for paper production are exported by several countries in South-East Asia, but statistics for domestic consumption and exports are lacking.

Properties Some tropical provenances of *E. camaldulensis* (e.g. 'Petford') are rich in 1,8-cineole leaf oil and are potential commercial sources of medicinal-grade eucalyptus oil.

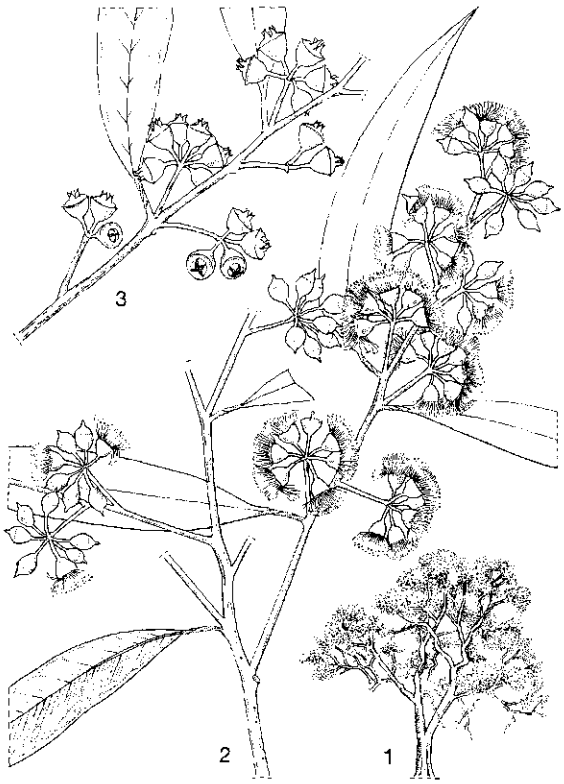
The medium-weight to heavy timber is hard and durable. The heartwood has a handsome red colour, turning red-brown upon exposure, and is clearly demarcated from the paler sapwood, which is 50–75 mm wide. The texture is moderately coarse, the grain interlocked, straight or wavy, often producing an attractive figure. The density is 700–980 kg/m^3 at 12% moisture content, with samples from natural forest having the higher densities. Density of plantation-grown *E. camaldulensis* varies with age, the provenance used and planting site, but does not appear to be closely correlated with rate of growth. Density is positively correlated with charcoal and pulp yield. Provenances from tropical northern Queensland (e.g. 'Petford') produce wood with the highest density and thus the highest yields of charcoal and pulp.

Mechanical properties of samples from Australia at 12% moisture content are: modulus of rupture 101 N/mm^2, modulus of elasticity 11 180 N/mm^2, compression parallel to grain 55 N/mm^2, shear 15 N/mm^2, cleavage 89 N/mm radial and 98 N/mm tangential, Janka radial hardness 9745 N, Janka tangential hardness 9525 N and Janka end hardness 10 415 N. The timber is easy to saw despite its high density, and mature material can be seasoned with little degrade. The rates of shrinkage are high: from green to 12% moisture content: 4.4% radial and 8.9% tangential.

The heartwood is resistant to termites, but the sapwood is susceptible to attack by *Lyctus* borers. Preservation is necessary if the timber is to be used in contact with the ground; the heartwood is extremely resistant, the sapwood is permeable to preservatives.

The wood of plantation-grown *E. camaldulensis* often has unfavourable characteristics such as growth stresses, shrinkage on drying, collapse, spiral grain and starch in the sapwood. Its durability is less than that of trees in natural stands in Australia. Careful post-harvest procedures can ameliorate this. The energy value of the wood is 21 000 kJ/kg. One kg of seed and chaff contains 700 000–800 000 viable seeds, the chaff being ten times heavier than the seed.

Description Tree, commonly up to 20 m tall, occasionally reaching 50 m with a trunk diameter of 1(–2) m; in open formations with a short, thick bole and a large, spreading crown; in plantations, with a clear bole of 20 m with an erect, lightly-branched crown. Bark smooth, white, grey, yellow-green, grey-green or pinkish grey, shedding in strips or irregular flakes; rough bark may occupy the first 1–2 m of the trunk. Leaves alternate, petiolate, pendulous, (narrowly) lanceolate, 8–30 cm × 0.7–2.0 cm, acuminate, evenly green or grey-green; petiole terete or channelled, 12–15 mm long. Inflorescence an axillary, simple, umbelliform, condensed and reduced dichasium called a conflorescence; umbels solitary, 7–11-flowered; peduncle slender, terete or quadrangular, 6–15 mm long; pedicel slender, 5–12 mm long; flowers regular, bisexual; flowerbuds globular-rostrate or ovoid-conical, divided into a calyx tube or hypanthium (lower part) and the operculum (upper part) which is shed at anthesis; hypanthium hemispherical, 2–3 mm × 3–6 mm; operculum hemispherical, rostrate (northern provenances) to conical (southern provenances), obtuse, 4–6 mm long; stamens numerous, on a staminophore. Fruit a dry thin-walled capsule enclosed in a woody hypanthium, opening with 3–5 strongly exserted valves, hemispherical or ovoid, the hypanthium 3–6 mm × 4–10 mm; disk broad, ascending. Seed minute, about 15 per fruit, smooth, yellow-brown. Seedling with epigeal germination and bilobed cotyledons; first 4–6 pairs of leaves decussate; subsequent leaves alternate. Juvenile leaves al-



Eucalyptus camaldulensis Dehnh. – 1, habit; 2, flowering branch; 3, fruiting branch.

ternate, petiolate, ovate to broadly lanceolate, 13–26 cm × 4.5–8 cm, green, grey-green or blue-green, slightly discolorous.

Growth and development The germination rate is generally high and can reach almost 100%. Lignotubers develop early in the life of northern Australian provenances of *E. camaldulensis*, but are mostly absent in those from southern Australia. Growth rates vary greatly between provenances and are heavily site-dependent. Seedling growth may exceed 3 m per year for well-adapted provenances on favourable sites. In trials in Peninsular Malaysia using a provenance from Ferguson River (Northern Territory) on three different sites, 4-year-old trees showed a mean annual height increment of 2.3–4.0 m and a mean annual diameter increment of 1.6–3.9 cm. In a trial over 8 years with 51 provenances conducted in Biñga, the Philippines, the survival rate ranged from 1–89%, and the average annual growth rate from 1.15–6.84 m in height and from 0.25–6.3 cm in diameter. In trials in Thailand, the mean annual increment was 1.7–4.1 m in height and 1.6–3.9 cm in diameter in the first two years after planting.

Time of flowering in natural stands depends on the geography of a given location. Flowering peaks in summer in southern Australia, in autumn in the far north-west and in winter–spring in the far north-east. In Thailand, some provenances flower almost throughout the year on a range of sites, although September–November is the peak period. Pollination is mainly by insects but also by birds and small mammals. Seeds ripen about six months later. In Thailand, peak flowering corresponds with seed ripening in April–May.

In South-East Asia, the period from planting to production of the first seed crop may be as short as three years. In Thailand, *E. camaldulensis* may start flowering when 16–38 months old, but 24–28 months is common.

Eucalypts do not develop resting buds and grow whenever conditions are favourable.

Other botanical information There is considerable morphological variation within *E. camaldulensis*, which is not surprising given its wide geographic distribution. Six varieties have been described, but this division has been largely ignored because of difficulties in identification. The northern and southern provenances are sometimes accommodated in two varieties: var. *camaldulensis* and var. *obtusa* Blakely, respectively. Var. *camaldulensis* has rostrate opercula, while var. *obtusa* has obtuse or rounded ones. However, the variation in this character seems to change gradually with the location.

E. camaldulensis is closely related to *E. tereticornis* Smith. The latter can be distinguished by its taller and more steeply branched habit, its acutely conical opercula and the black, rough-coated seeds. Where both species grow naturally, as in eastern Victoria and Queensland, hybridization and subsequent introgression occurs. Several populations in far northern Queensland, previously identified as *E. tereticornis*, show several characteristics of *E. camaldulensis* and are now considered a separate subspecies of the latter called subsp. *simulata*. Among them are the fast-growing provenances of 'Laura River', 'Palmer River' and 'Walsh River' that are widely used in South-East Asia. Natural hybrids between *E. camaldulensis* and *E. alba* Reinw. ex Blume are also reported, while in plantations hybridization with *E. grandis* W. Hill ex Maiden occurs.

Ecology Under natural conditions, *E. camaldulensis* occurs typically along watercourses and on floodplains, very occasionally in southern Australia extending to hills or ranges, usually in open forest and woodland, at 20–700 m altitude. It grows under a wide range of climatic conditions, from temperate to hot and from humid to arid. Annual rainfall in natural stands varies from 250–2500 mm, but planted trees can survive in areas with as little as 150 mm annually. In arid regions, it depends on the presence of a high water table or seasonal flooding for survival. The length of the dry season may vary from 0–8 months and the rainfall distribution varies from a winter maximum in southern regions to a monsoon type with summer rains in northern areas. Mean minimum temperature of the coldest month ranges from 3–22°C, mean maximum temperature of the hottest month from 21–40°C and mean annual temperatures from 13–28°C. In general, *E. camaldulensis* tolerates up to 20 frosts per year, but does not tolerate temperatures below –10°C. The optimum temperature for germination is 32°C, but a wide range is tolerated. *E. camaldulensis* occurs on a variety of soils, commonly on sandy and silty alluvial soils, but occasionally on heavy clays in southern Australia; it is also found along the borders of salt lakes. It is not adapted to calcareous soils, except for a few populations in southern and western Australia growing on shallow soils over limestone. Provenances may differ considerably in frost tolerance, fire resistance and salt tolerance.

Propagation and planting Selection of the proper genetic material for particular planting conditions is of paramount importance. *E. camaldulensis* is usually propagated by seed. As a rule-of-thumb, 1 kg of seed is sufficient to provide plants for 100 ha at a spacing of 3 m × 2 m and the typical seedling recovery rate of 25%. Seed is best stored dry (5–8% moisture content) in airtight containers at 3–5°C. Viability will be maintained for several years and is still about 30% after being stored for seven years. No pre-sowing treatment is required. The fine yellow-brown seed and chaff are sown together under shade in a well-drained and sterilized medium and covered very sparingly with sand. After 4 days, seed has germinated and shade should be reduced. When 2 pairs of leaves have developed, seedlings are pricked out into containers such as polythene bags filled with a sterilized potting mix. Shading is needed for the first week after transplanting, thereafter plants should be fully exposed. A polythene bag size of 15 cm × 5 cm proved most economic in Nigeria. Direct sowing in polythene bags or in open nursery beds for the production of bare-rooted planting stock is also practised. Growth is fast under tropical conditions, and plants can be planted out after 3 months, occasionally after 6 weeks, when they are 30 cm tall. Excessive watering and shade often result in damping-off and in seedlings becoming too tall and weak for easy transplanting.

E. camaldulensis is suited to mass vegetative propagation. Cuttings from juvenile shoots (i.e. below the 10th node) root readily in about 30% of the genotypes. A major reforestation project in Morocco is based entirely on cuttings of *E. camaldulensis*. In South-East Asia, propagation by cuttings is an integral component of breeding programmes. Elite trees are selected in young plantations (5 years old) and felled or girdled to promote coppicing. Coppice shoots of about 1 m long are collected and divided into pencil-sized cuttings with two leaf pairs. Half of the leaf blade is then trimmed and the cuttings are dipped into a hormone preparation and planted in pots under mist and shade. Rooted cuttings are usually planted in nurseries to provide further shoots. Methods of in vitro propagation have been developed.

Spacing varies with the management system – from community planting around homes, villages and roads to closely-spaced commercial plantations – and depends on the end-products required. For firewood, spacings as close as 2 m × 2 m are used; for pulpwood, a spacing of 3 m × 2 m is often applied. Wider spacings of 4 m × 2 m or 5 m × 2 m are recommended when larger trees are the objective. In plantations, *E. camaldulensis* has a comparatively narrow crown and pendulous leaves which allows light to reach the forest floor. This is favourable for intercropping with food crops but also promotes weed growth. A spacing of 5 m × 2 m is recommended to allow intercropping during the first three years. Application of 100 g of NP or NPK (3:2:1) fertilizer to each tree at planting to assist establishment and early growth is common. In trials in Thailand, survival was 80–90% 12 months after planting.

Husbandry Poor competition ability with weeds and the development of an open crown imply frequent weeding, up to 3 times per year, until the canopy closes 3–5 years after planting. Inadequate weed control may lead to complete failure of the plantation. Intercropping may facilitate proper weed control. A thinning to less than 700 stems/ha at 5 years provides posts, poles, fuelwood and pulpwood, leaving the better trees for the production of e.g. sawn timber after 10 years.

Crown dieback during the dry season as a result of boron deficiency is prevalent in parts of Africa, Asia and South America and must be corrected. A dosage of 10–20 g of borax per tree is recommended, depending on soil type.

All fast-growing provenances tested coppice well. The rotation may be as short as 3–5 years for small-sized pulpwood in Thailand and Vietnam, but is generally 8–10 years. In Israel, maintaining a plantation for 5 successive 10-year coppice rotations has been successful, but in general 2–3 coppice rotations of 10–12 years are feasible. Reduction of the number of coppice shoots on a stool is a most important and time-consuming operation in coppice management. In Nepal, a single reduction at 3–6 months to one shoot per stump is recommended. Competition from eucalypts can severely reduce yields of interplanted crops. In an experiment in northern Nigeria, pearl millet (*Pennisetum glaucum* (L.) R. Br.) yields were reduced up to at least 18 m from a eucalypt shelter-belt and pruning the roots of the eucalypts down to 1 m significantly increased millet yields.

Diseases and pests In the nursery, *E. camaldulensis* is susceptible to various fungi causing damping-off and leaf diseases. Proper hygiene and watering sparingly minimize damage. Insects (e.g. termites and aphids) and rodents may be troublesome, and both physical and chemical control measures are used.

In Australia, natural stands and plantations are affected by many fungi and insects. On suitable sites outside Australia, *E. camaldulensis* is relatively free of diseases and pests. Stem canker and leaf diseases proliferate where rainfall and humidity are much higher than encountered in the natural habitat. In South-East Asia, *E. camaldulensis* may be defoliated by fungi including *Cylindrocladium* spp. during the rainy season. The most susceptible provenances suffer mortality and general decline, but well adapted provenances (e.g. 'Katherine') are little affected.

In parts of Africa and Asia, termites attack seedlings and young trees and must be chemically controlled. In Africa, the Eucalyptus snout beetle (*Gonipterus scutellatus*), of Australian origin, feeds on young shoots but is controlled biologically; moribund or newly-felled trees may become infested with an Australian stem borer or the longicorn beetle (*Phoracantha semipunctata*).

Harvesting *E. camaldulensis* is usually grown on a short rotation and clear-felled at an age that maximizes production for a particular end-use. Generally, this is small-diameter material for fuelwood or pulp. The felling season affects coppice regeneration. Felling during the dry season delays sprouting and increases the risk of the stump drying out. Felling by saw to give a clean-cut short stump with minimum bark damage is best. In coppice systems e.g. in Nepal, some stems are sometimes left uncut as standards. This practice is recommended to produce wood of a range of diameters suitable for various products.

Yield Very high productivity is possible under favourable conditions: a mean annual increment of 70 m^3/ha of four-year-old trees planted at 3 m × 2 m on a fertile site with high water availability has been recorded in Israel. However, such conditions are seldom met. In the drier tropics, yields of 5–10 m^3/ha per year on a 10–20-year rotation are common, whereas in moister regions up to 30 m^3/ha per year may be achieved on 7–20-year rotations. In southern Vietnam, mean annual increments of 12 m^3/ha over 4 years have been recorded, which can reach 20 m^3/ha for the best adapted provenances. Coppice rotations give higher yields than the initial seedling rotation (e.g. 25–30 m^3/ha per year versus 17–20 m^3/ha per year in Turkey) and the length of the rotation may be adjusted accordingly.

Handling after harvest End-splitting of roundwood may be reduced by felling during winter months. For sawn timber production in Pakistan, it is recommended to fell in October, convert immediately into 70 mm quarter-sawn planks, carefully stack in a well-ventilated room and then top load each stack, in order to reduce defects.

Genetic resources Both primary and secondary centres of diversity hold vast genetic resources of *E. camaldulensis*. It is often impossible to trace the origin of seed used for plantations, so the extent of genetic variation available in various areas is uncertain. Systematic introduction of appropriate seedlots from native Australian stands is highly recommended to ensure that a wide genetic variation is used for selection and breeding.

In Australia two groups of provenances are distinguished: a northern tropical group and a southern temperate group. The better-performing tropical provenances, such as 'Petford' and 'Katherine' are generally the most sought-after for breeding programmes in South-East Asia. The Australian Tree Seed Centre (ATSC) provides both single-tree and bulk provenance collections of *E. camaldulensis* for breeding programmes. A well-documented, 400-tree collection from the Petford region is presently available at ATSC along with accessions from many other areas.

Breeding The ideal commercial tree should have good vigour and resistance to diseases and

pests, a straight single bole, drought tolerance, good coppicing ability, high pulp yield (light-coloured timber), thin branches and good self-pruning ability, and a thin bark.
Although seed availability of climatically adapted northern Australian provenances has increased, supplies are still insufficient to meet demand in South-East Asia. Consequently, a number of countries in the region support selection and breeding programmes, for instance the comprehensive programme in Thailand is based on seed from local trees and 308 seedlots from northern Australia including 200 from Petford. These accessions have been planted in orchards in 4 locations with different environments; they will be thinned progressively and supply improved seed and coppice material.

Prospects *E. camaldulensis* is one of the best performing trees in the seasonally dry tropics for an impressive array of end-products. The success of *E. camaldulensis* as an exotic is attributed to its superiority to other trees in the production of wood for firewood, charcoal and other purposes on infertile dry sites, its tolerance of drought and high temperature combined with rapid growth when water is available, its tolerance of periodic waterlogging and soil salinity and its fair tolerance of fire and frost. Its productivity and versatility can be enhanced by breeding programmes now under way in South-East Asia and elsewhere.
With careful selection of provenances for specific sites, *E. camaldulensis* is expected to gain importance in South-East Asia.

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J.C. Doran & W. Wongkaew

Eucalyptus tereticornis J.E. Smith

Spec. bot. New Holland 1: 41 (1795).
MYRTACEAE
$2n = 22$

Synonyms *Eucalyptus subulata* Cunn. ex Schauer (1843), *E. insignis* Naudin (1891), *E. umbellata* (Gaertner) Domin (1928) non Desf.

Vernacular names Forest red gum, blue gum (En). Cambodia: pré:ng khchâl' slök tô:ch.

Origin and geographic distribution *E. tereticornis* has an extensive natural distribution in a long strip about 100 km wide, from southern Papua New Guinea and the northern tip of Queensland to southern Victoria along the east coast of Australia. The Great Dividing Range separates its area of distribution from that of *E. camaldulensis* Dehnh. It was one of the first eucalypts exported from Australia and is now cultivated throughout the tropics, on an especially large scale in India and Brazil.

Uses *E. tereticornis* is used for reforestation, shelter-belts and shade. The wood is a major source of fuelwood, charcoal, and timber for local use. It is hard, strong and durable and is also used for light and heavy construction, railway sleepers, bridges, wharves, piles, poles, mining timber, pulpwood, hardboard and particle board. *E. tereticornis* is a major source of pollen and nectar, producing a caramel-flavoured honey. The leaves are one of the sources of eucalypt oil. The essential oil and the tannin from wood and bark are not utilized commercially.

Production and international trade *E. tereticornis* is among the four most commonly planted *Eucalyptus* species throughout the world. It is, therefore, most likely that saw and veneer logs and pulp of *E. tereticornis* are internationally marketed, but specific information is lacking. In Vietnam approximately 16 000 ha have been planted, in India over 500 000 ha and in Brazil about 250 000 ha.

Properties The sapwood is grey to cream-coloured and fairly well demarcated from the pale

to dark red heartwood, of even texture with wavy or interlocked grain, making it somewhat difficult to finish. At 12% moisture content the density of the wood from plantations is considerably lower (e.g. 730–800 kg/m^3, Madagascar) than that from natural forests (910–1010 kg/m^3, Australia). The energy value of the wood is 20 000–22 000 kJ/kg. The shrinkage of wood during seasoning is high and it has a strong tendency to warp. In Australia, the wood is one of the most resistant to marine borer attack, but it failed after 2.5–10 years at the Pacific coast of the United States. Sapwood is susceptible to *Lyctus*. The wood contains 0.5% essential oil and 6–12% tannin; the bark contains 3–15% tannin. The wood yields a very good quality pulp.
Commercial seed contains 320–600 viable seeds per gram. About 90% of commercial seed is chaff consisting mainly of unfertilized ovules.

Description A large tree, up to 50 m tall, bole straight and clear for more than one-half, up to 2 m in diameter. Bark decorticating over the whole

Eucalyptus tereticornis J.E. Smith – 1, habit; 2, flowering branch; 3, juvenile leaf; 4, adult leaf; 5, flower buds; 6, fruits.

trunk in large plates or flakes to leave a smooth or mat, mottled surface, white, grey or grey-blue; some rough, dead bark is frequently retained at the base of the tree. Leaves alternate, thick; petiole 13–24 mm long, terete or channelled; blade narrowly lanceolate to lanceolate, 10–20 cm × 1–2.7 cm, acuminate, glabrous, shiny green, concolorous with venation conspicuous, pinnate, lateral veins angled at 40–50° to the midrib. Inflorescence an axillary, simple, condensed and reduced, umbelliform dichasium, usually called a conflorescence; umbels solitary, 7–11-flowered; peduncle terete or angular, 7–25 mm long; pedicel 3–10 mm long; flowers regular, bisexual, white; flower buds clearly divided into a calyx tube or hypanthium (lower part), and operculum (upper part, formed by the calyx lobes and petals) which is shed at anthesis; hypanthium hemispherical, 2–3 mm × 4–6 mm; operculum acutely conical, 8–13 mm × 4–6 mm; stamens numerous, on a staminophore, erect and all fertile, anthers versatile, oblong, opening by longitudinal slits; ovary inferior, with many ovules. Fruit a dry, thin-walled capsule enclosed in a woody hypanthium, opening with 4–5 strongly exserted valves, subglobular to ovoid, 5–7 mm × 4–8 mm, with broad, steeply ascending disc. Seed rough, brown-black. Seedling with epigeal germination, at first with square stem; cotyledons bilobed; leaves decussate; juvenile leaves opposite for 2–3 pairs, then alternate, petiolate, ovate, 6–16 cm × 5–6 cm, dull, green to blue-green, slightly discolorous.

Growth and development In plantations, *E. tereticornis* starts flowering when 2–6 years of age; 2-month-old seedlings have been observed flowering in Brazil. Small clusters of white flowers appear every year, but heavy blooming occurs only once every 3–4 years. In a 3-year-old plantation in Java the mean annual increments in height and in diameter were 4.2 m and 3.5 cm, respectively; in 4-year-old trials in Peninsular Malaysia they were 2.0–3.6 m and 1.7–3.3 cm; in 1-year-old trials in Thailand, 1.7–6.5 m and 2.5–6.8 cm, depending on provenance and site. On a poor site in Papua New Guinea the annual increments were 3.3 m and 2.1 cm. On favourable sites in Indonesia trees attain a height of 35 m in 10 years, on poorer sites 15–18 m. The presence of ectomycorrhizal associations in *E. tereticornis* has been assumed, but has not yet been confirmed.

Other botanical information *E. tereticornis* is closely related to *E. camaldulensis* and natural hybrids are sometimes encountered. *E. camaldulensis* differs by its usually smaller habit, the alternate juvenile leaves, the rostrate to obtusely conical operculum and the smooth seed. Many early introductions of *E. tereticornis* were derived from very few original seed trees. The inbred landrace 12ABL is thought to be descended from a single tree in Madagascar and is widely planted in West Africa; *Eucalyptus* C is a landrace or possibly a hybrid from Zanzibar and is planted in East Africa. 'Mysore Gum', which represents about half of the eucalypt plantations in India, is believed to originate from a few trees in the Nandi Hills (Andhra Pradesh, India). It is also known as 'eucalyptus hybrid' or 'Mysore hybrid', although it is now considered to be mainly *E. tereticornis*, with only occasional evidence of hybridization with *E. robusta* J.E. Smith and probably *E. camaldulensis*.

Ecology *E. tereticornis* occurs from 6–38°S latitude and climatic conditions in its natural range vary greatly. Rainfall distribution varies from monsoonal with marked dry and wet seasons in southern Papua New Guinea, a summer rainfall climate with a very dry winter in Queensland, and an even distribution of rainfall in southern Queensland, to a dry summer and cold, wet winter in eastern Victoria. Mean annual rainfall is (500–)800–1500(–3500) mm with a dry season of up to 7 months. *E. tereticornis* is mainly found on alluvial flats in cooler and drier areas, on lower hill-slopes in higher rainfall areas, and on upper slopes and plateaux in the tropics. Its altitudinal range is from near sea level up to 900 m in Australia and up to 1800 m in Papua New Guinea. The mean maximum temperature of the hottest month is 22–32°C, the mean minimum temperature of the coldest month 2–12°C. Up to 15 days of frost are tolerated. In southern China and Pakistan adapted selections are reported to survive –7°C. Soil conditions seem to limit its natural occurrence. It is not found on heavy clay, acid or dry, shallow soil, preferring deep, well-drained, fairly light-textured alluvial soil. *E. tereticornis* can stand occasional flooding and in India, it is highly resistant to waterlogging during the first year, although in natural forest it is rare under such conditions.

Propagation and planting *E. tereticornis* can be propagated by seed or cuttings. For transport of seed, it may be worthwhile to separate seed and chaff, e.g. by sieving. Seed can be stored for several years if air-dried and stored in the dark in sealed containers at a temperature of 1–4°C. The germination rate can be maintained at an acceptable level for 1–2 years by storing the seed in unsealed containers at room temperature. The germination rate of *Eucalyptus* spp. is commonly given as the number of plants obtainable from 1 g of seed (with chaff), e.g. 480 for *E. tereticornis*, corresponding with about 80% germination. The most common and effective way to raise seedlings is to sow the small and untreated seed in trays under light shade in a sterilized medium (e.g. soil or vermiculite). A sowing rate of 10–15 g/m^2 is recommended, but the sowing density should be decreased in areas with a high risk of damping off. Seed germinates in 4–14 days. The young seedlings are pricked out and transplanted into containers when 2–4 pairs of leaves above the cotyledons have developed. An additional 3–6 months in the nursery is required to obtain seedlings of plantable size. Direct sowing in containers is also practised, but it is very difficult to sow only a few of the minute seeds per container. Watering is done by spraying. Bare-rooted planting stock may be used in areas with a humid climate, while stumps have proved satisfactory in India. Recorded spacings at planting are 2 m × 2 m (East Java), 2.7 m × 3.0 m (Peninsular Malaysia), 1–2 m × 1–2 m (the Philippines) and 2.7 m × 2.7 m (Papua New Guinea). In Papua New Guinea, growth is satisfactory on infertile and poorly drained grassland and on copper mine tailings, provided that N, P and K fertilizer is applied. Vegetative propagation using branch cuttings of 2–3-year-old saplings and from suckers has been successful.

Husbandry Clean weeding is extremely important for good establishment and early canopy closure. In grasslands with *Themeda triandra* Forssk. and *Imperata cylindrica* (L.) Raeuschel in the Philippines, weeding is done every 3–4 months to obtain a seedling survival of 80–100%. For the production of firewood and pulpwood, rotations of 7–12 years are applied. Thinning is done 2–5 years after planting. *E. tereticornis* coppices vigorously and regeneration by coppice is commonly practised. After the original seedling crop, 2–4 coppice crops can be harvested. After cutting, two–several coppice shoots remain after 'self-thinning'. These are thinned to 1–3 coppice shoots per stool at the age of 18 months. For the production of construction wood the rotation is 20–30 years with a final density of 70–120 trees/ha. In Papua New Guinea, ploughing and mounding helps to mineralize sufficient soil nutrients to enable adequate growth. The initial planting density is 1300–1600 trees/ha, reduced to 900 trees/ha after 5 years. Resprouting after fire was observed in the

Philippines, but fire killed 80% of the seedlings planted six months earlier.

Diseases and pests *E. tereticornis* is fairly free from diseases and pests. Damping-off in the nursery may be a serious problem, but reducing shade and humidity can prevent major damage. In the Solomon Islands, dieback attributed to the coreid bug *Amblypelta cocophaga* was observed in 3–4-month-old plantings. Resistance to termite attack is generally very high, but *Neotermes insularis* may attack the tree in its natural distribution area.

Harvesting When harvested the stool should be lower than 12 cm to allow for the development of stable shoots.

Yield In East Java, the mean annual increment over 10 years is 27 m^3/ha for a trial plantation at 800 m altitude. On good sites, 18–25 m^3/ha may be generally expected. A mean annual increment of 30–35 m^3/ha for the hybrid of *E. tereticornis* × *E. grandis* W. Hill ex Maiden was recorded over 6–7 years on savanna sands in Congo.

Genetic resources Provenances have been conserved ex situ in Congo, Nigeria, Zambia, Fiji and Bangladesh. Seed is commercially available in Australia from a great number of provenances. The 'Mysore hybrid' or 'eucalyptus hybrid', used in most plantations in India, is a complex of landraces of *E. tereticornis*, suspected to have originated from a restricted genetic base of Australian trees, and hybrids with *E. robusta* or *E. camaldulensis*. Performance in plantations has left much to be desired due to the great variability within stands and slow growth compared with pure species of appropriate provenance.

Breeding An important effort has been put into progeny and provenance research particularly in the tropical provenances from north-eastern Queensland. *Eucalyptus* species often hybridize readily. Natural populations with intermediate characteristics between *E. tereticornis* and *E. camaldulensis* occur in north-eastern Queensland. These two species also hybridize spontaneously in plantations and artificial crossing in India showed a striking degree of hybrid vigour; the hybrid, designated as F.R.I.-4 and F.R.I.-5, produced three times the wood volume of *E. tereticornis* at 4 years of age. *E. tereticornis* × *E. grandis* (South Africa) does not have the hybrid vigour, but is resistant to pink disease (*Corticium salmonicolor*) whereas *E. grandis* is not.

Prospects Its rapid growth and its adaptability to a variety of environmental conditions make *E. tereticornis* very promising to be included in trials in South-East Asia on a wider scale. However, testing and selection of locally adapted provenances should receive high priority if *E. tereticornis* is to be utilized to its full potential.

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E. Boer

Eucalyptus urophylla S.T. Blake

Austrobaileya 1(1): 7 (1977).

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Synonyms *Eucalyptus alba* auct., non Reinw. ex Blume, *E. decaisneana* auct., non Blume.

Vernacular names Timor white gum, Timor mountain gum (En). Indonesia: ampupu, popo (Indonesian, Timor), palavao preto (Portugese, East Timor). Vietnam: b[aj]ch d[af]n d[or].

Origin and geographic distribution The natural distribution of *E. urophylla* is confined to the eastern part of the Lesser Sunda Islands (Bali and

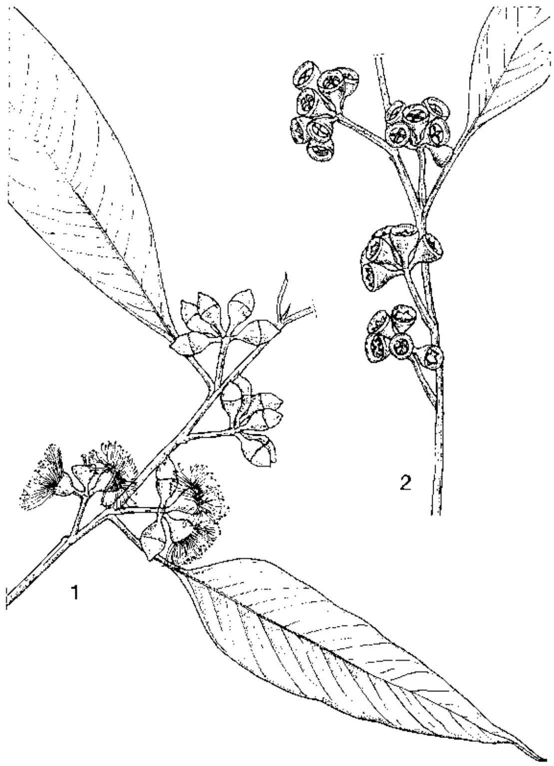
Nusa Tenggara), occurring principally on the islands of Timor, Alor and Wetar with fewer occurrences on Adonara, Lomblen, Pantar and the eastern parts of Flores. The natural range extends about 500 km between longitudes 122–127°E and latitudes 7°30'–10°S. It has been introduced to Java in 1890 and in 1919 to Brazil (as *E. alba*). In 1966, it was introduced to Australia and since then to many other countries, notably Papua New Guinea, Malaysia, China, Cameroon, Congo, Ivory Coast, Gabon, Madagascar and French Guiana.

Uses *E. urophylla* is increasingly used in reforestation programmes and is economically important for wood production. It makes satisfactory fuelwood and charcoal. In Timor, the wood is used for heavy construction and bridging, elsewhere also for framing and flooring. Round wood is used for building poles and fence posts. It is particularly suitable as a source of mid-density to low-density eucalypt fibre for pulp and paper production. The bark has a tannin content of over 10%, but is not used commercially.

Properties The wood of *E. urophylla* is moderately durable. The heartwood is pinkish-brown to red-brown, and contains little gum. The basic density is in the range of 540–570 kg/m^3, which is comparatively light compared to other *Eucalyptus* species. The wood is fairly easy to saw. Fibres are relatively short, 0.7–1 mm, and the wood is suitable for bleached chemical pulp and has a good pulp yield of about 50%.
On average, there are 210–470 viable seeds per g of uncleaned seed.

Production and international trade No statistics on trade are available. Extensive plantations of *E. urophylla* and its hybrids have been established in Brazil, China, Congo and elsewhere. The most commonly planted hybrid is *E. grandis* W. Hill ex Maiden × *E. urophylla*.

Description Evergreen tree up to 45(–55) m tall, in unfavourable environments a gnarled shrub; bole usually straight, branchless for up to 30 m, up to 1(–2) m in diameter. Bark variable depending on available moisture and altitude, usually persistent and subfibrous, smooth to shallowly and closely longitudinally fissured, red-brown to brown, sometimes rough especially at the base of the trunk. Juvenile leaves subopposite, stalked, broadly lanceolate, 10–15 cm × 5–8 cm, discolourous, lateral veins just visible, at 50–70° to the midrib; adult leaves phyllodinous, subopposite to alternate, long stalked (12–30 mm), broadly lanceolate and abruptly narrowed into a short tip or lanceolate and tapering into a long drip tip,



Eucalyptus urophylla S.T. Blake – 1, flowering branch; 2, fruiting branch.

12–20 cm × 2–5 cm, lateral veins visible, at 40–50° to the midrib, dark green above, paler green below. Inflorescence an axillary, simple umbelliform condensed and reduced dichasium called a conflorescence; umbels solitary, 5–8-flowered; peduncle somewhat flattened, 8–22 mm long; pedicel angled, 4–10 mm long; flowers regular, bisexual; flower buds ellipsoid to obovoid, shortly pointed to rotund, 10–14 mm × 6–10 mm, divided into a calyx tube or hypanthium (lower part) and an operculum (upper part) which is shed at anthesis; stamens numerous, on a staminophore. Fruit a dry thin-walled capsule enclosed in a woody hypanthium, opening with 3–5 included to partly exserted valves, obconical to cup-shaped, 6–14 mm × 7–18 mm; disk almost flat to obliquely depressed. Seed small, 4–6-angular to more or less semi-circular, black. Seedling with epigeal germination; cotyledons usually bilobed to about the centre; first 5–7 pairs of leaves opposite, subsequent pairs subopposite.

Growth and development Mature seed germinates readily under favourable conditions and does not require pregermination treatment. Seedlings usually reach 25 cm in height in 10–12 weeks. In conditions of high relative humidity, young seedlings may be susceptible to damping-off.

E. urophylla retains its leaves during the dry season, and grows actively when moisture and temperature conditions are favourable, with a strong apical dominance. In dry locations and on shallow soils on mountain ridges, apical dominance is less pronounced and plants may develop into shrubs. In Thailand, early growth of two different provenances during the first year was 2.4–6.2 m in height and 3.9–7.4 cm in diameter. In Peninsular Malaysia, growth during the first four years was 1.7–3.5 m/year in height and 2.0–3.9 cm/year in diameter. In East Java, a trial of trees aged 7 years and 9 months showed a mean height of 27 m and a mean diameter of 22.8 cm. Very rapid initial growth has been reported from the Solomon Islands, but the trees remained thin-stemmed and developed a thin canopy, most probably because the climate was too humid. In general, progenies from low altitudes in Flores, Alor and Timor grow fastest.

Flowering usually starts within 2 years after planting and seeds are produced abundantly by 4 years of age. In Brazil, flowering of two-month-old seedlings has been observed occasionally. In its natural habitat, peak flowering of *E. urophylla* is strictly tied to the rainy season in January–March. Pollination is by insects. Fruits reach maturity about 4 months after flowering, in May–July(–August).

Other botanical information *E. urophylla* appears to be one of the most variable of all eucalypts, with considerable variation in morphological features such as adult leaf size and expression of a drip tip, bud characteristics, fruit size and shape. There are also differences between the seedling, juvenile, intermediate and adult leaves. The extreme variation in bark characteristics appears to be associated with differences in available moisture and altitude. Boles are mainly smooth at lower altitudes and under drier conditions. Smooth boles with rough bark at the base are found below 1000 m altitude in Alor and Flores, at 1000–2000 m in Timor the boles are usually entirely covered with rough bark, above 2000 m in moist conditions the bark is usually subfibrous. Recent analyses indicate that specimens from high altitude sites in Timor and from dry sites in Wetar are distinct from the residual *E. urophylla*. These have been designated *E. orophila* L.D. Pryor and *E. wetarensis* L.D. Pryor respectively.

E. urophylla has been distinguished as a separate species only recently. It has been widely cultivated under the name *E. alba* Reinw. ex Blume or as *E. decaisneana* Blume. In Java, the name *E. platyphylla* F. Muell. was used for *E. alba*. As a consequence, considerable confusion exists about the true nature of several provenances. Where natural populations of *E. urophylla* meet those of *E. alba*, hybrids are frequently encountered and introgression of characters may take place. This enhances the confusion about true identities of provenances. *E. alba* is a smaller tree of poor shape, the adult leaves are generally broader (2–5 cm), concolourous, and lack the characteristic drip tip, while its fruit is hemispherical to obconical and 4–7 mm × 5–8 mm. Hybrids may be recognized by their white, smooth trunk, their larger and less numerous leaves but the extreme variability in the bark characteristics of *E. urophylla* can make identification of hybrids difficult.

Ecology *E. urophylla* (including *E. orophila* and *E. wetarensis*) has the largest altitudinal range of any eucalypt, extending from 1000–2960 m in Timor, from 70–800 m in Wetar and from 300–1100 m in Flores and the smaller islands to its east. It is frequently found as the dominant species in secondary montane forest. At lower altitudes and in drier, exposed locations usually below 1500 m, it is often replaced by *E. alba*. The natural range of *E. urophylla* is in the humid and sub-humid climatic zones. At about 400 m altitude the mean maximum temperature of the hottest month is 27–30°C, which may drop to only 15–21°C at 1900 m. Mean maximum temperature of the coldest month is 8–12°C. In Timor many of the *E. urophylla* forests occur at about 1000 m altitude, where mist and fog are common, annual rainfall is 1300–2200 mm, and the dry season is (2–)3–4 months. On other islands, drier conditions prevail with rainfall of 600–1500 mm, and a dry season of 5–8 months.

E. urophylla grows on mountain slopes and in valleys. It develops best on deep, moist, well-drained, acidic or neutral soils derived from volcanic or metamorphic rock. It is also commonly found on basalts, schists and slates, but rarely on limestone.

Propagation and planting Nursery establishment is generally by sowing untreated seed in germination beds. Mature seed germinates readily in 7–12 days and does not require any pretreatment. Damping-off can be prevented by reduced watering and shade, and allowing ventilation. The seedlings are transplanted into polythene bags when they have developed 2 pairs of leaves. The potting medium is usually a freely draining mixture of loam and sand. Seed may also be sown directly into containers and thinned out after germination. Seedlings are planted out in the field when they reach a height of about 25 cm, 10–12 weeks after sowing.

In Brazil, *E. urophylla* or hybrids of *E. urophylla* and *E. grandis* are raised using rooted cuttings derived from stump sprouts. After coppicing, when the new sprouts are 60–80 cm long, they are removed and divided into cuttings with two pairs of leaves. The leaves are treated with a fungicide. The cuttings are dipped in a rooting hormone and then set to a depth of 4 cm in polythene bags filled with subsoil clay. They are kept under 50% shade and intermittent mist spray for 30–40 days. At this stage, roots have formed and the cuttings are moved to full sunlight and 1 g of complete fertilizer is added to each bag. They are planted out when 70–80 days old. After culling clones with poor rooting capacity, 80% rooting is generally achieved in commercial production. Tissue culture has proved successful on an experimental scale in Indonesia; the explants are taken from 3-week-old material. The hybrid *E. urophylla* × *E. grandis* has been planted using tissue cultured plants on a pilot scale in Guangdong Province, China.

Intensive site preparation by ploughing is beneficial; on compacted sites, deep ripping may also be used. NPK fertilizer is applied in each planting hole. Spacing varies with the purpose of the plantation. For pulpwood, 3 m × 2 m is commonly used, for fuelwood or poles planting may be closer.

Husbandry Plantations are invariably established using containerized seedlings or cuttings. It is essential to keep the planting site weed-free, at least until the trees reach 6 months of age, since eucalypts are highly sensitive to competition. After 6 months, their dense foliage should suppress competing vegetation. Thinning is done every two years from the age of 3 years onwards, when the initial spacing is 3 m × 2 m. *E. urophylla* has good coppicing ability and trees can be expected to produce at least 3 coppice rotations after the initial seedling rotation. The tree is fairly resistant to fire.

Yield An annual increment of 20–30 m^3/ha with bark at 5–10 years of age is usually obtained. Better provenances can yield up to 50 m^3/ha per year on favourable sites. Hybrids generally yield considerably higher, e.g. a mean annual increment of *E. urophylla* × *E. alba* in Congo was 30–35 m^3/ha, while that of *E. urophylla* × *E. grandis* in Brazil was 35–70 m^3/ha with individual plots yielding over 100 m^3/ha annually. Mass-propagated cuttings from selected hybrids of *E. urophylla* with *E. tereticornis* J.E. Smith, *E. alba* and *E. grandis* in Cameroon gave annual increments of over 30 m^3/ha in an 8-year rotation.

Diseases and pests In conditions of high relative humidity, young seedlings may be susceptible to damping-off. In Indonesia, death of 2-month-old seedlings has been attributed to attack by root fungi such as *Botryodiplodia* sp., *Fusarium* sp. and *Helminthosporium* sp. A canker disease caused by *Cryphonectria cubensis* is found on *E. urophylla* in West Africa and South America. Although it is much more resistant than *E. grandis* or *E. saligna* J.E. Smith, some provenances are quite susceptible, especially in humid tropical lowland conditions. Seedlings and small trees of *E. urophylla* are susceptible to termite attack and stem borers such as *Zeuzera coffeae* and these may also cause damage to older trees. In the Solomon Islands, dieback attributed to the coreid insect *Amblypelta cocophaga* was observed in 3–4-month-old plantings. The introduction of the ant *Oecophylla smaragdina* and clearing the undergrowth controlled the attack satisfactorily.

Genetic resources Since 1963 more than 15 expeditions have collected seed from the natural range of *E. urophylla*. Much of this material has been used in Indonesian domestic planting programmes, but a significant amount has been established elsewhere. Comprehensive provenance trials exist in Indonesia, Thailand, China, Congo, Ivory Coast, Malawi, Brazil, Colombia, Puerto Rico, and elsewhere. It appears that provenance variation is closely related to the altitudinal gradient of the seed sources. The CSIRO Australian Tree Seed Centre in Canberra holds a comprehensive collection of seed samples of *E. urophylla* from throughout its natural range. *E. urophylla* disappeared from the Indonesian island of Solor, but its genetic base is not seriously affected by man as the trees are generally found in rugged and remote areas and are fairly resistant to fire.

Breeding An isozyme survey of *E. urophylla* has revealed a rather unstructured isozyme differentiation pattern with small genetic distances between populations. Only populations from the island of Wetar clustered together on the basis of their isozyme genotypes. This lack of genetic variability between populations contrasts with the high degree of differentiation in morphological characters and growth rates in provenance trials. The main outcome from the provenance trials has

been the demonstration that provenances from altitudes of above 1500 m perform poorly in the lowland tropics. Moreover, those provenances from lower altitudes (300–1100 m) and from drier locations grow well in humid and sub-humid tropical and subtropical conditions with a dry season of 1–5 months in the coolest part of the year.
Breeding programmes in Brazil, China, Congo and Indonesia have selected superior individuals in provenance trials and plantations or superior offspring in progeny trials. In Brazil *E. urophylla* has been hybridized with *E. grandis* to produce vigorous hybrids for clonal pulpwood plantations. In Cameroon, hybrids with *E. tereticornis* and *E. alba* have been used similarly. These hybrids are increasingly being planted following mass vegetative propagation by cuttings. Breeding programmes have focused on optimizing growth rate, stem straightness, wood density and coppicing ability, while rooting capacity of cuttings is an additional prerequisite for mass vegetative production.

Prospects *E. urophylla* plays an important role in afforestation in a small but growing number of countries. However, it has the potential to become much more widely used in humid and sub-humid tropical regions, as it belongs to the most productive of the low-latitude eucalypts. Its fast growth, coppicing ability, adaptability to a range of environments, early canopy closure, relative resistance to fire and to diseases and pests, and the various products which can be obtained from the wood, make it a very useful tropical tree.

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J.W. Turnbull & J.C. Doran

Flemingia macrophylla (Willd.) Merrill

Philip. Journ. Sci. 5: 130 (1910).
LEGUMINOSAE – PAPILIONOIDEAE
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Synonyms *Flemingia congesta* Roxb. ex Ait.f. (1812), *F. latifolia* Benth. (1852), *Moghania macrophylla* (Willd.) Kuntze (1891).

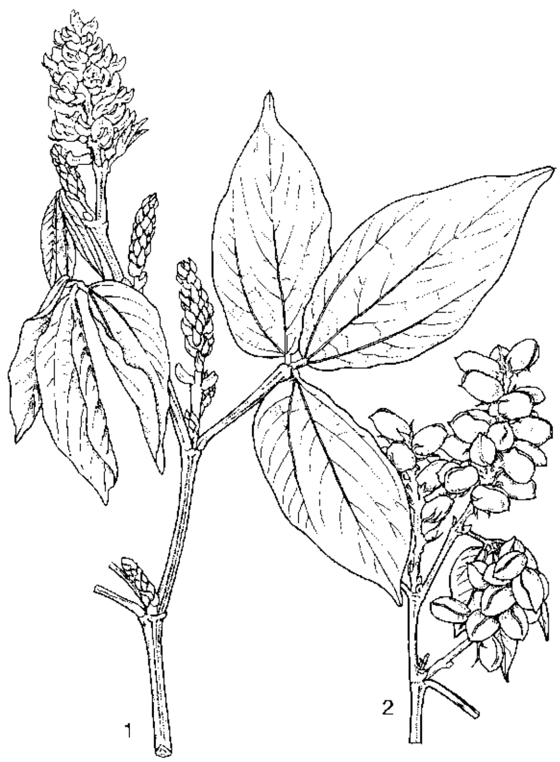
Vernacular names Indonesia: apa-apa (Javanese), hahapaan (Sundanese), pok-kepokan (Madura). Malaysia: serengan jantan, beringan. Philippines: laclay-guinan (Tagalog), gewawini (Ifugao), malabalatong (Pampanga). Laos: thwàx h'è: h'üad, thwàx h'üad (Vientiane), h'ôm sa:m müang (Xieng Khouang). Thailand: mahae-nok (northern), khamin-nang, khamin-ling (central). Vietnam: t[os]p m[ow] l[as]to, c[aa]y dau ma (Vinh Phu), cai duoi chon (Thuan Hai).

Origin and geographic distribution *F. macrophylla* originated in and is widely distributed in South-East Asia and in India, Sri Lanka, southern China and Taiwan. It has been introduced and naturalized in Papua New Guinea, East, Central and West Africa and is cultivated in tropical America.

Uses *F. macrophylla* is grown in hedges and provides mulch for associated food crops grown in alley-cropping systems, and fuelwood as a valuable by-product. As a green manure it is less effective. It is grown on terraces to control soil erosion. In Indonesia, Malaysia, Sri Lanka, West Africa and Madagascar the plant is used as a cover crop and as a shade crop in young plantations of cocoa, coffee, banana and rubber, while in Ivory Coast, it is used in pineapple plantations to reduce nematode infestation and as green manure and mulch. In Costa Rica, it is grown as an understorey in plantations of Honduras pine (*Pinus caribaea* Morelet var. *hondurensis* Barrett & Golfari). *F. macrophylla* is grown as a forage crop and is especially important as a dry season forage e.g. in the savanna zone of Nigeria. It is one of the sources of the Arab dye called 'waras' or 'warrus'. 'Waras' is a coarse purple or orange-brown powder, consisting of the glandular hairs rubbed from dry *Flemingia* fruits, capable of dying silk but not wool or cotton; the active compound is called flemingin. *F. macrophylla* is a minor host of the Indian and Chinese lac insects. In Indonesia and Malaysia the leaves are used medicinally.

Properties The leaves contain per 100 g dry matter: N 2.3–3.8 g, P 0.2–0.25 g, K 1.0–1.4 g, Ca 0.55–0.75 g, and Mg 0.2–0.3 g. The lignin content of the leaves is high, the content of tannic acid fairly low (17.2 g and 2.4 g per 100 g dry matter, respectively). Palatability of the leaves is rather poor and in vitro digestibility (40%) is much lower than that of *Leucaena leucocephala* (Lamk) de Wit. The leaves decompose slowly, making them more useful as mulch material than as green manure. Under humid tropical conditions, about 50% of an initial quantity of 4 t/ha of dry matter decomposed in 53 days, while in another experiment only 60% of a mulch layer was decomposed after 120 days. The stem contains flavonoid compounds. The weight of 1000 seeds is 15–20 g.

Botany Woody, deep-rooting, tussock-forming shrub, 1–4 m tall. Young branches greenish, ribbed, triangular in section, silky. Old stems brown, almost round in section. Leaves digitately trifoliolate; stipules lanceolate, 1–1.5 cm long, covered with silky hairs, early caducous; petiole up to 10 cm long, narrowly channelled, slightly winged; leaflets elliptical-lanceolate, 6–16 cm × 4–7 cm, papery, dark green, base rounded, veins covered with silky hairs, apex rounded to acuminate. Inflorescence a dense axillary raceme, subspiciform, sessile, 2.5–10 cm long, silky; bracts ovate, 3–6 mm long; calyx 6–13 mm long, pale velutinous, green, with 5 lanceolate lobes; corolla with greenish elliptical standard and distinct parallel red veins, wings narrow and much shorter than the keel, light purple at the apex. Pod oblong, inflated, 8–15 mm × 5 mm, covered with fine glandular hairs, dehiscent, dark brown, 2-seeded. Seed globular, 2–3 mm in diameter, shiny black.



Flemingia macrophylla (Willd.) Merrill – 1, flowering branch; 2, fruiting branch.

F. macrophylla forms root nodules and fixes atmospheric nitrogen in symbiosis with *Bradyrhizobium* strains. Root nodules are often difficult to locate, partly because they are very small.

Ecology *F. macrophylla* can be found from sea level up to 2000 m altitude, within a wide range of rainfall patterns, from sub-humid to per-humid (1100–2850 mm/year). It can tolerate fairly long dry spells and is capable of surviving on very poorly drained soils with waterlogging. Its natural habitat is along watercourses, both on clay and lateritic soils, as well as under drier conditions such as in fields infested with *Imperata cylindrica* (L.) Raeuschel. It tolerates shade and poor, acid soils with a high content of soluble aluminium.

Agronomy *F. macrophylla* is propagated by seed. Scarification of the seed is usually required to increase the germination percentage. A good weed-free seed-bed should be prepared, and the necessary fertilizers for a particular soil should be worked in prior to sowing, or banded under the row of seed. When planting in a new area, seed should be inoculated with a suitable strain of *Bradyrhizobium* such as CIAT 4203 or 4215. Planting density varies according to the projected use of the stand. In Indonesia, seed is often sown in rows 90 cm apart with 3–4 seeds planted every 60 cm along the row; in coconut plantations on sloping land, sowing in a dense line along the edges of terraces is recommended. Good weed control is required during the first six months after sowing, since the plants are relatively slow to establish. Once established, they require little attention.

The interaction between *F. macrophylla* hedgerows and associated crops is not fully understood. In an alley cropping experiment in Nigeria, *F. macrophylla* hedgerows significantly increased the yield of the associated maize crop. This can be attributed only partly to the the effect of mulching or added nutrients: removing the prunings or leaving them on the soil surface caused only small and inconsistent differences in maize yield. However, the combined effect of mulching and added nitrogen fertilizer was very pronounced and stronger than with hedgerows of *Senna siamea* (Lamk) Irwin & Barneby or *Gliricidia sepium* (Jacq.) Kunth ex Walp. Mulching at a rate of 3 t/ha effectively controls the germination of weed seeds for about 3 months.

Under tropical, humid, lowland conditions in the Ivory Coast, with 10 000 plants/ha and 9 regrowth cycles of 3 months each, an average annual production of 12 t/ha of leaf dry matter has been achieved, although typical yields in South-East Asia may be closer to 8 t/ha. Plants can be cut more frequently than every 3 months, but preferably not at intervals of less than 40 days. They will survive under this cutting regime for many years.

Insect pests such as the fly *Agromyza* sp. reduce seed production by laying eggs in green pods. In Malaysia, spraying with Endrex (1:800) once every two weeks after flowering has begun gives effective control.

Genetic resources and breeding Germplasm collections are maintained at the Centro Internacional de Agricultura Tropical (CIAT, Cali, Colombia), the Research Institute for Animal Production (Ciawi, Bogor, Indonesia), Australian Tropical Forage Genetic Resource Centre (ATFGRC, CSIRO, Canberra, Australia), and the International Plant Genetic Resources Institute (IPGRI, Bangkok, Thailand).

Prospects *F. macrophylla* has excellent coppicing capacity and is promising when used in hedges to provide mulch to associated food crops in alley cropping and forage. As a green manure and feed *F. macrophylla* is inferior to species such as *Leucaena leucocephala* and *Gliricidia sepium*, since its leaves decompose slowly and are less easily digested. Owing to its slow decomposition, the mulch has long-term effects in weed control, moisture conservation and reduction of soil temperature. Furthermore, *F. macrophylla* is useful as a cover crop in perennial plantations, as a shelter belt in erosion control, and in planted fallows for soil improvement. Improvement of the crop's early development and its integration into alley-cropping systems and planted fallows deserve priority in research.

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Gliricidia sepium (Jacq.) Kunth ex Walp.

Repertorium bot. syst. 1: 679 (1842).
LEGUMINOSAE – PAPILIONOIDEAE
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Synonyms *Gliricidia maculata* (Kunth) Kunth ex Walp. (1842).

Vernacular names Gliricidia, mother of cocoa, Mexican lilac (En). Quickstick (Am). Indonesia: gamal, liriksidia (Javanese). Malaysia: bunga jepun (also used for *Thevetia* spp.). Philippines: kakawate (general), madre-cacao, balok-balok (Tagalog). Laos: kh'è: no:yz, kh'è: fàlangx. Thailand: khae-farang. Vietnam: anh d[af]o g[is]a, s[as]t thu, h[oo]ng mai.

Origin and geographic distribution Gliricidia is a native of the seasonally dry Pacific Coast of Central America. It has long been cultivated and is naturalized in tropical Mexico, Central America and northern South America. It was also introduced to the Caribbean and later to West Africa. The Spaniards took it to the Philippines in the early 1600s. From Trinidad it was taken to Sri Lanka in the 18th Century; from there it reached other Asian countries including Indonesia (about 1900), Malaysia, Thailand and India.

Uses Gliricidia is considered to be the most widely cultivated multipurpose tree after leucaena (*Leucaena leucocephala* (Lamk) de Wit). In former times it was mainly used as a shade tree in plantation crops, but more recently it has become a widely cultivated multipurpose tree integrated into several cropping systems, e.g. as a shade tree in tea, cocoa or coffee plantations, as live stakes to support black pepper, vanilla and yam (in West Africa), as a hedge and green manure crop in intercropping systems such as alley-cropping systems. It has also been planted to stabilize soil, to prevent erosion and to reclaim denuded land or land infested with *Imperata cylindrica* (L.) Raeuschel. In this last respect gliricidia has been found to be more effective than leucaena. The wood is often utilized as firewood, for charcoal production or as posts and farm implements, and locally for furniture, construction and railway sleepers. Gliricidia provides useful forage in the form of leaves, green stem and bark, and is commonly used to supplement poor quality, low protein roughage, especially in dry seasons when it may become a major source of feed for goats and cattle in dryland cropping areas. Its forage has been reported to be toxic to horses, but clear confirmation is lacking. Leaf meal can also be fed to poultry and rabbits. Flowers are a source of nectar for bees. Seeds, bark, leaves and roots may be used as a rodenticide and pesticide after fermentation. Gliricidia is often planted as an ornamental. The juice of the leaves, bark and roots is used as a traditional anti-dermatophyte to control eczema and to alleviate itches and wounds.

Properties Gliricidia prunings have a low C/N ratio, a low content of lignins, silica and polyphenols, and a high nutrient level. When applied as green manure they quickly decompose; in one trial gliricidia residues had a half-life of 20 days, which is shorter than that of other green manure crops such as *Leucaena leucocephala* or *Flemingia macrophylla* (Willd.) Merr. Consequently, gliricidia mulch has only a short-lived effect on soil temperature and moisture content. Analyses of gliricidia prunings (leaves and twigs) grown on an alfisol in Nigeria indicated a nutrient content per 100 g dry matter of: N 3.1–3.6 g, P 0.13–0.20 g, K 2.6–2.7 g, Ca 1.2–1.6 g, Mg 0.3–0.45 g, lignin 11.6 g, cellulose 19.4 g, hemicellulose 12.2 g, polyphenols 1.6 g and a C/N ratio of about 13. Water extracts of both fresh and dried gliricidia leaves have been found to produce some allelopathic effect caused by phenolic acids. The effect does not last long and can be eliminated by applying gliricidia mulch at least one week before planting.

Forage quality varies with age, plant part, season and genotype. It is highest in the youngest leaves; with maturity N concentrations decrease slightly and crude fibre increases. The leaves contain 3–5% N, 13–30% crude fibre and 6–10% ash. Digestibility ranges from 48–77%. In 3-month-old growth, gliricidia bark had lower N concentrations than the leaves, but higher levels than the stem. Palatability is problematical, as the forage contains some anti-nutritional factors, with 1–3.5% flavonol and 3–5% total phenols on a dry matter basis. Ruminants unaccustomed to eat the foliage may initially refuse it. However, once they have overcome their initial aversion they will eat a high proportion in their diet for extended periods of time. In some cases it has been observed that one-day-old wilted leaves are preferred to fresh leaves; also silage is more palatable than fresh foliage.

Gliricidia has light-brown sapwood and dark-brown heartwood turning reddish on exposure to air. It is hard, coarse-textured with irregular grain, very durable and termite-resistant. The wood has a high density of up to 750 kg/m^3 and proves difficult to work. The wood of young coppices is less dense, about 500 kg/m^3. As the bole seldom has a diameter of more than 40 cm and a length of 8 m, especially in coppiced trees, timber of large dimensions is rare. The heartwood of gliricidia burns slowly thus producing good embers, and gives off little smoke or sparks; its energy value is 19 800–20 600 kJ/kg. The weight of 1000 seeds is about 125 g.

Description A small deciduous tree up to 12 m tall with a short trunk up to 50 cm in diameter, with smooth or slightly fissured, whitish-grey to light brown bark, often branching from the base; the mature tree has an irregular spreading crown of thin foliage. Leaves alternate, pinnate, 15–40 cm long; petiole 5 mm long; rachis slender, yellow-green, finely hairy; leaflets 7–17 per leaf, opposite except in upper part of rachis, elliptical or lanceolate, 3–6 cm × 1.5–3 cm, rounded or cuneate at base, acuminate at top, thin, dull green and glabrous above, grey-green and often pubescent beneath. Flowers in a 5–12 cm long, axillary raceme, about 2 cm long, on an 8–12 mm long, slender pedicel; calyx campanulate, 5-toothed, light green tinged with red; corolla whitish-pink or purple, with a broad standard, folded back and yellowish near the base, 2 oblong, curved wings, and a narrow keel; stamens 10, white, 9 united in a tube and 1 free; pistil with stalked, narrow, red ovary and whitish, curved style. Pod narrow, flat, 10–15 cm × 1.2–1.5 cm, yellow-green when immature, turning yellowish-brown, shortly stalked and with a short mucro, splitting open at maturity, 4–10-seeded. Seed ellipsoid, about 10 mm long, shiny, dark reddish-brown.

Gliricidia sepium (Jacq.) Kunth ex Walp. – 1, leaf; 2, flowering branch; 3, fruiting branch.

Growth and development Seeds germinate in 3–10 days. Early seedling growth is slow, but once established, growth is fast and the annual increase in height may be as much as 3 m. The root system is relatively weakly developed and does not extend strongly laterally. Flowering may start at the age of 6–8 months; abundant flowering takes place during the dry season if the tree has not been coppiced or pruned, after it has shed its leaves. Flowers are insect-pollinated; a wide variety of insects, often large bees, are attracted to the abundant nectar. These may distribute pollen over several kilometres. Pods ripen 40–55 days after flowering, the seeds are mature when the pods turn yellow-brown. Fruiting is relatively uniform, with about 20 days from first to last seed dehiscence. In its native area seed production is usually abundant and can be predictably timed. In more humid areas, shoot growth tends to be continuous and the evergreen tree flowers only sporadically on the basal parts of twigs from which the leaves have fallen.

Other botanical information *G. maculata* has been used extensively as a synonym for *G. sepium*. *G. maculata* has been recently proposed as a distinct species with a different natural geographical distribution. i.e. Yucatan Peninsula, northern Guatemala and Belize. It differs from *G. sepium* in having white flowers and smaller pods and seeds. Most gliricidia planted as exotics can be attributed to *G. sepium*, but former introductions of *G. maculata* cannot be ruled out.

Ecology In its native range the climate is relatively uniformly sub-humid with an annual rainfall of 900–1500 mm and a five-month dry period. Gliricidia has been introduced successfully in more humid zones with up to 3500 mm annual rainfall and without a marked dry season. In its native range the mean annual temperature varies from 20–29°C, the mean maximum temperature of the hottest month from 34–41°C, the mean minimum temperature of the coldest month from 14–20°C. Light night frost is tolerated, but not prolonged frost. Gliricidia occurs naturally in early and middle successional vegetation types on disturbed sites such as coastal sand dunes, river banks, floodplains and fallow land, from sea level up to 1500 m altitude. It can tolerate a wide range of soil types, both alkaline and acidic, but prefers free drainage. It is also more tolerant of acid and low fertile soils than leucaena, but will respond to fertilizer application on such soils. It is not as well adapted to the subtropics as leucaena; leaves are shed with the onset of lower temperatures during winter, and plants are less resistant to frost. It is, however, more tolerant of waterlogged conditions than leucaena. In its native, seasonally dry habitat, trees are often exposed to annual fires. Gliricidia tolerates such fires well and trees quickly resprout when the rains start, which explains the abundance of the tree in secondary vegetations and fallows.

Propagation and planting Gliricidia can be propagated easily by seed and cuttings. Direct seeding is seldom used, and potted plants or bare-rooted stock are raised in nurseries. Fresh seed or seed that has been preserved in cold storage has a germination percentage of 80–90%. Seed may be sown directly in nursery beds or in polythene bags. Seed pretreatment is not necessary. Nursery stock can be transplanted after 10–12 weeks. Vegetative propagation is by large cuttings, 3–6 cm thick and 0.5–2 m long; the bark may be incised to promote rooting. Cuttings should be taken from mature branches with brownish-green bark and planted fresh. Rooting starts 6–7 weeks after planting. Plants grown from cuttings may have 50–150 root nodules after 3 months, compared with 20–70 nodules after 6 months on plants from seed. Trees obtained from cuttings have shallower roots than trees grown from seed. Inoculation with an appropriate strain of *Bradyrhizobium* and fertilization can stimulate growth on degraded lands. On soils with low P content gliricidia is mycorrhiza-dependent; inoculation with ectomycorrhizal fungi (*Boletus suillus*) or vesicular-arbuscular mycorrhizal fungi (VAM) may enhance plant growth.

Gliricidia may be planted in hedges spaced 4–10 m apart with 25–100 cm between trees in the rows, or as live fences with 10–25 cm spacing. When it is used for live posts for black pepper or vanilla the crops can be planted at the same time as the tree. In fodder plots spacings of 0.25 m × 1.0 m or wider may be used; yields of leaves are little affected by planting densities ranging from 5000–40 000 trees/ha. Sometimes, trees are planted at wider spacings (e.g. 10 m × 10 m) over pasture lands. Where animals are grazed in young plantations, young trees must be protected. In woodlots spacings of 1.5–2 m × 2–2.5 m are common.

Husbandry Gliricidia can be managed for either wood or foliage (green manure, fodder) production, for shade, fencing or for live posts. It may be planted in pure stands for the production of fuelwood, as protein banks which are periodically harvested for fodder, or for land reclamation. Hedges may be planted around homesteads, in pastures and along the contours in fields to serve as erosion barriers and be managed for green manure production. Sometimes some of the tree prunings obtained from the alley-cropping system are fed to animals. Experimental data indicate that at low crop yields and low crop response to mulching, feeding part of the tree foliage to small ruminants is economically gainful. Gliricidia hedgerows for fodder production may also be established in existing pastures and interplanted with pasture grasses. In Sri Lanka the tree has been integrated in pastures under coconut to produce dry season fodder. In Bali, Indonesia, gliricidia has been incorporated in a 'Three Strata Forage System' consisting of a strip of 5 m wide, in which fodder trees (*Ficus subcordata* Blume, *Lannea coromandelica* (Houtt.) Merrill, *Hibiscus tiliaceus* L.), shrub legumes (*Gliricidia sepium*, *Leucaena leucocephala*, *Acacia glauca* (L.) Moench) and grasses and herbaceous legumes (*Cenchrus ciliaris* L., *Panicum maximum* Jacq., *Stylosanthes* spp.) are combined. Cattle feed mainly on the grass-legume stratum in the wet season, the shrub legumes in the mid-dry season and leaves from the fodder trees in the late dry season.

A wide variety of agricultural crops or fodder grasses and legumes can be grown together with gliricidia. Although the competitive effect of the tree on crop and pasture grass production depends on the species, site conditions and management it seems to be limited. Due to its open crown and thin foliage and weakly developed root system the tree does not provide heavy competition. In alley-cropping experiments it was found that crop growth next to the hedges is depressed less by gliricidia than by alternative hedge species such as

Erythrina poeppigiana (Walpers) O.F. Cook. Similarly, when used as living posts for yam cultivation, tuber yields were higher with gliricidia than with leucaena. In pastures, gliricidia may be combined with *Panicum maximum* Jacq. var. *trichoglume* Robijns, *Cenchrus ciliaris*, *Urochloa mosambicensis* (Hack.) Dandy, *Stylosanthes scabra* Vogel, and *Stylosanthes hamata* (L.) Taub. Even if grass production is depressed, gliricidia production may compensate for this loss, because the total production is more evenly distributed over the year. Gliricidia has improved the survival of ewes and lambs, lambing percentage, and birth weight and growth of lambs when fed as a supplement to poor quality grass. It is normally recommended that gliricidia be used mixed with either grass, straw or other roughages. When fed to poultry in place of lucerne (*Medicago sativa* L.), levels not exceeding 2–4% are recommended.

Diseases and pests Few serious diseases and pests have been recorded. Some problems with foliar diseases caused by *Pellicularia filamentosa* (India) and *Colletotrichum gloeosporioides* and *Cercosporidium gliricidiasis* (Nigeria) have been noted; in Trinidad a root fungus attacks the tree, but not very seriously. In the Caribbean a number of insects, such as aphids, mealy bugs and scale insects attack the tree. One of the reasons for the popularity of gliricidia is its complete resistance to the leucaena psyllid (*Heteropsylla cubana*), which seriously attacks many cultivars of *Leucaena leucocephala*. When intercropped the tree may affect crop pests positively or negatively. In several cases the tree has been reported to control pests, e.g. termite damage to tea was minimized in Sri Lanka, as was stem-borer damage to rice in the Philippines. In India on the other hand, it was found to increase the number of aphids (*Aphis craccivora*) causing rosette disease in groundnut; in Indonesia, this aphid adversely affected buffelgrass (*Cenchrus ciliaris*) intercropped with gliricidia.

Harvesting The first harvest of gliricidia can be as early as 6–8 months from plants grown from cuttings and 12–16 months from plants grown from seedlings. There should be only one or two harvests per year during the first 2 years. Harvesting should be less intensive (every 3–4 months) in the dry season than during the rainy season (every 2–3 months). Regrowth should be 1–2 m in height before each harvest. To obtain fodder during the dry season the trees should be cut about 3 months before the onset of this season. If trees are not cut 4–6 months before the dry season they will shed their leaves during the dry season. Cutting heights commonly range from 0.5–2 m. Trees grown along contours and in fodder banks are usually cut lower than those cultivated in living fences or as shade trees in pastures, where browsing cattle may interfere with regrowth.

Forage from gliricidia is usually cut by hand and left on the ground for grazing or carried to paddocks or livestock sheds. Acceptable silage can be prepared using standard techniques; the chopped forage may be mixed with grasses or maize and additives such as molasses and sugar cane or formic acid (0.85%) should be added to provide fermentable carbohydrate.

In woodlots the first harvest can be carried out after 3–4 years, giving wood yields of 8–15 m^3/ha. From then on, coppicing is done every 2–3 years yielding up to 40% more than the first harvest.

Yield Under average conditions yields of 3–4 kg dry matter per tree per harvest may be obtained. In Nigeria gliricidia hedgerows interplanted with 4 rows of *Panicum* grasses yielded 20 t/ha per year of mixed dry matter, which was sufficient to feed 3 head of cattle. Annual yields of 9–16 t/ha of leaf dry matter or up to 43 t/ha fresh leaves have been obtained in fodder plots.

In woodlots coppiced every 2–3 years the wood yield varies from 10–20 m^3/ha. Wood production in living fences has been reported at 9 m^3/km per year. Harvested produce is usually used locally.

Marked differences in yield have been found between different provenances (e.g. up to 500% for biomass production).

Genetic resources Major germplasm collections are being maintained at the Oxford Forestry Institute in the United Kingdom, the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Turrialba, Costa Rica), and at the Humid Zone Programme of the International Livestock Research Institute (ILRI, Ibadan, Nigeria). In Asia, collections have been made by the Visayas State College of Agriculture (VISCA, Leyte, the Philippines). The Oxford Forestry Institute administers an international network of provenance evaluation involving 29 provenances from 8 Latin American countries. CATIE collected 49 provenances from Costa Rica; the ILRI Humid Zone Programme has developed a high yield bulk composite from four Costa Rican accessions.

Breeding Early germplasm introductions in many countries usually had a very narrow genetic base and distinct types have evolved in several areas. They are largely arboreal types selected for use as shade trees, and may not be optimally suited for other uses. Provenance evaluations indicate significant differences in growth rate; local landraces in Indonesia, Nigeria, the Philippines and Sri Lanka have been outperformed by new introductions. At some sites large differences in biomass production were found, with some provenances showing superior production of leaves and wood, others with outstanding leaf production but poor wood production. This indicates the need for distinct selection programmes for high-yielding, palatable fodder cultivars, for arboreal cultivars for wood production, or for cultivars combining wood and foliage production. Recently, progeny testing with some superior provenances has started as a basis for future seed orchard establishment. Rapid genetic gains can be expected, as seed production starts early, superior types can be cloned and production cycles are short.

Prospects *G. sepium* is an extremely versatile multipurpose tree well adapted to a wide range of humid and sub-humid areas and soil conditions, including acid and infertile soils. Favourable properties include its versatility and ease of incorporation in a variety of agricultural production systems. It can be grown together with arable crops in alley-cropping systems, with fodder crops such as grasses or small legumes, or as shade trees in perennial crops. Its auxiliary effect on other crops is facilitated by its relatively open crown and non-spreading root system causing little competition. Plant residues of gliricidia have a relatively high nutrient level and decompose quickly thus having a high direct nutritional contribution to crops but a low mulching effect. It is also showing considerable promise as a fodder crop throughout the tropics, although the quality (anti-nutritional factors) of its forage is still being debated. Although most fodder is produced in the wet season, the tree can be managed to provide fresh leaf during the dry season. Its prospects may be further enhanced by breeding programmes to improve production and forage quality and the development of innovative production systems such as the 'Three Strata Forage System'. It has excellent properties for site reclamation, including suppression of obnoxious weeds such as *Imperata cylindrica* (L.) Raeuschel.

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K.F. Wiersum & I.M. Nitis

Grevillea robusta A. Cunn. ex R. Br.

Suppl. prodr. fl. Nov. Holl.: 24 (1830).

PROTEACEAE

$2n = 20$

Vernacular names Silky oak, silver oak (En). Silk oak (Am). Indonesia: salamandar (Sundanese). Thailand: son-india (central). Vietnam: ng[aa]n hoa (northern), tr[ax]i ban (southern).

Origin and geographic distribution *G. robusta* occurs naturally in Australia, over the latitudinal range of 26–30°S in southern Queensland and northern New South Wales from the coast up to 160 km inland. It has been introduced into warm temperate, subtropical and tropical highland regions around the world and is widely planted in India, Sri Lanka and many countries in Africa. It performs poorly in lowland tropical environments and is not grown very commonly in Malesia.

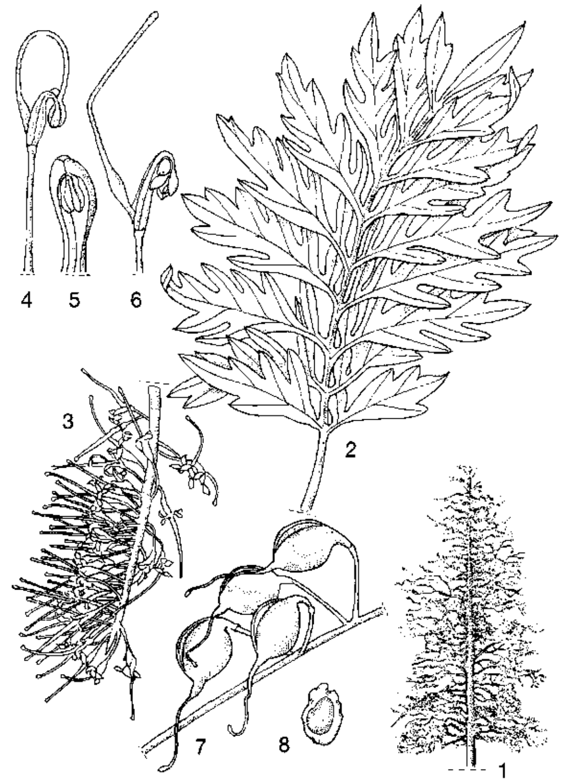
Uses *G. robusta* is used to provide high shade for tea and coffee plantations in southern Asia and Africa. It is now very popular in agroforestry systems in the highlands of east and central Africa, being planted in rows along farm boundaries and between fields, and scattered among crops. It is regarded as more compatible with crops on small farms than most other tree species. In Burma (Myanmar), it is planted on a limited scale as a shade tree in coffee plantations.

The wood is used for firewood, poles and sawn timber. The leaves are applied as mulch. Some farmers in Kenya use fresh leaves as a dry-season fodder supplement for cattle. *G. robusta* has some value for honey production. It is planted in many countries, e.g. in Thailand, for shade and ornamental purposes because of its attractive fern-like foliage and brilliant orange floral display. The cut leaves are used in flower arrangements and young plants are grown as indoor pot plants in Europe.

Properties Leaves contain rutin, a quercetin glucoside (about 0.6 g per 100 g dry matter). Through contact with the leaves sensitive persons may develop contact dermatitis due to tridecylresorcinol, a chemical compound related to the allergen of *Toxicodendron* spp. (*Anacardiaceae*). Gum from *G. robusta* exudates contains small amounts of hydroxyproline, a free amino acid, in addition to galactose and arabinose. The flower buds, fruits and seeds are cyanogenic. Seed extracts exhibit antifungal activity. The weight of 1000 seeds is 10–20 g.

The air-dry density of the heartwood is 550–600 kg/m^3, that of sapwood and branches is lower. The sapwood is cream-coloured, heartwood pale pink or red-brown after drying. Broad rays give the wood an attractive appearance on both the quartersawn and backsawn faces. The sawn timber is of medium strength and is used for furniture, flooring, packing cases, and the manufacture of small wooden items. The wood is used for firewood in African countries, and trials indicate it is suitable for pulping. Mean fibre length is about 1.5 mm and width about 26 μm. Some fair-skinned people are allergic to the sawdust.

Description An erect, single-stemmed tree up to 25(–40) m tall with a stem diameter of 50 cm or more and with a strong taproot. Crown conical and symmetrical with major branches spaced at intervals of about 1 m, projecting upwards at a 45° angle. Bark dark greyish-brown, rugged, furrowed. Branchlets angular and ridged, subsericeous to tomentose, becoming glabrous on older growth. Leaves pinnate with (4–)10–20 pinnatifid segments, fern-like; petiole 1.5–6.5 cm long; blade in outline 10–34 cm × 9–15 cm, secondary lobes or segments entire or again lobed, lanceolate or rarely linear, terminal one mostly longer than 2.5 cm, margins recurved, upper surface glabrous, green, lower surface subsericeous, silvery. Inflorescence a raceme, 7–12 cm long, simple to 4-branched from near the base, borne on very short, leafless, tomentulose branches on the older wood, many-flowered and all flowers pointing one way; rachis slender to stoutish, glabrous; pedicel 1.5 cm long, glabrous; flowers borne in pairs, 2 cm long, bright orange to golden-yellow or golden-brown; tepals 4, glabrous inside and outside, tube 0.6–1 cm long, rolled back under the 3 mm long ovate



Grevillea robusta A. Cunn. ex R. Br. – 1, habit; 2, leaf; 3, inflorescence; 4, young flower with stigma retained in bud; 5, tepal with anthers directly attached; 6, mature flower with extended style and stigma; 7, fruits; 8, winged seed.

limb, with concave apex of each tepal holding a small anther 0.1 cm long; receptacle slightly oblique with prominent disc; ovary glabrous, stipitate; style filiform, 1.5 cm long, protruding from a slit on the lower side of the perianth tube before the apex is free from the limb, accrescent during and after anthesis, ultimately straight and erect, bearing the small stigma at its apex. Fruit a 2-seeded follicle, broad, very oblique, boat-shaped, pointed, 1.5–2 cm long with a slender persistent style. Seed flat-ovoid, 13–19 mm × 8–10 mm × 0.8–0.9 mm, brown, with papery wing all around.

Growth and development Seed germinates readily in a moist environment. The optimum temperature for germination is about 25°C. Seedling growth is quickest during the summer months at temperate latitudes, and during the wet season in tropical highlands. In its natural range *G. robusta* is semi-deciduous, shedding most of its leaves in the dry spring. Substantial leaf fall is also noted in the dry season in tropical environments. When climate and soil are suitable and weed competition not severe, annual height and diameter increments of at least 2 m and 2 cm respectively are usually achieved for the first few years in row plantings on farms. Annual height increments of 3 m have been observed at the most favourable sites.

The tree first flowers when about 6 years old. In the region of natural occurrence, flowering occurs over a few weeks in October–November, but when planted in equatorial latitudes, flowering is sporadic throughout the year, or absent as in Jakarta. During flower development the style protrudes through a slit in the lower side of the perianth tube before the perianth apex opens, giving the flower a 'looped' appearance. At anthesis, the apex of the perianth opens and the perianth falls away, depositing pollen on the stigma. Studies in Australia show that at the time of pollen deposition the receptive cells of the stigma are still covered by protective cells. The stigma does not become sticky and receptive until several days after anthesis, by which time the pollen has usually fallen off. Birds attracted by the nectar produced by the scales around the gynophore are believed to be the principal pollinating agents. The period from fertilization to fruit maturity is about 2 months. Fruits open during hot, dry weather, releasing the seeds, which can be carried considerable distances by wind. Seeds exhibit no dormancy, and remain viable for at least two years if dried to below 8% moisture content and stored dry and cool (20°C or less).

Proteoid roots develop seasonally near the growing tips of the young roots; these regions with a cylindrical mass of finely-divided root hairs are believed to increase the plant's ability to take up water and nutrients under unfavourable conditions.

Ecology *G. robusta* occurs naturally in two distinct habitats. It grows in riverine rain forest of the *Castanospermum australe* A. Cunn. & C. Fraser ex Hook. association, usually within a few dozen metres of the water's edge on soils of fairly high fertility and good moisture availability. It also occurs away from the rain forest along creeks and rivers in association with *Casuarina cunninghamiana* Miquel. The second major habitat is the vine forest dominated by *Araucaria cunninghamii* Aiton ex D. Don, which covers extensive areas including steep upper-valley slopes. This type of forest is found on basalt-derived soil. *G. robusta* occurs at very low densities in these forests. Climatic studies in the areas of natural and planted occurrence indicate the following ecological requirements for satisfactory growth: mean maximum temperature of hottest month 25–31°C, mean minimum temperature of coldest month 2–12°C, mean annual temperature 14–23°C, mean annual rainfall 700–1700 mm, dry season 0–6 months (0–4 months on shallow soils or towards the hotter extreme of the acceptable temperature range). Rainfall distribution has a summer maximum in the region of natural occurrence, but *G. robusta* also grows well in climates with a winter maximum or a bimodal rainfall distribution. Growth is best over the altitudinal range of 130–2300 m at equatorial latitudes, the preferred altitudinal range decreasing to 0–1000 m at 30° latitude. In temperate areas *G. robusta* can survive moderate winter frosts. It is not resistant to persistent strong winds.

Soils should be of moderate to high fertility with pH of 4.5–8; heavy clays and waterlogging are not tolerated. On acid soils, symptoms of boron deficiency and manganese toxicity have been observed.

Propagation and planting *G. robusta* can be propagated by seed and by cuttings. No pretreatment of seed is required for germination. Seeds are usually germinated on loamy soil with a thin covering of sand. Seedlings are pricked out when their second leaf pair starts to develop and are put into tubes containing a fertile loamy potting mix. Seedlings are grown in the nursery until planting out during the rainy season when a height of 20–40 cm is attained. Farmers also obtain planting stock by digging up wildlings. Cuttings can easily be established using shoots from seedlings or saplings, which can also be air layered. A plant density of 800–1200 trees per ha is recommended for plantations.

Husbandry Some control of competing vegetation is required for the first 1–2 years after planting. This is normally achieved by manual weeding. Fertilizer is seldom applied; 50 g per tree of an NPK fertilizer (12:12:12) applied shortly after planting would be appropriate for infertile soils. If symptoms of boron deficiency such as dieback of main leader, bronze leaf colour and loss of leaves become apparent, an application of about 100 g of borax per tree at planting or preferably the equivalent amount of the less soluble ulexite is recommended.

G. robusta regrows well after complete defoliation following pruning and pollarding, which can be carried out repeatedly to yield wood and to regulate shading and competition with adjacent crops.

Diseases and pests In the lowland humid tropics and other very humid regions *G. robusta* is vulnerable to attack by fungal diseases such as *Corticium salmonicolor*. Fungi such as *Amphichaeta grevilleae*, *Cercospora* sp. and *Phyllostica* sp. have been observed to cause considerable damage to leaves and stems of young plants in Sri Lanka, particularly if they are overwatered in the nursery. Under lowland conditions in the Caribbean *G. robusta* is severely attacked by the scale insect *Asterolecanium pustulans*. Attack by termites can be a problem when it is planted on dry sites in Africa. In Peninsular Malaysia the big white ant *Termes gestroi* destroyed experimental trees.

Harvesting Farmers in the East African highlands commonly harvest branches of *G. robusta* by high pruning and pollarding every 3–4 years from 4–6 years after planting onwards, using the leaves for mulching or sometimes as cattle fodder. The main trunk of the tree may be harvested as a sawlog from the age of 15–25 years.

Yield When grown in monoculture in woodlots or plantations, annual wood increments of 10–15 m^3/ha of *G. robusta* as measured over bark with stem diameter down to 10 cm have been recorded in rotations of 10–20 years in Uganda, Kenya and Hawaii.

Handling after harvest Firewood of *G. robusta* dries quickly, within a few days of cutting, except in wet weather. Logs are commonly pit-sawn green in rural areas. Timber for external use has to be treated chemically to improve its durability. It is susceptible to attack by *Lyctus* borers.

Genetic resources Isozyme studies have demonstrated that the genetic base of *G. robusta* in a number of African countries is very narrow. In recent years the Australian Tree Seed Centre of the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Queensland Forest Service have distributed seed collections from natural provenances, covering the altitudinal and geographical range of sites where it occurs, for evaluation in other countries.

Breeding Studies of reproductive biology and genetic improvement programmes have commenced in several African countries, coordinated by the International Centre for Research in Agroforestry (ICRAF). Several provenance and progeny trials have been established in Africa and India, and selection of preferred genotypes has commenced in Kenya.

Prospects Because of the importance of *G. robusta* in the tropical highlands of Africa, considerable research effort has started in the fields of genetic improvement and silviculture for agroforestry. *G. robusta* is little used in South-East Asia, but could be of substantial value as an agroforestry tree for use on small farms in the highlands of countries such as Burma (Myanmar), Indonesia, Laos, the Philippines and Vietnam.

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C.E. Harwood

Homonoia riparia Lour.

Flora Cochinch.: 637 (1790).
EUPHORBIACEAE
$2n = 42$ (44)

Synonyms *Adelia neriifolia* Heyne ex Roth (1821), *Lumanaja fluviatilis* Blanco (1837), *Ricinus salicinus* Hassk. (1844).

Vernacular names Water-willow (En). Indonesia: sobah (Javanese), jurai (Sundanese), sangkir (West Sumatra). Malaysia: kelereh, mempenai, kayu suarah. Philippines: agukuk, agoyoi, managos (Tagalog). Burma (Myanmar): momakha. Cambodia: réi tük. Laos: kh'aiz fa:d. Thailand: khrai-nam, khrai-hin (peninsular), khrai (central, northern). Vietnam: ru ri, ri ri, cay ru ri nuoc.

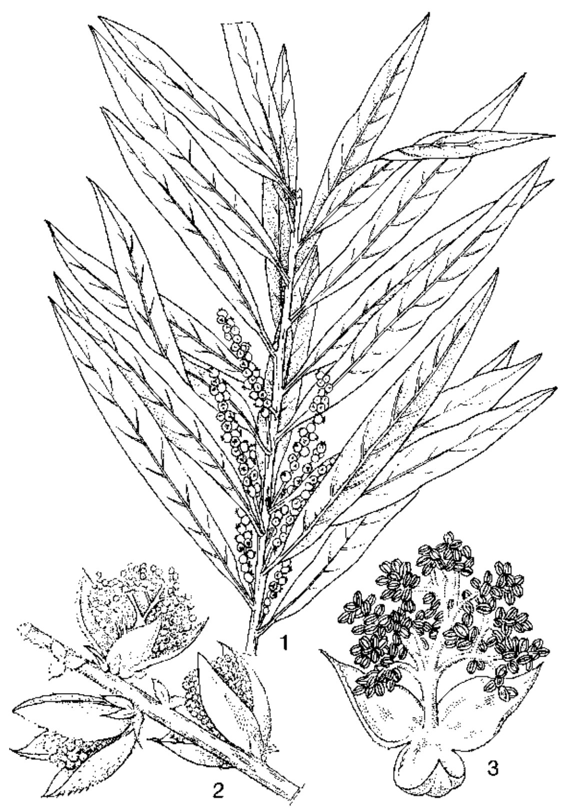
Origin and geographic distribution *H. riparia* is widely distributed in Asia from India through Indo-China and southern China to Taiwan and from Peninsular Malaysia, throughout Indonesia and the Philippines to Papua New Guinea.

Uses Because of its long and extended root system *H. riparia* is planted along rivers and streams to stabilize and protect the banks. Stems and branches provide firewood. In southern China the bark is used as rope. Leaves are eaten as a vegetable in the Philippines and can be used for fodder as well. In Sabah the root is used to make handles.

H. riparia provides a number of popular local medicines. In Laos, a decoction of the leaves is used against itches. In Cambodia, the stems and leaves are applied as a purgative, whereas an infusion of the wood is used against malaria and scabies. In Java, leaves were used to blacken teeth and to fix loose ones. The pounded leaves and sometimes fruits are applied as a poultice against skin diseases in Malaysia, Thailand and Cambodia. A decoction of the leaves and fruits is similarly effective. Young shoots and leaves are a component of a hair oil in Cambodia.

Properties Seeds contain a fatty oil. Most parts of the plant have a high tannin content. The bark contains cyanogenic glycosides. The grey-brown wood is moderately hard and close-grained.

Botany A gregarious shrub or small, crooked and twisted tree, 1–4 m tall, up to 10 cm in stem diameter, forming a woody, deep and extensive root system. Branches smooth to slightly grooved. Leaves alternate, simple; stipules keel-like, enlarged at base, 5–6 mm long, caducous; petiole 5–15 mm long, pubescent; blade narrowly lanceolate to oblong, 4–20 cm × 1–2.5 cm, obtuse or rounded at base, acuminate, obtuse or mucronate at apex, bright green, penninerved, thin, chartaceous, upper surface shiny, glabrous, lower surface pubescent, closely glabrescent and minutely lepidote, margin entire or dentate. Male inflorescence an axillary, densely-flowered spike, 5 cm long or more, pubescent; peduncle grooved; bracts triangular, acuminate; flowers solitary, axillary, with two lateral, sterile bracteoles; sepals 3, minute, mucronate; stamens numerous, united in fascicles or bundles which at base are connate into a common trunk, unilocular. Female inflorescence an elongated, pauciflorous spike, to 7 cm long; flowers sessile, axillary, bracteate; sepals 5, ovate, 1.5–2 mm long, acuminate, imbricate, abaxially puberulous; ovary globose, trilocular, 2 mm in diameter; style tripartite, 5 mm long, strongly papillate, basally united over a short distance. Fruit a



Homonoia riparia Lour. – 1, fruiting branch; 2, part of male inflorescence; 3, male flower.

globose capsule, 4 mm in diameter, puberulent, tricoccous. Seed ovoid, 2 mm long, crustaceous.
In seasonal climatic conditions *H. riparia* is deciduous. In Vietnam it flowers from April to June and fruits from August to October. In West Java flowering and fruiting is from June to November, in Central Java it flowers from June to October and fruits from September to April. Most plants are unisexual, but sometimes male and female flowers can be found on the same plant.

Ecology *H. riparia* is restricted to river banks, lake shores and rocky stream beds, from 50–500 m altitude. In its natural habitat it is regularly flooded, at least annually. Its extended root system protects it against uprooting during floods; even floods that completely submerge the shrub during the rainy season for up to 9 months per year can be withstood (such plants are called 'rheophytes').
It is found under ever-wet and seasonal climatic conditions, preferring exposed sunny sites on stream banks and in stream beds in not too deep or too swift streams. As to the stream bed soil, *H. riparia* seems to have no preferences; it occurs on sand, granite, shale, andesite, and other volcanic-derived material, but also on calcareous soil.

Agronomy Since *H. riparia* is only occasionally planted on river banks hardly any information on its cultivation is known to exist. It can be propagated by seed and by cuttings.

Genetic resources and breeding It is unlikely that any germplasm collections of *H. riparia* are being maintained.

Prospects *H. riparia* is a good source of firewood because the woody roots, stems and branches are hard and have a high energy value. Its strong and extended root system and strong, branched stem make it a useful plant to protect river banks. Its strong bark is worth testing for fibre.

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Nguyen Nghia Thin

Indigofera hendecaphylla Jacq.

Collectanea 2: 358 (1789).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 16$ (diploid), 32 (tetraploid)

Synonyms *Indigofera celebica* Miquel (1855), *I. siamensis* Hoss. (1907), *I. spicata* Forssk. sensu auct. mult. Note: *I. hendecaphylla* is often misspelled *I. endecaphylla*.

Vernacular names Creeping indigo (En). Trailing indigo (Am). Indigotier rampant (Fr). Indonesia: basingan, sibar (Sumatra), baleh angin (Sulawesi). Thailand: khram-khrua (northern). Vietnam: ch[af]m b[uj]i.

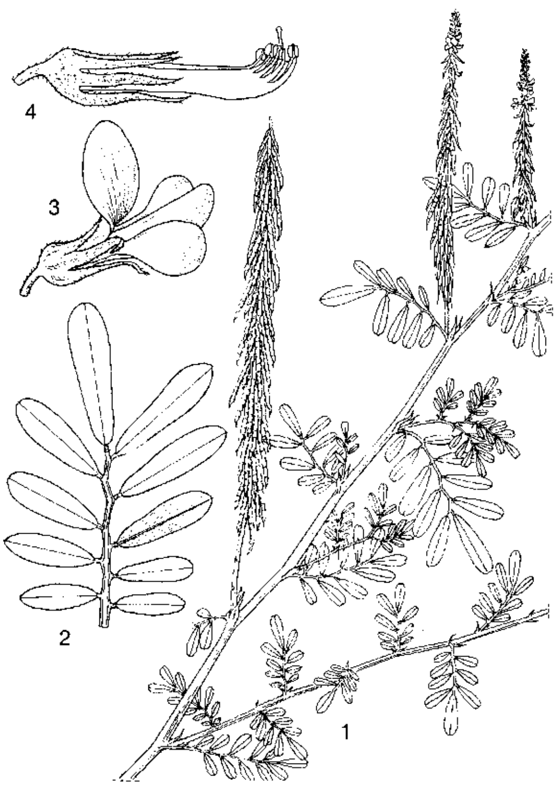
Origin and geographic distribution *I. hendecaphylla* occurs naturally in Africa, Madagascar, throughout South and South-East Asia and in Papua New Guinea. It was taken into cultivation in Java and Peninsular Malaysia in 1923 from Sri Lanka. Cultivation spread from Java to the Philippines in 1927. *I. hendecaphylla* has been grown experimentally in Australia and has become naturalized in northern Queensland. Later, it was brought to the Americas, where it is widely cultivated in Hawaii, Jamaica, Puerto Rico, and Florida.

Uses *I. hendecaphylla* provides a good soil cover and smothers weeds. In tea estates in Sri Lanka *I. hendecaphylla* was the most popular green manure and cover crop. In Indonesia and Peninsular Malaysia it is used as a cover crop in rubber, sisal, oil palm and tea plantations; in Africa in coffee plantations. Some strains of *I. hendecaphylla*, especially those from Africa, provide valuable and palatable fodder, but the leaves and seeds of other strains are highly hepatotoxic.

Properties Tests in Sri Lanka and Indonesia indicate that green material contains per 100 g dry matter: organic matter 87.4 g, ash 12.6 g, N 3.1 g, P 0.2 g, K 1.3 g, Ca 2.6 g. Analysis of the leaves and stems used for fodder gave the following values per 100 g dry matter: protein 20.5 g, fat 3.0 g, soluble carbohydrates 39.5 g, fibre 23.5 g, ash 11.0 g; the digestibility of the components

was: protein 76%, fat 67%, soluble carbohydrates 81%, fibre 60%.
The leaves of *I. hendecaphylla*, possibly only of tetraploid forms originally from Sri Lanka, contain per 100 g dry matter 0.1–0.5 g indospicine (2,7-diamino-7-amino-heptanoic acid) while the seeds contain 0.1–2 g. Indospicine is a specific antagonist of arginine, interfering with its synthesis and incorporation into proteins and with the synthesis of DNA. Indospicine is highly toxic to chicken, rabbits, pigs, goats, sheep, cattle and horses. In small doses it causes loss of vitality and abortion in cattle and goats. Indospicine is especially dangerous to horses, which relish plants containing it and eat them preferentially. *I. hendecaphylla* also contains nitrogenous compounds called endecaphyllins, as well as 3-nitropropionic acid.
The weight of 1000 seeds is about 20 g.

Description Sub-erect shrublet (20–)40–75 cm tall, gradually becoming prostrate. Main root 50–100 cm × 0.5–1 cm, white. Stem creeping, up to 2 m long, rooting at the nodes, pale green to yellow, tough; branches ascending, striate, with appressed, biramous hairs with equally long arms. Leaves pinnate, alternate, 3–5 cm long; stipules narrowly triangular, apex caudate, 5–6 mm × 1.5–2.0 mm; petiole 1–3 mm long; leaflets 9–11, shortly petioluled, alternate, sometimes almost opposite, narrowly oblong-elliptical to narrowly oblanceolate, 3–20 mm × 2–9 mm, apex rounded, mucronate, upper surface subglabrous. Inflorescence an axillary raceme, 5–17(–23) cm long; flowers 4–6 mm long, crowded, brick red to pink, occasionally purple or white; pedicel about 1 mm long; calyx tube 1.5 mm × 1.5 mm, teeth narrowly triangular, 2.5–3 mm long; standard broadly ovate 4.0–5.5 mm × 3.0–4.0 mm, strigose on the back; wings 3.0–4.5 mm × 1.5–2.0 mm, glabrous, margins long-ciliate along the upper auricle; keel 3.5–5.0 mm × 2.0–2.5 mm, hairy, margin ciliate, lateral pocket 1 mm long; staminal tube 4–5 mm long, apex rounded to obtuse, anthers 0.5 mm × 0.5 mm; ovary glabrous. Fruit a descending, straight, needle-like, dark brown pod, stiff, somewhat quadrangular to round in cross-section, 2.0–3.5 cm × 2–2.5 mm, 5–10-seeded, beak 2 mm long, endocarp not blotched. Seed very small, cubic to quadrangular-ellipsoid, 2 mm × 1 mm, yellowish to dark brown.



Indigofera hendecaphylla Jacq. – 1, flowering and fruiting branch; 2, leaf with one inverted leaflet; 3, flower; 4, calyx and staminal sheath.

Growth and development Seedlings develop a strong taproot which assists in loosening the soil. When cuttings are used for planting *I. hendecaphylla* remains very low, the cover rarely exceeding 12 cm in height. A fair cover can be formed in 6 months and a continuous even cover in a year from planting. The plants send out trailing stems which, under favourable conditions, may attain a length of 2 m, producing numerous adventitious roots at the nodes. As the plants mature they become taller and at 2 years of age they are usually about 30–40 cm tall. Vigorous regrowth occurs at the start of the rainy season.

Other botanical information *I. hendecaphylla* and *I. spicata* Forssk. used to be considered as the same species and were then named *I. spicata*. They are now considered to be different species. The literature is therefore confusing, and references to toxicity most probably refer to *I. hendecaphylla*. In *I. hendecaphylla* the staminal tube is 4–5 mm long, distinctly longer than the calyx, the apex of the keel rounded to obtuse, and leaves have 9–11, narrowly oblong-elliptical to narrowly oblanceolate leaflets. In *I. spicata* the staminal tube is 3–3.5 mm long, not exceeding the calyx, the keel apex acute, while the leaves have 5–8 obovate leaflets with cuneate base. *I. spicata* is restricted to Africa and Yemen, often in the drier regions. *I. hendecaphylla* occurs pantropically, often in more humid areas; it is a very variable species and many varieties have been described, distinguished by leaflet form and hairiness. These distinctions are not considered useful, because many intermediate forms occur.

Ecology *I. hendecaphylla* thrives from 0–700 m altitude and is found to about 2500 m. It requires an average annual temperature of 16–27°C and an annual rainfall of 600–1500 mm, but may be found in wetter locations receiving up to 4000 mm annual rainfall. In cultivation it is fairly resistant to drought and shade. Under heavy shade, as in old rubber plantations, growth is poor. *I. hendecaphylla* performs best on clay soils, but grows on various soil types, including sandy soils, with a pH of 5.0–7.7. It is tolerant of poor, moderately acid, P-deficient soils. Soil covers of *I. hendecaphylla* are notorious for harbouring snakes and leeches.

Propagation *I. hendecaphylla* can be propagated by seed and by stem cuttings. Seed is very hard and germinates poorly without scarification. Mechanical scarification and treatment with sulphuric acid for 40–60 minutes can increase the germination rate to about 80%. To obtain a good distribution of the seed it is mixed with sand or filtered dry soil at a ratio of seed to sand of 1 : 4 before sowing. If planted in rows 60 cm apart the seed rate is about 3.3 kg/ha. Cuttings are used when seed is difficult to obtain. For large-scale plantings, they should be raised in nurseries. Cuttings of about 20 cm long are planted at a spacing of 60 cm × 60 cm with 5 cuttings per hole. Once established, *I. hendecaphylla* is self-sowing.

Husbandry The maximum effect of *I. hendecaphylla* as a green manure is reached when the cover crop is incorporated in the soil when still green and flowering has started. Green manure crops produce 4.5–25 t/ha of green material. In trials in Indonesia *I. hendecaphylla* has produced a green matter yield of 3.0 t/ha 3 months after planting, containing 10 kg nitrogen and 3 kg phosphorus. After 6 months the green matter yield was 18 t/ha, containing 86 kg nitrogen and 21 kg phosphorus.
A cover crop of *I. hendecaphylla* controls erosion effectively on hilly and undulating land even under heavy rainfall, and is considered more effective than *Clitoria ternatea* L. Few weeds, except some grasses, can grow through this cover and, once established, a reduction in weeding costs may be anticipated. Weeds such as *Mikania* spp. and *Convolvulus* spp. can cause some trouble. When ring-weeding around young tea plants the stems of *I. hendecaphylla* have to be cut, as these are otherwise difficult to incorporate into the soil.

Diseases and pests *I. hendecaphylla* is remarkably free from diseases. The only important pest in Sri Lanka is the caterpillar *Dichomeris ianthes*, which sometimes completely defoliates the crop; however, it normally recovers very quickly. In Peninsular Malaysia, the plant is liable to attacks by the larvae of a small moth, probably *Lamprosema diemenalis*, but the damage is not permanent.

Genetic resources and breeding A germplasm collection of *Indigofera* L. is being maintained at the Southern Regional Plant Introduction Station of the United States Department of Agriculture, Griffin, Georgia containing a few accessions of *I. hendecaphylla*. Strains with a reduced indospicine content have been bred in Australia, but indospicine-free material has not yet been obtained.

Prospects *I. hendecaphylla* remains an excellent cover crop, providing a dense, well-rooted, low cover in humid areas. In drier areas growth is too slow. More research is needed on the variation in indospicine content, its relation with polyploidy and its presence in African material. Strains from Africa that have been used as fodder crop may be developed into cover crops safe for farm animals.

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B. Sunarno

Indigofera hirsuta L.

Sp. pl.: 751 (1753).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 16$

Synonyms *Indigofera indica* Miller (1768), *I. ferruginea* Schum. & Thonn. (1829), *I. angustifolia* Blanco (1837).

Vernacular names Hairy indigo (En). Rough hairy indigo (Am). Indigotier hérissé (Fr). Indonesia: tom-toman, jukut lulut (Java), tebawang amjak (Sulawesi). Malaysia: cermai burong. Philippines: tayom (Iloko), tagum (Bisaya), tina-tinaan (Tagalog). Papua New Guinea: tildjil, wiereka. Thailand: khram-khon (northern). Vietnam: c[aa]y c[or] ch[af]m, c[aa]y s[uj]c s[aj]c ma, ch[af]m l[oo]ng.

Origin and geographic distribution *I. hirsuta* is native to Asia and Africa. It was cultivated as a green manure in Bogor in the 19th Century and was first tried as such in Malaysia in 1913. It was introduced into the United States in 1908 and proved suitable for cultivation in the coastal regions of Florida and Texas. It is now cultivated throughout the tropics.

Uses *I. hirsuta* is a valuable green manure and cover crop, used especially in tea, coffee and rubber plantations. Research interest in hairy indigo as a cover crop or green manure in South-East Asia has been limited in recent years. In Florida it is often considered a weed in row-crop fields, but in citrus plantations it is grown as a cover crop. It is used especially where erosion control is important.

It is grown as an annual fodder in Florida and Brazil and in mixtures with grasses as a forage crop. A decoction made from the leaves is used against stomach problems in the Philippines, and against yaws in Ghana. In West Africa it has occasionally been used as a dye.

Properties Per 100 g dry matter, leaves contain: N 2.14 g, P 0.12 g, K 1.53 g, and Ca 3.00 g. Hay cut at the flowering stage contains per 100 g: moisture 10.7 g, crude protein 13.7 g, crude fat 1.4 g, N-free extract 46.0 g, fibre 21.0 g, ash 7.2 g; digestibility coefficients are: dry matter 62.5%, protein 67.0%, fat 61.0%, N-free extract 67.0%, fibre 53.5%. Cattle do not graze hairy indigo readily, but intake is good after adaptation. It is somewhat toxic and should not constitute a large proportion of the diet. Cattle grazing on it for extended periods of humid weather may develop sores on their feet and legs. It is believed that the hairs of the plants irritate their wet skin.

The weight of 1000 seeds is 1.5–2.5 g.

Description Annual herb or subshrub, up to 1.5 m tall, covered with conspicuous brown hairs, which are biramous and spreading with very unequally long arms, looking almost simple. Branches erect, striate, becoming woody at seed maturity. Leaves imparipinnate; stipules narrowly triangular to linear, 10–12 mm long; petiole 2–5 cm long; rachis up to 9 cm long; stipels 1–2 mm; petiolule 1.5–3 mm long; leaflets 5–11, opposite, elliptical to obovate, terminal one 2.5–3.5(–6) cm × 1–2(–3) cm, lateral ones 1.5–3 cm × 0.7–1.5 cm, base cuneate, apex rounded, mucronate, hairy to strigose on both surfaces, veins distinct, main vein brown. Inflorescence a densely flowered raceme, (3–)10–30 cm long; bracts linear-triangular, about 4 mm long, caducous; peduncle 3 cm or longer; pedicel about 2 mm long; flowers up to 6 mm long; calyx about 4 mm long, with stiff brown hairs, divided almost to the base into linear, setaceous

Indigofera hirsuta L. – 1, flowering and fruiting branch; 2, flower; 3, fruiting branch.

lobes; corolla red to pink; standard elliptical, 4–5 mm × 2–2.5 mm, emarginate at apex; white pubescent outside; wings 4–5 mm × 1.5 mm, hairy at upper margin; keel 4–5 mm × 1.2–1.5 mm, upper margin with hairs, lateral pocket 0.7 mm long; staminal tube 4.5 mm long; anthers 0.4 mm long; ovary hairy with 6–9 ovules. Fruit a reflexed, straight pod, rounded to tetragonal in cross-section, 1–2 cm × 1–2.5 mm, with well developed sutures, and with long spreading hairs, dehiscent, (4–)6–9-seeded, endocarp blotched. Seed cuboid, 1 mm long, brown, distincly pitted.

Growth and development Early growth of seedlings is very slow. Weeding is therefore only possible after 4–6 weeks, when plantlets can be distinguished from weeds. Under suitable conditions the plants reach a height of 30 cm after about 50 days, 60 cm after 65 days and 90 cm after about 80 days. In Sri Lanka, *I. hirsuta* flowers and fruits from September to February and in the United States it flowers late in the growing season, producing a good green manure or forage crop before seed maturation. Pollination is by insects. Hairy indigo fixes atmospheric nitrogen symbiotically with cowpea-type rhizobium.

Other botanical information *I. astragalina* DC. is sometimes included in *I. hirsuta*, forming a single, polymorphic species. *I. astragalina* usually has more leaflets than *I. hirsuta*, often whitish hairs, a shorter peduncle and paler flowers. It occurs in the Sudano-Sahel zone, south-eastern Africa, Pakistan, India, Sri Lanka and Burma (Myanmar). Where both species occur in the same region, *I. hirsuta* occupies the wetter areas. Genetic diversity in hairy indigo is greatest in Africa, from where cultivars have been reported showing tolerance to diseases, pests, weeds, low pH, poor soil, and shade.

Ecology *I. hirsuta* occurs as a weed in cultivated and waste areas, in grassland, savanna, dry and deciduous forest, on river banks and beaches, at 0–1500 m altitude. It requires an annual rainfall of 900–2500 mm and an annual mean temperature of 15–28°C. It does not tolerate frost. A dry season stimulates flowering and seed production. Although generally fairly tolerant to shade, growth under heavy shade in an established stand of pine trees in Costa Rica was poor. Hairy indigo is tolerant to poor soil conditions, growing well on moderately poor, sandy soils with low pH, and on slopes. It requires moderately to well-drained soils with a pH of 5–8 and is intolerant of waterlogging.

Propagation and planting *I. hirsuta* is propagated by seed. Germination percentage is often low, but can be improved by hot water treatment (70–80°C for 20–30 minutes). Seed of early selections is smaller than that of later ones. In Florida, hairy indigo is sown from early to late spring, with early sowing being preferred. When drilled in closely spaced rows a seeding rate of 3–5 kg/ha is used; when broadcast in a well firmed seed-bed 6–10 kg/ha of seed is needed. Lower rates are recommended for seed production. Seed should preferably be sown at a depth of 1 cm, but may be broadcast without any follow-up soil cultivation. Trampling by cattle and rain will result in the seed being covered sufficiently. Seed germinates after 7–9 days. Under grazing in Florida, hairy indigo is a self-regenerating annual, even in fields that are burned or disked.

In permanent, mixed pastures, cattle need not be removed during the period of seed development. Reducing grazing intensity is sufficient to produce enough seed for a volunteer crop. Disturbing the soil superficially results in a better volunteer crop.

Husbandry In the United States, weeding and earthing up is done 1–1.5 months after planting and again 1 month later. Cover crops in tree-crop plantations are slashed at regular intervals. Slashing and lopping is tolerated well. Phosphate and potash applications increase growth, recommended amounts in Florida are: P_2O_5 30–70 kg/ha and K_2O 30–50 kg/ha. Hairy indigo can be relay-planted in maize. When planted 40 days after germination of maize, it produces a dense soil cover soon after the maize harvest, yielding 4–5 t dry matter per ha containing about 100 kg of nitrogen. Established mixed grasslands should be grazed closely at the beginning of the growing season until *I. hirsuta* germinates and establishes itself.

Diseases and pests *I. hirsuta* exhibits some tolerance to most diseases and pests. The following fungi have been reported as occurring on hairy indigo but without causing serious dieseases: *Colletotrichum dematium*, *Corticium solani*, *Rhizoctonia solani*, and *Sclerotium rolfsii*. It has shown extensive tolerance to root-knot and sting nematodes. Experiments indicate that hairy indigo in a rotation markedly reduces the numbers of several *Meloidogyne* spp. Genetic variation in tolerance and antagonistic effects to nematodes is considerable and should be further investigated.

Harvesting *I. hirsuta* can be harvested as common hay crops with ordinary farm equipment. It should be cut early when 75–90 cm tall. If cut early when 20–25 cm tall before flowering, a second growth may be expected. The regrowth may then

be used for grazing or hay. Grazing should be rotational, to prevent severe removal of leaves.
Seed can be harvested by cutting the infructescences by hand. Very large plants may be cut with a mowing machine, allowed to dry in windrows and threshed. Stands that are not too heavy can be combine harvested. Harvesting should be done when seed is mature, but before shattering. Seed set is abundant. In the United States seed of large-seeded strains matures in late autumn, while smaller-seeded strains mature 3–4 weeks earlier.

Yield In Florida green matter yields of *I. hirsuta* average about 22 t/ha (13 t/ha dry matter) and in coconut plantations in India 10 t/ha. Seed yields average 100–300 kg/ha. No information is available on yields in South-East Asia. In Florida in mixed stands with pangola grass (*Digitaria eriantha* Steudel) or Bahia grass (*Paspalum notatum* Flueggé), annual dry matter yields of about 5.5 t/ha are obtained with an average crude protein content of about 10%. Forage yields were lower than those of mixtures with *Desmodium intortum* (Miller) Urban, *D. heterocarpon* (L.) DC. and *Macroptilium atropurpureum* (DC.) Urban.

Genetic resources A small germplasm collection of *I. hirsuta* is maintained by the United States Department of Agriculture in Florida and at the Southern Regional Plant Introduction Station, Griffin, Georgia.

Breeding Very little breeding work has been done in *I. hirsuta*. Early and late-maturing lines were developed in Florida in the early 1940s, but they no longer exist. New early ('FL-24') and late ('Fl-101') cultivars were released in 1988.

Prospects The strong ability to reseed itself and its development late in the season make *I. hirsuta* a good green manure in annual crops. Further selection work is needed to investigate its potential to produce high organic matter yields. Its efficacy to reduce nematode infestation needs further investigation.

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T. Djarwaningsih

Indigofera suffruticosa Miller

Gard. Dict. ed. 8, No 2 (1768).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 12, 16$

Synonyms *Indigofera anil* L. (1771).

Vernacular names Anil indigo (En). Anil de pasto (Am). Indonesia: taem-taem (Sumatra), tagom-tagom (Kalimantan), tom janti (Javanese). Malaysia: tarom, sekebak (Peninsular Malaysia). Philippines: tina-tinaan (Tagalog), tayum (Bisaya, Ilokano), sangifaria (Mindanao). Thailand: khram-thuan (Shan, Chiang Mai), khram yai (Ubon Ratchathani). Vietnam: ch[af]m b[uj]i, c[aa]y ch[af]m.

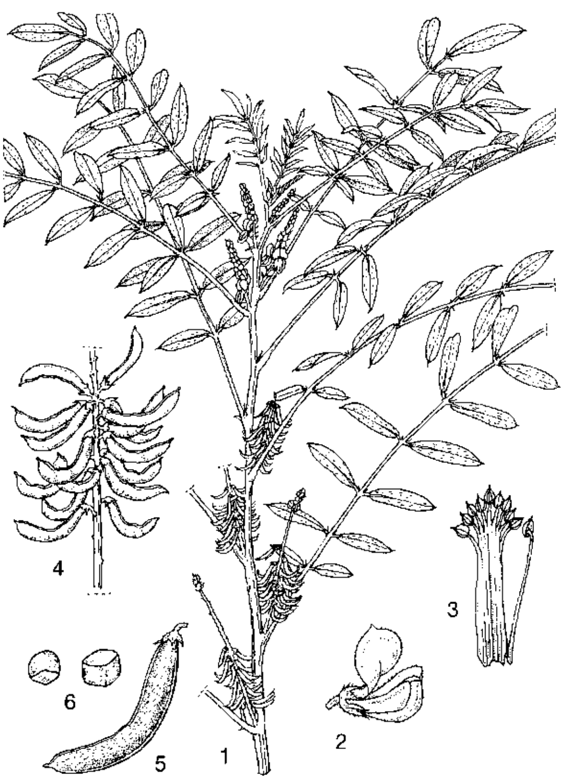
Origin and geographic distribution *I. suffruticosa* originated in tropical America, but is now widely distributed and naturalized throughout the tropics, including South-East Asia.

Uses *I. suffruticosa* is used mainly in Java and Sri Lanka as a cover crop and green manure in coffee, rubber and tea plantations. In South America it is one of the components of natural pastures developing after clearing rain forest. It has been widely cultivated as a dye plant yielding indican from which indigo is prepared. Its cultivation for local use still continues on a small scale. In Malaysia a decoction of the roots is taken against stomach-ache, an infusion of bruised leaves against fever and plant juice against diarrhoea. In China a mixture of the leaves of *I. suffruticosa*, *I. tinctoria* L., the bark of *Phellodendron chinense* C.K. Schneider and pig bile is used as a medicine against scrofula.

Production and international trade *I. suffruticosa* is still grown for dye on a very small scale in Java, Karnataka (India), Africa and Central America, but no statistics exist.

Properties In Hawaii fresh material of *I. suffruticosa* grown as a green manure has a nitrogen content per 100 g dry matter of 1.6–3.1 g in the above-ground parts, and 1.4–2.4 g in the roots.
Plants contain the glucoside indican, which transforms into indoxyl (indigo-white) and glucose by enzymatic hydrolysis. Indoxyl can be oxidized to indigo-blue. An aqueous extract of the fruit has an hepatotoxic effect and causes chromosome aberrations in mice.
The weight of 1000 seeds is about 4 g.

Description Shrub, 45–250 cm tall with erect, striate branches and with indumentum of appressed, biramous hairs with equally long arms. Leaves imparipinnate; stipules narrowly triangular, 3–6 mm × 0.2–0.3 mm; petiole up to 2 cm long; rachis 5–10 cm long; petiolule 1–1.5 mm long; stipels linear; leaflets opposite, (7–)9–15, narrowly elliptical to narrowly obovate, 10–40 mm × 3–15 mm, base cuneate, apex acute to rounded, mucronate, glabrous or with very few hairs above, appressed grey pubescent beneath. Inflorescence an axillary raceme, 2–6 cm long; bracts narrowly triangular; pedicel 0.5–1 mm long; flower 4–5 mm long, salmon pink to red; calyx campanulate, tube 1 mm long, teeth triangular, 0.7–1.2 mm long; standard ovate to orbicular, 3–4.5 mm × 2.5–3 mm, hairy on the back; wings 2–4 mm × 0.8–1.2 mm, glabrous; keel 2.5–4.5 mm × 1.2–2 mm, hairy, margins not ciliate, lateral pocket 0.5 mm long; stamens 10, 1 free, 9 connate into a staminal tube 3.5–4 mm long; ovary hairy, style with capitate stigma. Fruit a descending pod, 4–6-seeded, distinctly upcurved, 1.5–2(–3) cm × 2 mm, hairy. Seed cubical, 1.5–2.0 mm × 1.5 mm, shiny brown. Seedling with epigeal germination.



Indigofera suffruticosa Miller – 1, flowering and fruiting branch; 2, flower; 3, stamens; 4, infructescence; 5, pod; 6, seeds.

Growth and development The first leaves formed after germination are simple. Seedlings quickly develop a deep root system. *I. suffruticosa* may occasionally overgrow young tea plants, but can be removed very easily as it neither winds nor climbs. Flowering starts early, at an age of 4–5 months. After 4–5 loppings in 2–2.5 years, plants tend to die out.

Other botanical information Two subspecies are recognized in *I. suffruticosa*: subsp. *suffruticosa* and subsp. *guatemalensis* (Mocino, Sessé & Cerv. ex Backer) de Kort & Thijsse (synonym: *I. guatemalensis* Mocino, Sessé & Cerv. ex Backer). Subsp. *guatemalensis* occurs naturalized in Thailand and Vietnam and is cultivated in Java where it is sometimes adventive, but where it does not naturalize; it can be distinguished by its smaller leaves and flowers (to 3 mm long) and straight, 1–3-seeded pods; its branches are not striate. *I. suffruticosa* closely resembles *I. arrecta* Hochst. ex A. Rich. (taller, less bushy and always with straight pods) and *I. tinctoria* L. (smaller, pods smaller, straight or slightly curved, 7–12-seeded). It is possible that these 3 species sometimes hybridize.

Ecology *I. suffruticosa* is commonly found on roadsides, waste land, fallow land and cultivated fields up to 1800 m altitude. It is sometimes found on beaches and in grass fields.

Propagation Seed and stem cuttings are used for propagation. Sowing is done either in seedbeds or directly into the field. Seed should be soaked in water overnight for optimal germination. In direct planting seeds are sown in continuous lines about 30 cm apart or 3–4 together in holes 45 cm × 60 cm apart. Germination takes 4–6 days. When a seed-bed is used the seedlings can be transplanted 4–6 weeks after sowing. Cuttings are taken from well developed branches divided into 30 cm long pieces. They are kept for 2–3 days in a cool place before planting out, 2–3 per hole. Rooting starts in the second week.

Husbandry After sowing or planting, weeding is necessary. In *I. suffruticosa* cover crops, weeding is mostly done selectively. Some weeds are left like *Centella asiatica* (L.) Urb. and *Drymaria glandulosa* Bartl. as they also are valuable cover plants and help in checking erosion. Lopping can be started when the plants have a height of 50 cm, leaving about 25 cm. A good cover of *I. suffruticosa* can increase the nitrogen content of the soil considerably. In Sri Lanka for example, an increase from 3.7% to 5.3% in 4 years was found.

Diseases and pests No serious diseases or pests have ever been reported to attack *I. suffuticosa*. In humid conditions *Corticium salmonicolor* sometimes affects the stems after slashing.

Genetic resources and breeding Polyploid strains of *I. suffruticosa* seem to exist. A collection of *Indigofera* germplasm is being maintained at the Southern Regional Plant Introduction Station of the United States Department of Agriculture, Griffin, Georgia, which includes several accessions of *I. suffruticosa*.

Prospects *I. suffruticosa* forms in a short period a dense and well-rooted soil cover and is an excellent cover crop that deserves more attention from research and extension.

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B. Sunarno

Ipomoea L.

Sp. pl.: 159 (1753).

CONVOLVULACEAE

$x = 15$; *I. littoralis*: $2n = 30, 60$; *I. pes-caprae*: $2n = 30, 22–31$

Major species and synonyms

- *Ipomoea imperati* (Vahl) Griseb., Cat. pl. Cub.: 203 (1866), synonyms: *Convolvulus sinuatus* Petagna (1787), *Ipomoea stolonifera* (Cirillo) J.F. Gmelin (1791), *I. carnosa* R. Br. (1810).
- *Ipomoea littoralis* Blume, Bijdr.: 713 (1825), synonym: *I. denticulata* (Desr.) Choisy (1834).
- *Ipomoea pes-caprae* (L.) R. Br., Tuckey, Narr. exped. Zaire: 477 (1818), synonyms: *Convolvulus pes-caprae* L. (1753), *Ipomoea biloba* Forsk. (1775), *I. maritima* (Desr.) R. Br. (1810).

Vernacular names General: ipomoea (En).

- *I. imperati*: Little horse's foot print, white-flower beach morning glory (En). Indonesia: klemut, kangkungan (general), krangkungan (Javanese). Thailand: phakbung-thale (central).
- *I. littoralis*: Little horse's foot-print (En). Indonesia: akar hitang (Palembang), kangkung laut (Bangka), loboke ma loha (Halmahera). Malaysia: kangkong, tapak kuda kecil (Peninsular). Philippines: bulukan (Tagalog), malakamote (Ibanag), panggi-panggi (Sulu). Thailand: chingcho lek (Peninsular).
- *I. pes-caprae*: Beach morning glory, horse's foot-print, goat's foot creeper (En). Bay-hops (Am). Indonesia: daun katang, tapak kuda (general), katang-katang (Bali). Burma (Myanmar): pinlaikazum. Cambodia: trakuon kantek, pak bung tale. Thailand: phakbung-thale (central). Vietnam: rau mu[oos]ng bi[eer]n.

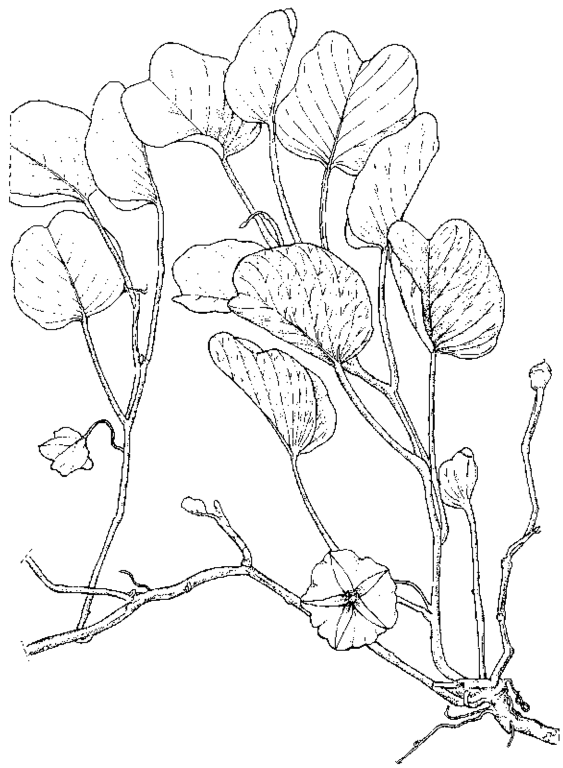
Origin and geographic distribution *Ipomoea* comprises about 500 species occurring throughout the tropics and subtropics, the majority in America and Africa. *I. imperati* is pantropical, rather rare in Malesia, but occurring in Peninsular Malaysia, Madura and the Philippines, *I. littoralis* is confined to the tropics of Asia, Australia and the western Pacific, *I. pes-caprae* is one of the most common beach plants throughout the tropics, including South-East Asia.

Uses The species treated here live on sandy beaches and act as sand binders by checking erosion and drifting of sand in wind-swept areas. They contribute to the accretion of land and facilitate the establishment of other plants. *I. pes-caprae* has been used successfully to revegetate mine spoil. Its seeds are used as a remedy for stomach-ache and cramp. In East Malaysia the leaves are made into poultices and applied to ulcers, swellings and wounds, and also against rheumatism. In Kambangan Island, south of Central Java, and in Thailand, the juice from the stem is used to treat the sting of jellyfish and toadfish, elsewhere it is taken as a diuretic. The leaves are given as a fodder to pigs, but if eaten by dairy cows their milk is spoiled. Young leaves of *I. imperati* are eaten as a vegetable by the Madurese, while those of *I. littoralis* were eaten in times of famine in the Pacific. Flowers of the latter are used in garlands.

Properties The seed of the three *Ipomoea* spp. contain glycoside resins. An aqueous extract of the stems and leaves reversibly counteracts the spasmodic effects of the poison of jellyfish.

Description Herbs or shrubs, usually twining, sometimes prostrate, floating or erect. Leaves mostly with petiole, alternate, variable in shape and size, entire, lobed or divided. Inflorescence mostly in axillary, one to many-flowered dichasia; flowers small to large; sepals 5, herbaceous or coriaceous, persistent, often somewhat enlarged in fruit; corolla regular, usually funnel-shaped or campanulate; limb 5-lobed; mid-petaline bands well-defined by 2 distinct veins; stamens 5, inserted near base of corolla tube, not exserting the corolla, filaments often unequal in length; ovary 2(–4)-locular, with 4(–6) ovules; style 1, simple, filiform, not exserting the corolla. Fruit a globose or ovoid capsule, 4(–6)-valved, 4(–6)-seeded.

- *I. imperati*. Perennial, glabrous vine. Stem trailing, rooting at the nodes, terete, up to 5 m long. Leaves fleshy, very variable in shape, even on the same plant; petiole 0.5–4 cm long; blade linear, lanceolate, ovate or oblong, 1.5–4(–8) cm × 1–3(–5) cm, margin entire or undulate, base truncate, obtuse or cordate, apex obtuse to emarginate or 2-lobed; blade sometimes 3–7-lobed. Inflorescence axillary, 1(–3)-flowered; peduncle 12–15 mm long; pedicel 8–15 mm long, in fruit up to 25 mm; bracts minute, linear, 2–3 mm long; sepals oblong, unequal, inner ones 10–15 mm long, outer ones shorter, acute or obtuse, mucronulate, glabrous, subcoriaceous; corolla funnel-shaped, 3.5–5 cm long, glabrous, white, pale yellow inside with a purple centre; filaments hairy at base. Capsule globular, about 1 cm long, smooth, 2-celled, 4-valved, up to 4-seeded. Seed trigonous-rounded, 5–9 mm long, short-tomentose, with longer hairs along edges, light brown.
- *I. littoralis*. Perennial vine. Stem prostrate and rooting at the nodes or twining, thin, slender, herbaceous, glabrous, or sometimes sparsely pubescent, woody at the base with age. Leaves coriaceous, glabrous; petiole 0.5–7 cm long; blade broadly ovate to oblong in outline, occasionally orbicular to reniform, 1–10 cm × 1–8 cm, base cordate, apex acute to obtuse, rarely retuse, margin entire, undulate, angular or 3(–7)-lobed. Inflorescence axillary, 1–few-flowered; peduncle 1–9 cm long; pedicel 1–4 cm long; bracts 1–2 mm long; sepals unequal, 2 outer sepals oblong-elliptical to elliptical-ovate, coriaceous, 6–10 mm long, apex acute to obtuse, mucronulate, 3 inner sepals thinner, with membranous margins, suborbicular to sometimes elliptical, 8–12 mm long; corolla funnel-shaped, 3–4.5 cm long, lavender to pinkish-purple, with a darker centre; stamens unequal, filaments 6–12 mm long, hairy at base. Capsule depressed globose, about 1 cm in diameter, 4-seeded, sometimes fewer. Seed suborbicular with a notch, 3.5–4 mm long, glabrous, black or dark brown.
- *I. pes-caprae*. Perennial, glabrous vine with thick taproot. Stem prostrate, sometimes twining, 5–30 m long, often rooting at the nodes.



Ipomoea pes-caprae (L.) R. Br. – habit flowering plant.

Leaves often pointing to one side only; petiole up to 17 cm long; blade variable, ovate, elliptical, circular, reniform, nearly square or oblong, 3.5–10 cm × 3–10 cm, rather thick, with 2 abaxial glands at base of midrib, base broadly cuneate, truncate, or shallowly cordate, margin entire, apex emarginate or deeply 2-lobed, mucronulate. Inflorescence 1–several-flowered; peduncle stout, 3–16 cm long; bracts early caducous, broadly triangular, 3–3.5 mm long; pedicel 1–7 cm long; sepals unequal, somewhat leathery, glabrous, apex obtuse, mucronulate, 2 outer ones ovate-elliptical, 5–9 mm long, 3 inner ones nearly circular and concave, 7–13 mm long; corolla funnel-shaped, 3–6.5 cm long, purple to reddish-purple, with darker inside centre; filaments 7–12 mm long, hairy at base. Capsule globular, 1–1.7 cm in diameter, glabrous, leathery. Seeds 4, trigonous-globose, 6–10 mm long, black, densely brownish tomentose.

Growth and development *I. pes-caprae* is self-incompatible, which is controlled by several genes.

Other botanical information *I. imperati* is better known as *I. stolonifera*. The nomenclature of this taxon is complicated. The oldest valid name is *Convolvulus sinuatus* Petagna (1787) with *Convolvulus stolonifer* Cirillo (1788) as homotypic synonym and *Convolvulus imperati* Vahl (1790) as oldest heterotypic synonym. After being transferred to the genus *Ipomoea*, the combination *I. sinuata* was not allowed, because this name had been given to a different species in 1798 by Ortega. The combination *I. stolonifer* is not permissible because its basionym is an illegitimate name; hence *I. imperati* is the correct name.

I. littoralis Blume used to be considered to be identical to *I. gracilis* R. Br. The latter, however, is a distinct species; it is quite rare and confined to the northern coast of Australia.

In *I. pes-caprae*, 2 subspecies are recognized: subsp. *brasiliensis* (L.) Ooststroom (leaf apex emarginate or truncate; leaf base truncate, rounded, attenuate to slightly cordate; outer sepals 5–8 mm, inner ones 7–11 mm long; corolla 3–5 cm long; pantropical, and the most common form in South-East Asia) and subsp. *pes-caprae* (leaf apex deeply lobed with rounded lobes, leaf base cuneate to attenuate; outer sepals 9 mm, inner ones 13 mm long; corolla 6.5 cm long; occurring in Arabia and tropical Asia).

Ecology The sand-binding *Ipomoea* species form a characteristic component of the 'pes-caprae' communities on tropical beaches. They usually grow in association with *Canavalia maritima* (Aubl.) Thouars and salt-tolerant grasses and sedges. *I. pes-caprae* also occurs inland, along roadsides and ditches, up to 800 m altitude.

Although these *Ipomoea* species grow on the beach, they depend on ground water with a lower salt content than sea water. They are tolerant of high temperature, periodic drought, sea water spray, high soil pH and low soil nitrogen content.

Propagation Natural propagation of sand-binding *Ipomoea* species is by seed. The capsules float and are probably dispersed by sea currents. When planted for erosion control, stem cuttings are used, placed 60–100 cm apart, in rows perpendicular to the prevailing wind.

Husbandry The 'pes-caprae' formation may form a complete soil cover that traps leaf litter and wind-blown organic material, thus accumulating organic matter and improving soil fertility. Analysis of a beach soil in Sulawesi indicated per 100 g dry soil: C 0.2 g, N 0.03 g, P 3.3 ppm at the edge of the sea, and at a distance of 8 m from the sea: C 1.1 g, N 0.13 g, P 18.6 ppm.

Genetic resources A small number of accessions of *I. littoralis* and *I. pes-caprae* are maintained at the Southern Regional Plant Introduction Station, Griffin, Georgia, United States.

Breeding *I. littoralis* is one of the likely progenitors of *I. batatas* (L.) Lamk, the sweet potato, and is used in experimental breeding programmes.

Prospects Most sand-binding *Ipomoea* species grow spontaneously on beaches. With more intensive utilization of beaches and the agricultural hinterland, planting may become more important. There is an urgent need for selection of good planting material and research into cropping methods. The species' usefulness for reclamation of mine spoils also needs further investigation.

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B. Sunarno & L.P.A. Oyen

Kleinhovia hospita L.

Sp. pl., ed. 2: 1365 (1763).
STERCULIACEAE
$2n = 20$

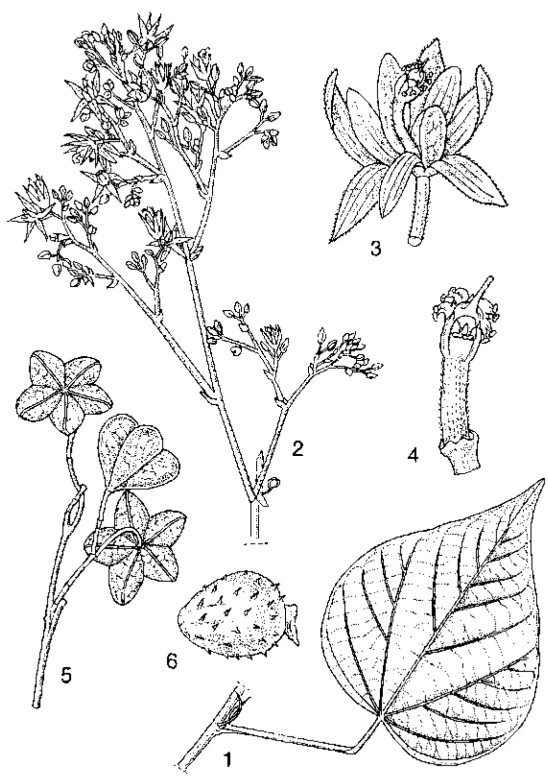
Vernacular names Guest tree (En). Indonesia: (ka)timaha, (ka)timanga (Javanese), tangkele (Sundanese). Malaysia: temahai. Papua New Guinea: maroai, matakara, metakek (Bismarck Archipelago). Philippines: tanag (Tagalog), bignon (Ilokano), hamitanago (Bikol). Thailand: chomphu-phuang, hatsakhun-thet, po-farang. Vietnam: tra d[or], c[aa]y tr[af].

Origin and geographic distribution *K. hospita* occurs naturally throughout tropical Asia, from the Mascarene Islands to Polynesia. It is more common in Central and East Java than in West Java. In Peninsular Malaysia *K. hospita* is naturally distributed along river banks, especially in Perak and in coastal areas near Melaka.

Uses In the Solomon islands *K. hospita* provides fuelwood. Its branches which are often twisted, are favoured for ornamental pieces such as knife handles. Straight branches are used for house rafters. Poles are used as stakes for yams (*Dioscorea* spp.). The fibrous bark is used for rough cordage. The young leaves are eaten as a vegetable. The juice from the leaves makes a good eye wash. In Papua New Guinea and the Solomon Islands a preparation from the cambium is used to treat pneumonia. The leaves are also used as a hair-wash to get rid of lice. The attractiveness of the pink-coloured panicles accounts for its spread as an ornamental.

Properties The wood shows a pinkish buff, is moderately fine in texture, soft, light, easy to season, work, and finish. Its energy value is about 19 000 kJ/kg. The leaves and bark of *K. hospita* contain cyanogenic compounds that are assumed to help to kill ectoparasites such as lice. Extracts of the leaves have shown anti-tumour activity against sarcoma in mice. A number of fatty acids with a cyclopropenylic ring (scopoletin, kaempferol, and quercetin) have been isolated from the leaves.

Botany Evergreen, bushy tree up to 20 m tall, with a dense rounded crown and upright pink sprays of flowers and fruits. Bole forking low, developing many suckers when old. Bark fissured, greyish outside, yellowish inside. Twigs softly hairy. Leaves simple, alternate; stipules ensiform to linear, about 8 mm long; petiole 2.5–30 cm long; blade ovate to heart-shaped, 5–30 cm × 4–25 cm, glabrous on both sides, apex pointed, secondary veins in 6–8 pairs, palmately nerved. Inflorescence a terminal, loose panicle protruding from the crown; flowers about 5 mm wide, pale pink;



Kleinhovia hospita L. – 1. leaf; 2, part of inflorescence; 3, flower; 4, flower with removed sepals and petals; 5, fruiting branch; 6, seed.

pedicel 2–10 mm long; bracteoles lanceolate, 2–4 mm long, pubescent; gynandrophore 4–7 mm long, pubescent; sepals 5, linear lanceolate, 6–8 mm long, pink, tomentose; petals 5, inconspicuous, upper one yellow; stamens 15, monadelphous, 8–15 mm long, staminal tube broadly campanulate, adnate to gynandrophore, 5-lobed, each lobe with 3 anthers and alternating with staminodes; anthers sessile, extrorse; pistil with a 5-celled, pilose ovary, one style and a capitate, slightly 5-lobed stigma. Fruit a rounded, 5-lobed, membranous capsule, 2–2.5 cm in diameter, loculicidally dehiscent, each locule 1–2-seeded. Seed globose, whitish, warty, exalbuminous.

Young trees have a fast growing, deeply penetrating main root and develop an extensive, superficial root system. *K. hospita* flowers throughout the year. The fruits are more conspicuous than the flowers because of their abundance and size. Fruit production starts early, often in the third year after planting.

Ecology *K. hospita* is commonly found in abandoned clearings, grassland and secondary forest from 0–200(–500) m altitude. In Indonesia and Malaysia *K. hospita* is restricted to areas with a pronounced dry season. In Indonesia it is common in teak forest. In Malaysia it occurs mainly along river banks of the northern part of the Peninsula. It is associated with riverside settlements where it is a vigorous component of secondary forest.

Agronomy Propagation is by seed. Cuttings are sometimes said to be difficult to root, which is associated with the presence of an uninterrupted sclerenchym band in the pericycle. Other sources report that in the Solomon Islands the bark of the lower part of stakes used in yam plantations is removed to prevent rooting and the development of a shade-producing crown.

K. hospita has been tested in alley-cropping systems. It grows well on acid soils and provides a nutrient-rich mulch. Planting material is often easily available from natural stands. Planting in teak forest is not recommended, as it will overgrow the teak trees.

The wood is susceptible to drywood termites and powder post beetles.

Genetic resources and breeding No germplasm collections and breeding programmes are known to exist.

Prospects *K. hospita* warrants further testing as a reforestation species, as it is common in abandoned clearings and secondary forest. It is also a promising ornamental, similar in habit to *Hibiscus tiliaceus* L.

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A. Latiff

Kummerowia Schindler

Feddes. repert. 10: 403 (1912).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 20$ (*K. stipulacea*), 22 (*K. striata*)

Major species and synonyms

- *Kummerowia stipulacea* (Maxim.) Makino, Bot. Mag. (Tokyo) 28: 107 (1914), synonym: *Lespedeza stipulacea* Maxim. (1859), *Microlespedeza stipulacea* (Maxim.) Makino (1914).
- *Kummerowia striata* (Thunb. ex Murray) Schindler, Feddes repert. 10: 403 (1912), synonyms: *Hedysarum striatum* Thunb. ex Murray (1784), *Desmodium striatum* (Thunb. ex Murray) DC. (1825), *Lespedeza striata* (Thunb. ex Murray) Hooker & Arnott (1838).

Vernacular names General: kummerowia (En).

- *K. stipulacea*. Korean lespedeza, Korean bush-clover, Korean clover (En).
- *K. striata*. Japanese lespedeza, annual lespedeza, common lespedeza (En).

Origin and geographic distribution *Kummerowia* consists of 2 species and both are native to temperate eastern Asia. *K. stipulacea* is distributed in Japan, Korea, the Amur and Ussuri regions of the Russian Federation, China (except in the southern parts) and central Taiwan. It was introduced into the United States, where it became naturalized in the south-east, particularly in the

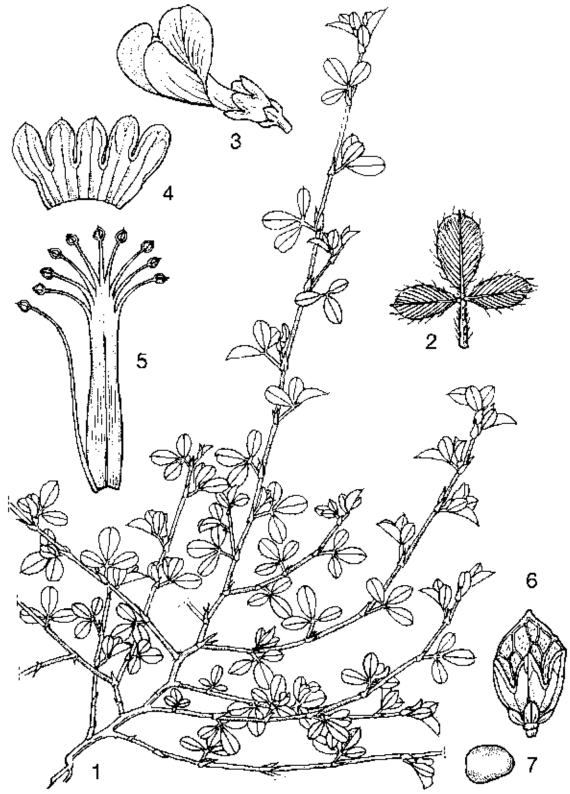
35–40°N area, east of 96°W. *K. striata* is distributed in Japan, the Amur and Ussuri regions of the Russian Federation, China, northern Taiwan, and Vietnam. It was first reported in the United States in 1846, where it also became naturalized in the south-eastern region, particularly of 30–35°N, eastward of 96°W. A taller, more vigorous, late-maturing strain was introduced from Kobe (Japan) into the United States in 1919, which led to a greatly expanded area under *Kummerowia*. In the early 1950s increasing fertilizer use led to a rapid decline in its importance. Both species are scarcely cultivated outside the United States.

Uses Both species produce a thick mat of vegetation providing good ground cover and they are used in the United States for soil conservation and as cover crops. *Kummerowia* provides good quality forage during summer and is used for grazing and hay. In the United States it is often double-cropped with small cereals harvested for grain or fodder, or is oversown in pastures. Medicinal uses for *K. striata* have been reported in China.

Properties The hay quality of both species is considered to be nearly as good as that of lucerne hay and palatability is excellent. In poor soils their phosphorus and cobalt contents may be lower than required by ruminants. The forage is non-bloating. After flowering starts the feeding value declines, becoming inadequate for dairy cattle. The approximate average composition of hay of *K. striata* per 100 g dry matter is: crude protein 15 g, fat 3 g, crude fibre 35 g, N-free extract 45 g, ash 5 g, Ca 1 g, P 0.3 g, K 1 g, Mg 0.3 g, Fe 35 mg. The composition of the hay of *K. stipulacea* is very similar, its ash and mineral nutrient contents being slightly higher. The weight of 1000 seeds is about 1.9 g.

Description Erect or decumbent, much branched, annual herbs with taproot. Stems slightly pubescent. Leaves alternate, trifoliolate, petiolate, usually small; stipules 2, ovate-lanceolate, large, soft-membranaceous, persistent; stipels absent; leaflets about equal in shape, subentire. Inflorescence an axillary, 1–6 flowered cluster; flowers chasmogamous or cleistogamous, pedicelled; bracts 2, subtending the pedicel; bracteoles 4, persistent, ovate; calyx campanulate, 5-lobed, lobes subequal, pinnately nerved, persistent in fruit; standard suborbicular to oblong, clawed; wings and keel about equal in length; stamens diadelphous; style long, filiform or strongly recurved in cleistogamous flowers. Fruit a unilocular, indehiscent, 1-seeded pod.

– *K. stipulacea*. Stem erect or semi-erect, coarse, strongly and diffusely branched, 10–60 cm long, with upward pointing appressed hairs. Lower leaves spreading, upper leaves folding around developing pod; stipules 4–8 mm long, brown, scarious; petiole 2–5(–10) mm long, glabrate to sparsely antrorse appressed-pubescent; leaflets spatulate to obovate, 0.8–2.5 cm long, 1.5 times as long as wide, base triangular, emarginate, apex mucronulate, glabrous or glabrate, margins conspicuously ciliate. Inflorescence mainly in axil of upper leaves, 1–3-flowered, 1–2 cm long, leafy; bracteoles 1–3-veined; calyx-tube 1 mm long, with obtuse lobes, glabrous; corolla pink to purple, (4.5–)6–7(–10) mm long. Pod ellipsoid, 2.5 mm long, up to halfway covered by the persistent calyx, more commonly borne terminally than along the stems. Seed purplish-black.



Kummerowia stipulacea (Maxim.) Makino – 1, habit; 2, leaf with three leaflets; 3, flower; 4, calyx; 5, stamens; 6, pod; 7, seed.

– *K. striata*. Stem decumbent or erect, slender, branched and wide-spreading, 10–40 cm long, with downward curved, white hairs, often reddish. Stipules 3–6 mm long, striate, brown, papery; petiole 2–4 mm long, retrorsely appressed-pubescent; leaflets obovate to oblong, 6–15(–20) mm × 2–8 mm, tapered at base, apex obtuse to acute, lateral nerves close and distinctly parallel, inconspicuously appressed-ciliate. Flowers in clusters of (1–)2–6, 5 mm long; bracteoles 5–7-veined, not longer than the calyx-tube; calyx 2.5–3.5 mm long, with acute lobes, loosely short-pilose, margins hairy; corolla pink to purple; standard 2 mm × 2 mm; wings white, 3 mm long; keel white, purple-brown-tipped. Pod flat-ellipsoid, 3 mm × 2 mm, minutely hairy and glandular, mottled reddish purple on light brown, covered by the persistent calyx for more than half way. Seed mottled black.

Growth and development Hard-seededness reduces germination of both species immediately after harvesting to about 50%; 4 months later the germination rate has increased to 90%. Both species will germinate in early spring in the United States, but usually grow very little until June. Flowering is induced by short daylength. In the United States, plants start flowering in August and mature in October–November. *K. striata* flowers later and requires a longer growing season than *K. stipulacea*. Exposure of *K. stipulacea* to a daylength of less than 13–14 hours inhibits vegetative growth and induces flowering. Therefore, early cultivars are not suitable for planting early in the season in the United States.

Other botanical information Both species were formerly classified in the genus *Lespedeza* Michaux. They have been transferred to their own genus *Kummerowia* because of the number of bracteoles (4; in *Lespedeza* there are 2), petals non-persisting in fruit, and their reproductive isolation.

Older cultivars of *K. stipulacea* are 'Climax' and 'Harbin'. The improved cultivars 'Summit' and 'Yadkin' were released in the 1960s. The most widely grown cultivar of *K. striata* is 'Kobe', which is best suited to the southern part of its range in the United States. The more recently released 'Marion' is resistant to bacterial wilt and tar spot, and is better adapted to the northern part of the *K. striata* area. In New South Wales (Australia), 'Kaloe' was released in 1971. 'Rowan' is fairly nematode-resistant.

Ecology Both are warm temperate species, and early frost may kill young plants, whereas mature plants will be killed by the first severe frost in autumn. Both species are fairly drought-resistant. Growth may be severely reduced under dry conditions, but plants recover quickly after rain. The mean annual temperature required ranges from 8–26°C.

Kummerowia is adapted to a wide range of soil conditions. *K. striata* does not grow well on wet, poorly drained soils. Optimum pH is 5.5–6.0. *K. stipulacea* is more sensitive to soil acidity than *K. striata*. Strain 'Iowa 39' of *K. stipulacea* can grow in soils of pH 8.

Both species failed in trials in Singapore; they are apparently only suited to higher altitudes in the tropics.

Propagation and planting *K. stipulacea* and *K. striata* are propagated by seed. They can be oversown in established grassland by broadcasting seed at a rate of 15–20 kg/ha. When sown as a sole crop, 25–35 kg/ha are needed. Sowing may be carried out from winter to early spring in the United States. *K. striata* reseeds easily because its fruits are formed close to the ground.

Husbandry Until the 1950s *Kummerowia* was most commonly grown in an annual rotation with winter cereals. The initial sowing would be made into the cereal crop during late winter or early spring. The cereal would be harvested for pasture or grain, leaving *Kummerowia* to be used for summer pasture or hay. About the time *Kummerowia* was making seed, the field would be ploughed and sown back to cereals.

Although adapted to poor soils, both species respond well to fertilizers and lime. *K. stipulacea* is more responsive to lime than *K. striata*. It is recommended to apply nitrogen and phosphorus fertilizers at sowing or when the crop starts to develop. Nitrogen applications of more than 35 kg/ha will reduce stands in mixtures with grasses. Fertilizing with boron is important when harvesting seed or when reseeding of the crop is desired. Natural reseeding in both species results in good stands year after year if competition is not too severe and harvested not too late in the season. Grazing or mowing will stop upward growth, causing lower branches to spread along the ground. Heavy trampling is tolerated and some seed is produced even under heavy grazing.

Diseases and pests Both species are considered fairly tolerant to diseases and pests in the United States, but they may nevertheless experience considerable losses. Losses caused by diseases are much greater than those caused by pests. Bacterial wilt (*Xanthomonas lespedezae*) is serious in the growing area in the United States. Tar spot (*Phyllachora lespedezae*) causes heavy spotting of leaves, followed by defoliation and reduction in yield and quality. *K. stipulacea* is more susceptible to both diseases than *K. striata*. Several nematodes attack *Kummerowia*; root-knot nematode (*Meloidogyne* spp.) may cause serious losses on sandy soils. 'Rowan' is fairly resistant. Grasshoppers may cause defoliation, but only when no other crops are available. Larvae of the crane fly (*Tipula simplex*), the alfalfa hopper (*Stictocephala festina*) and the lespedeza webworm (*Tetralopha scortealis*) occasionally cause damage in the United States.

Harvesting If reseeding is desired, plants should be cut early and at more than 10 cm above the ground, to allow adequate regrowth. For hay, the crop should be cut at early bloom to obtain optimal quality. The hay contains less moisture than most other forages and cures quickly. Under optimum conditions, it can be cut in the morning and baled in the afternoon of the same day. When grown for seed, the crop is combine-harvested as soon as it is mature, to reduce losses from shattering.

Yield Hay yield ranges from 2500–5000 kg/ha. Average daily weight gains of steers fed with *Kummerowia* hay is 600–900 g. Seed yield is commonly 200–400 kg/ha, but up to 600 kg/ha can be obtained under favourable conditions.

Genetic resources and breeding The number of accessions of both species held by the United States Plant Germplasm System is small (22 of *K. stipulacea* and 43 of *K. striata*) and in need of thorough evaluation. There is a great need for collection of additional germplasm material that could provide breeders with more variability. At present, no *Kummerowia* breeding programme exists.

Prospects *Kummerowia* species are promising as cover and forage crops under subtropical or tropical highland conditions. It would therefore be worthwhile to test both species under these conditions in South-East Asia. No new developments in the United States are expected for either species, unless the cost of nitrogen fertilizers increases and legumes become more economically attractive.

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J.A. Mosjidis

Lespedeza cuneata (Dumont de Courset) G. Don

Gen. syst. 2: 307 (1832).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 18, 20$

Synonyms *Hedysarum sericeum* Thunb. ex Murray (1784), *Anthyllis cuneata* Dumont de Courset (1811), *Lespedeza sericea* (Thunb. ex Murray) Miquel (1867), non Benth. (1852).

Vernacular names Chinese lespedeza, sericea lespedeza, perennial lespedeza (En). Indonesia: lurampa ghaki. Philippines: lalagim (Igorot).

Origin and geographic distribution *L. cuneata* is indigenous to the Sino-Indian region of Asia and occurs naturally from Japan to Australia and from northern Pakistan and India to Taiwan. In Malesia, it is reported from Java, the Philippines, and Papua New Guinea. Introduced to the United States in 1896, it became naturalized in the south-eastern region. In the United States, it is cultivated eastward of 96°W between 30–40°N.

Uses In the United States, *L. cuneata* is one of the most commonly used cover crops for planting on disturbed and eroding areas and on roadsides. In Japan, it is planted in mixtures with other species, also to control erosion of roadsides. It is often the first species planted when rehabilitating strip mine spoils. In the United States, it is grown as a non-bloating forage crop for grazing or hay. *L. cuneata* also has ornamental value.

Properties Fresh forage of *L. cuneata* is generally of low palatability and digestibility. Early work related this to a high tannin and lignin content and thick, coarse stems, but the factors affecting palatability are not yet fully understood. Finer-stemmed cultivars, some of them also lower in tannin, have been developed. Preservation of forage as hay reduces tannin content and increases intake and digestibility in ruminants. The approximate average composition of hay per 100 g dry matter is: crude protein 15 g, fat 3 g, N-free extract 48 g, crude fibre 27 g, ash 6 g, P 0.2 g, K 1 g, Ca 1.5 g, Mg 0.2 g, Fe 30 mg, Mn 125 mg, carotene 4 mg, riboflavin 1 mg. Whole plants contain 5–8% tannin, leaves 7.5–18%; young plant parts contain less tannin than older ones. The weight of 1000 seeds is 1–2 g.

Description A deep rooting, erect, rarely semi-prostrate, short-lived perennial herb, 0.5–1 m tall, copiously branched. Stem striate, sparsely appressed-pilose on the ridges. Leaves alternate, trifoliolate; stipules lanceolate, 3–11 mm long, 3-veined; petiole 2–7 mm long; rachis 1–2 mm long; leaflets oblong-cuneate to linear-lanceolate, up to 3 cm × 0.5 cm, glabrous above, grey-green or silvery-silky beneath, margins slightly incurved. Inflorescence an axillary, 1–4-flowered fascicle; bracteoles 2; pedicel 1–2 mm long; flowers chasmogamous or cleistogamous; chasmogamous flowers with sericeous calyx, tube 0.5–1 mm long, teeth 5, 3–5 mm long, petals white to cream, standard 6–9 mm long, 1–2 mm longer than keel and wings, purple-veined; cleistogamous flowers common, calyx sericeous, teeth 1.5–2 mm long, olive green to brown, corolla absent. Fruit an ovoid pod, 2.5–3 mm long, glabrous or appressed-pubescent, 1-seeded. Seed ovoid, 1.5–2 mm long, greenish-yellow with brown speckles.

Lespedeza cuneata (Dumont de Courset) G. Don – 1, flowering branch; 2, leaf; 3, chasmogamous flower; 4, cleistogamous flower; 5, pod; 6, seeds.

Growth and development Seedlings emerge 7–10 days after sowing under optimum conditions of temperature and adequate soil moisture. The optimum temperature for germination is about 30°C; germination percentage is reduced to less than 70% at 15°C and to less than 20% at 10°C in most lines. Growth of seedlings and young plants is slow.

In the United States, crown buds appear below ground level toward the end of the season and remain dormant until spring. In spring, new stems arise from those buds as soon as the temperature rises. A late frost may kill the new spring growth, but plants are not severely affected and will regrow. Unlike many other legumes in the United States, *L. cuneata* will grow actively throughout the summer. In August, shoot growth decreases and nutrient reserves are built up in the taproot for winter storage. Flowering starts in early September. The relatively long growing period contributes to its persistence in plant mixtures.

Chasmogamous flowers are pollinated by several species of bees.

Other botanical information Species of the genus *Lespedeza* Michx. are closely related to those of the genera *Kummerowia* Schindler and *Campylotropis* Bunge. They have all been included in *Lespedeza* in the past. However, *Kummerowia* has now been separated again, as no interspecific crosses have been obtained between species of *Lespedeza* and *Kummerowia*.

Pods of chasmogamous and cleistogamous flowers can be distinguished; those of chasmogamous flowers have a persistent style, those of cleistogamous flowers are blunt and rounded. Commercial cultivars in the United States can be grouped according to their tannin content. High in tannin are 'Appalow', 'Interstate', 'Interstate 76', 'Serala', and 'Serala 76'. Low in tannin are 'AU Donnelly' and 'AU Lotan'. 'AU Lotan', 'Interstate 76' and 'Serala 76' are tolerant of some nematode species, making them more persistent on light, nematode-infested soils. 'AU Donelly' is resistant to *Rhizoctonia* spp.

Ecology *L. cuneata* is adapted to tropical, subtropical and warm temperate areas with mean annual temperatures ranging from 10–29°C. It tolerates drought, high levels of aluminium, and low soil fertility. In the Philippines it occurs on grassy slopes, from 1200–2200 m altitude; in Taiwan it is common in open locations (roadsides, waste land, hill sides) up to 3100 m altitude.

Daylengths of 13 hours or less are required for *L. cuneata* to flower. Daylength and temperature also strongly influence the proportion of chasmogamous and cleistogamous flowers produced and the seed produced from them; short daylength and low temperature favour the production of seed from cleistogamous flowers. Although a pH of 5.8–6.5 is recommended, *L. cuneata* tolerates acid soils, including acid subsoils of pH 4. In high pH (8.0) soils, plants will not survive for more than 2 years. The phosphorus requirements of *L. cuneata* are low compared to those of other forage species.

Propagation and planting *L. cuneata* is propagated by seed. Mature seed is hard and needs to be scarified to germinate. Seed is placed at about 0.5 cm depth by broadcasting. Deep sowing will reduce emergence, but will not affect seedling vigour. Seed rate is 15–20 kg/ha when a herbicide is used, otherwise it should be increased to 20–30 kg/ha. *L. cuneata* is commonly grown as a sole crop; it is sometimes oversown with annual grasses to increase productivity. In the United States, *L. cuneata* is sown in early spring as soon as there is no risk of a severe frost.

Husbandry Seedlings are extremely slow to establish and are poor competitors with weeds, so weeding or the application of herbicides is essential for establishment. After the first year and with good management, it is highly competitive with weeds. Stands of *L. cuneata* are severely reduced when grown on poor soils and cut more than twice per year. However, on fertile soils, up to 3 cuts can be done. It is sensitive to being cut back to less than 4 cm, especially when more than 2 or 3 cuts per year are made. When harvested for hay, plants should be cut when stems are 30–35 cm tall, leaving 8–13 cm stubble. Grazing should begin when plants are 20–25 cm tall to avoid close grazing and stand reduction. Although *L. cuneata* fixes atmospheric nitrogen, this does not become readily available to companion crops. In the autumn, the above-ground growth becomes woody litter, which decomposes very slowly and accumulates on the soil surface. When fertility of degraded soils has improved sufficiently, *L. cuneata* can be replaced by more productive crops. Eradication can be achieved by increasing the cutting intensity, followed by light disking and then sowing a fast-growing annual crop. The procedure often has to be repeated the following year.

Diseases and pests *L. cuneata* does not have any major disease or insect pest problems. Some low-tannin genotypes are highly susceptible to a foliar disease caused by *Rhizoctonia* sp., but all cultivars released in the United States are resistant or tolerant. Root-knot nematodes can be a pest on light soils. Dodder (*Cuscuta campestris* Yunck.), a parasitic weed, can be a problem and should be eliminated immediately before it produces seed.

Harvesting Forage cut for hay in favourable weather cures rapidly and must be carefully handled to reduce leaf losses. Hay can be baled 1 day after cutting.

Yield Hay yields range from 5–8(–11) t/ha in the United States. Steers fed on *L. cuneata* pastures have achieved an average daily weight gain of 660–800 g. Seed yields average 350–1000 kg/ha.

Genetic resources There is a great need to collect germplasm of *L. cuneata*. The United States Germplasm System holds only 46 accessions, 23 of which are from Japan. Most of the accessions are of limited agronomic potential. Other collections also hold only a few accessions.

Breeding A programme to select genotypes tolerant of frequent clipping and to improve the grazing quality of older crops has been started at Auburn University, Alabama, United States.

Prospects Its tolerance for poor, acid soils with high aluminium and low phosphorus levels and its persistence in mixed stands make *L. cuneata* a potentially useful cover crop for tropical highlands. It is one of the best plants for the warmer parts of the United States to rehabilitate seriously degraded land and to grow in low-input systems, because of its adaptation to marginal soils, low fertilizer requirements, high production of organic matter, and ability to fix atmospheric nitrogen. It may be useful in pasture renovation, but more research is needed on its establishment and management in grass sods.

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J.A. Mosjidis

Leucaena diversifolia (Schlecht.) Benth.

Hook. J. Bot. 4: 417 (1842).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 52$ (diploid taxa), 104 (tetraploid taxa) (extra chromosomes are common)

Synonyms *Acacia diversifolia* Schlecht. (1838), *Leucaena laxifolia* Urban (1900), *L. stenocarpa* Urban (1900).

Vernacular names Leucaena (En). Indonesia: lamtoro. Philippines: ipil-ipil.

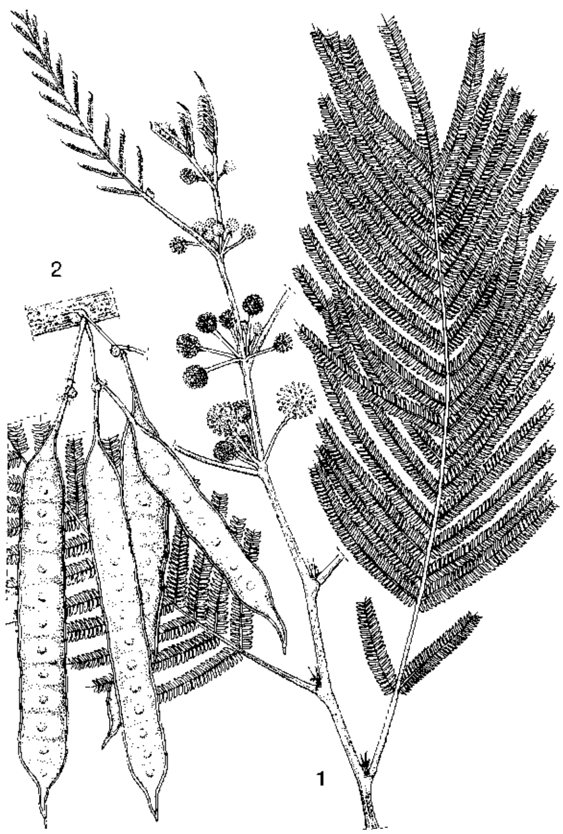
Origin and geographic distribution *L. diversifolia* is of Central American origin, occurring naturally from eastern and central Mexico through Honduras to Nicaragua. It was introduced into Cameroon, Ivory Coast and Java in the late 1800s. It is now widespread throughout the tropics, particularly in South-East Asia.

Uses *L. diversifolia* is primarily used as fuelwood and as a shade tree e.g. in coffee and cocoa plantations in Indonesia and Mexico, and as a green manure. In reforestation schemes, it is planted for soil amelioration and stabilization. In agroforestry and mixed pastures, it is grown as an alternative for *L. leucocephala* (Lamk) de Wit, where the latter performs poorly because of high altitude or psyllid attack. Sufficiently large logs are used in construction and as poles.

Properties The wood of *L. diversifolia* has a density of 400–500 kg/m^3, its energy value is 18 900–19 300 kJ/kg. The leaves have a lower digestibility of crude protein than those of *L. leucocephala*, but this may not affect the total protein uptake. The mimosine content is low (1.5–2.5%). Rations for ruminants should not contain more than 50% *L. diversifolia*, and the proportion in rations for non-ruminants should not exceed 10%. *L. diversifolia* produces a water-soluble gum containing the sugar rhamnose.

Botany Tree or erect shrub, 3–20 m tall, and with a straight bole up to 40 cm in diameter and slender, ascending branches with horizontal twigs. Bark greyish, lenticellate. Leaves bipinnate, 8–25 cm long, with 12–35 pairs of pinnae and up to 4 large glands between basal pairs of pinnae; petiole and rachis reddish; per pinna 20–60 pairs of leaflets; leaflets linear, 3–6 mm × 1–2 mm, apex acute. Inflorescence a globose, dense head, 6–15 mm in diameter, reddish, borne in clusters in leaf axil, bearing 50–90 flowers; flower light pink to bright red; calyx 1.5 mm long, corolla 3 mm, stamens 10, 4–7 mm long. Pod 10–18 cm × 8–12 mm, bright red, glabrous. Mature seed about 5 mm long.

L. diversifolia typically grows as a single-stemmed tree with a straight bole and slender upcurving branches. It nodulates and fixes atmospheric nitrogen with *Rhizobium* strains that also



Leucaena diversifolia (Schlecht.) Benth. – 1, flowering branch; 2, pods.

nodulate with *L. leucocephala*. On soils very low in nitrogen, a moderate application of N fertilizer may increase nodulation and nitrogen fixation. A fertilizer application of 50–100 kg N/ha was found to increase the number of nodules per tree from 11.5 to 25–30, while nodule dry weight increased by 63–70%.

L. diversifolia is variable in size, adaptation and pubescence, and is subdivided into 2 subspecies: subsp. *diversifolia* and subsp. *stenocarpa* (Urban) Zarate (synonym: subsp. *trichandra* (Zucc.) Pan & Brewbaker). Subsp. *diversifolia* is tetraploid and occurs wild only in Vera Cruz State in Mexico; it has long leaves, more leaflets per pinna, a longer corolla and pistil, larger pollen grains and larger seed. It is self-compatible, while the diploid subsp. *stenocarpa* is self-incompatible. Pods of subsp. *stenocarpa* mature in 80–160 days, those of subsp. *diversifolia* in about 90 days. Tetraploids are the more commonly cultivated. Cultivars 'K156' and 'K784' developed in Hawaii are commonly used in agroforestry. The widely used cultivar 'KX3' is an interspecific hybrid between *L. diversifolia* and *L. leucocephala*.

The taxonomy of *Leucaena* Bentham is still in flux; the currently recognized 17 species hybridize easily, but hybrids are rare in nature.

Ecology In the tropics, *L. diversifolia* grows in areas from 700–2500 m altitude; subsp. *diversifolia* occurs naturally above 1000 m altitude. *L. diversifolia* is found in cool and seasonally wet locations with an average annual rainfall of 600–2800 mm and a mean maximum temperature of the hottest month of 18–30°C. It does not withstand drought well. It has a strong light requirement and tolerates only partial shade. *L. diversifolia* prefers slightly acid, fertile soils, but is tolerant of leached soils. It is often grown in deforested, degraded areas, dominated by *Imperata cylindrica* (L.) Raeuschel and *Themeda triandra* Forssk.

Agronomy *L. diversifolia* is propagated by seed. Cuttings and grafts mostly fail, but propagation by tissue culture has been successful. Seed takes about a week to germinate if presoaked in water for 24 hours. The germination rate is generally over 90%. Mechanical scarification and soaking in concentrated sulphuric acid for 5–7 minutes or in hot water (75°C) for 3 minutes also give good results. Seedling vigour is poor, especially in tetraploid and small-seeded diploid forms. Seedlings reach a height of 15–30 cm in 8–12 weeks and are then transplanted into the field. Application of 15 g of a complete NPK fertilizer (14:14:14) per plant may improve the survival rate of seedlings. *L. diversifolia* has been tested in intercropping systems e.g. with sweet potato. The total biomass yield of sweet potato, firewood and green manure was considerably greater than the yield per unit area of sweet potato alone.

The annual leaf dry matter production of *L. diversifolia* can reach 10–16 t/ha. When incorporated as green manure, this adds per ha 72–119 kg N, 2.5–3 kg P, 29–60 kg K, 47–94 kg Ca and 7.5–18.5 kg Mg to the soil. This is equivalent to about 10 t/ha cattle manure per year. Soil erosion can be controlled effectively by planting *L. diversifolia*. In a trial planting, annual soil loss per ha decreased from 190 t before planting to 54 t in the third year after *L. diversifolia* had established.

The aggressive nature and profuse growth of *L. diversifolia* occasionally make it a weed. Seedlings can be controlled effectively by spraying them with diesel oil at the 3–5 leaf stage. Established trees can be controlled by impregnating freshly cut stumps of a basal diameter of 1–20 cm with diesel oil. The treatment should be repeated on coppiced stumps. Delaying application until one day after cutting will reduce its efficacy.

A common disease is leaf spot caused by *Camptomeris leucaena*. Spots on the upper leaves are often insignificant, but the fungus sporulates profusely, producing crowded black pustules on lower leaves. *Fusarium semitectum* causes gummosis and canker on stems, branches and peduncles, dark brown spots on young twigs, leaves, peduncles, pods and seeds, eventually causing the tree to die. A moth, *Spatularia mimosae*, may cause economically significant damage to seeds. Diploid forms of *L. diversifolia* have a high psyllid resistance, tetraploid forms are only moderately resistant. Diploids and tetraploids show high resistance to seed beetles, *Araecerus levipennis* and *A. fasciculatus*; in Hawaii damage to unprotected seed is often only one-quarter of that to seed of susceptible *Leucaena* species. There are indications that *L. diversifolia* is tolerant of some root-attacking nematodes.

Genetic resources and breeding Major germplasm collections are maintained by the Nitrogen Fixing Tree Association (Waimanolo, Hawaii, the United States) and at the Australian Tropical Forage Genetic Resource Centre (Brisbane, Australia), and a smaller collection at the Southern Regional Plant Introduction Station (Griffin, Georgia, the United States). *L. diversifolia* is important in *Leucaena* breeding programmes, as it is used as one of the sources of resistance to psyllids and of tolerance to low temperature to be incorporated into *L. leucocephala*. It easily crosses with nearly all *Leucaena* species, producing viable hybrids.

Prospects *L. diversifolia* is a fast growing, nitrogen-fixing tree, capable of producing high wood and fodder yields and is especially suitable for higher elevations in the tropics.

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I.B. Ipor

Leucaena leucocephala (Lamk) de Wit

Taxon 10: 53 (1961).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 104$

Synonyms *Leucaena glauca* (Willd.) Benth. (1842), *L. latisiliqua* (L.) Gillis (1974).

Vernacular names Leucaena (En). White leadtree (Am). Leucaene, faux mimosa (Fr). Indonesia: lamtoro (Javanese), pelending (Sundanese), petai cina (Indonesian). Malaysia: petai belalang, petai jawa, ipil-ipil. Papua New Guinea: lamandro. Philippines: ipil ipil, elena (Tagalog), palo-maria (Bikol), kariskis (Ilokano). Cambodia: khtum té:hs, krâthum' thé:t. Laos: kathin, kan thin, kh'o:ng ko:ng kha:w. Thailand: krathin (general), to-bao (southern). Vietnam: keo d[aaj]u, bo ch[es]t.

Origin and geographic distribution Leucaena evolved in the Guatemalan centre of genetic diversity, as a probable tetraploid hybrid of diploid species in that region. Two major forms are found. The 'common' shrubby form grows up to 8 m tall and is evidently indigenous to the Yucatan Peninsula. The arboreal 'Salvador' type grows to 16 m and appears to have originated in the regions of El Salvador, Guatemala and Honduras. Both forms were distributed widely throughout Mexico and Central America to northern South America prior to 1500 AD. A single variety of the common form was probably brought by Spanish galleons to the Philippines in the early 1600s, from where it was pantropically distributed in the 19th Century. The Salvador forms are more recent in distribution and are known by names such as 'lamtoro gung' in Indonesia, 'giant ipil-ipil' in the Philippines and 'subabul' in India. Leucaenas are found throughout South-East Asia; on many islands common leucaenas dominate the vegetation on coralline soils.

Uses Leucaena is a very versatile multipurpose tree. In South-East Asia it provides fuelwood, shade, fodder, green manure, mulch, posts, food and often combinations of these products. Leucaena is probably the most widely used species in alley cropping, where it is planted in hedges along contours at intervals of 3–10 m with crops in between. Other auxiliary uses include live fences, fire-breaks, shelter-belts, live support for vines such as pepper, vanilla, yam and passion fruit, and shade trees for coffee and cocoa. Selections low in seed production are preferred for these purposes. Throughout the tropics leucaena provides a major nitrogen-fixing component of lowland wasteland, fallow land and forest, where it is often a primary source of fixed nitrogen in the ecosystem. In Indonesia leucaena is often planted in home gardens.

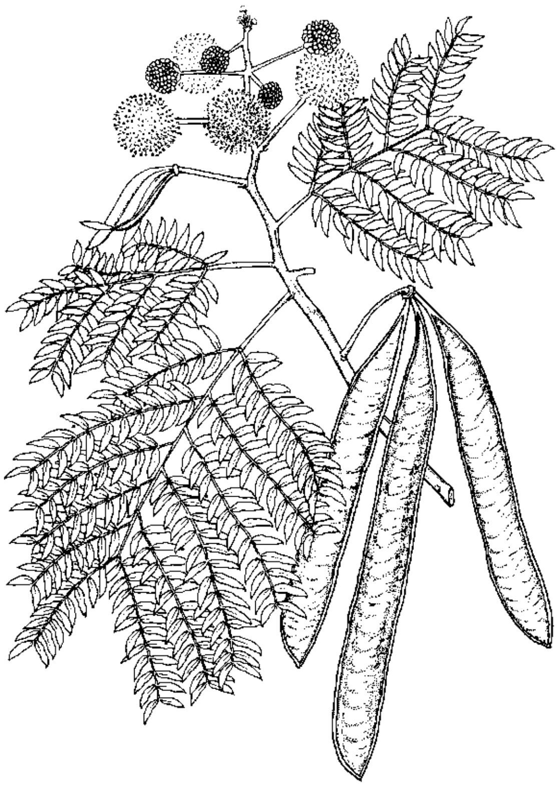
A dye has been extracted in Central America from the seeds, pods and bark. Research on extraction methods for this potential dye has been conducted in Indonesia.

Foliage is fed to ruminant animals as browse or by cut-and-carry methods and mixed with other green fodders; it is milled as a supplement for poultry feed and pelleted for export. Wood is harvested for fuelwood and used in households and industries such as ceramics; it is also converted into charcoal. Increasing use is made of the wood for posts and props, in chipboard and plywood manufacture, for paper pulp, and for furniture and parquet flooring. In Asia people eat the young green shoots before the leaflets unfold; in the Americas, the green seeds are eaten. In Indonesia the mature seeds are eaten, either raw, cooked or mixed with other ingredients, sometimes after fermentation as a substitute for soyabean, or added to coffee after roasting. Young pods are eaten raw or cooked and serve as a minor, but useful protein and vitamin supplement from the home garden. The dried seeds are widely used for ornamentation.

Production and international trade Leucaena is a major source of fuelwood and is a primary source of leguminous feed in large regions of Indonesia and the Philippines. Most production is on communal lands or small farms. Attempts to commercialize production on large fuelwood plantations (1000 ha or more) for electricity production in the Philippines have not been a great success.
Leucaena leaf meal is milled, pelleted and shipped internationally in a very variable annual volume, largely to Japan and Europe. Demand is estimated to be up to 1 million t/year, far exceeding production, with world prices similar to those for lucerne pellets or hay. Prices of fodder and wood vary widely in Asia.

Properties Prunings of leucaena applied as green manure decompose rapidly. In litterbag experiments in Nigeria using dried prunings, about 50% of the prunings had decomposed after 20 days and 80% after 40 days. Analyses in Ivory Coast gave a half-life time of 31 days. Chemical analyses of prunings of leucaena grown on alfisols in Nigeria indicated per 100 g dry matter: N 3.3–3.5 g, P 0.09–0.25 g, K 2.5–2.8 g, Ca 1.3–1.6 g, Mg 0.2–0.4 g, lignin 13.4 g, cellulose 21.1 g, hemicellulose 13.5 g, polyphenols 5.0 g and a C/N ratio of 45.5. The average composition of the leaves per 100 g dry matter based on various sources is: N 2.9–4.3 g, P 0.1–0.3 g, K 1.5–2.5 g, Ca 0.5–2.2 g, Mg 0.2–0.4 g.
Leucaena foliage is noted for its good digestibility and high protein value. Feeding leucaena generally improves the total intake of dry matter and of digestible nutrients. Typical values for 'browse fraction' of foliage include 55–70% digestibility, 3–4% N, 6% ether extract, 6–10% ash, 30–50% N-free extract (neutral detergent fibre 20%), 1.5–2.5% tannins, 0.8–1.87% Ca and 0.23–0.27% P. However, the Na levels are invariably low: 0.01–0.05%. The seeds and leaves contain galactomannan gums that block protein extraction and possibly protein utilization by animals; they may potentially have useful biomedical properties.
Leucaena contains the toxic amino acid mimosine which has antimitotic and depilatory effects on animals. It occurs in high concentrations in the growing tips (8–12%), young leaves (4–6%) and young pods and seeds (4–5%). For this reason leucaena leaf cannot safely be included in rations for non-ruminants at a level greater than 5% on a dry matter basis. In ruminants the ingested mimosine is converted to the goitrogenic toxin 3-hydroxy-4(1H)-pyridone (DHP) by plant enzymes and rumen bacteria. In most countries, including Indonesia and the Philippines, rumen bacterium (*Synergistes jonesii*), can completely detoxify mimosine and DHP.
Leucaena wood has an exceptionally high density and energy value for a very fast-growing tree and makes excellent firewood and charcoal. The wood has a density of 500–600 kg/m^3 and a moisture content which varies between 30–50% depending on maturity. Energy values (bone-dry) of wood average 19 250 kJ/kg, of charcoal 48 400 kJ/kg. The bark is thin. The wood turns well, matures to a golden-brown colour and is hard enough for flooring. It is perishable outdoors, but accepts preservatives well. It does not resist termites. Pulp yields are high (50–52%), lignin levels low, fibres short (1.1–1.3 mm); paper quality generally is considered excellent.
The trees occasionally exude a gum very similar to gum arabic, with similar uses and properties; sterile hybrids, especially *L. leucocephala* × *L. esculenta* Benth., exude copiously. The weight of 1000 seeds is about 55 g (arboreal forms) and 35–40 g (common bushy forms).

Description Shrub or tree up to 20 m tall, forked when shrubby or after coppicing, with greyish bark and prominent lenticels; branchlets terete, at the top densely grey pubescent. Leaves bipinnate with 3–10 pairs of pinnae, variable in length up to 35 cm, with an orbicular gland (up to 5 mm) below the proximal pair of pinnae; stipules small; pinnae about 10 cm long; leaflets opposite, 5–20 pairs per pinna, linear or linear-oblong, (6–)8–16(–21) mm × 1–2(–5) mm, base slightly asymmetrically cuneate, apex acute or short-apiculate, both surfaces glabrous, margins ciliate, lower surface glaucous. Inflorescence consisting of pedunculate glomerules aggregated up to 3 in leaf axils or in terminal raceme; peduncle 2–5 cm long, densely grey pubescent; glomerule 2–5 cm in diameter, white; flowers numerous, in globose heads with a diameter of 2–5 cm, white; calyx tubular-campanulate, about 2.5 mm long, puberulous at apex, teeth triangular, acute; petals spathulate, 4.5–5 mm long, puberulous; stamens 10, free, creamy-white to greenish-white; filaments 8–10 mm long; anthers pilose, dehiscing at dawn; pistil 10 mm long, ovary stipitate, velutinous at apex. Pod membranous, straight, dehiscent, 14–26 cm ×



Leucaena leucocephala (Lamk) de Wit – flowering and fruiting branch.

1.5–2 cm, pendant, brown at maturity, 15–30-seeded. Seeds held obliquely in pod, narrowly ovoid, compressed, 6–10 mm × 3–4.5 mm, brown, obtuse at apex, cuneate at base; areole oblong, open towards hilum.

Growth and development Leucaena establishes fairly slowly, particularly in competition with weeds and when grown on soils which are acid or low in nutrients. It sets pods cyclically every 6–8 months if moisture is sufficient, and this is associated with suppression of vegetative growth during fruiting. Arboreal cultivars have been selected for lower flowering rate. Fruits ripen in 10–15 weeks. The flowers are self-fertile and most seed results from self-pollination (this is not true for related species with $2n = 52$ or $2n = 56$). Seeds have a hard seedcoat and survive in the soil for a long time. Seedlings produce a single strong taproot in the first month. Nodulation occurs generally within 2 months in the top 20 cm of soil. Rooting is generally deep, making it a good wind-break and companion tree. Rates of growth usually increase after 3 months, continuing linearly for 3–4 years. Mature trees may reach a stem diameter at breast height of 40 cm. Leucaena coppices well. Coppiced stems sprout 5–15 branches, depending on diameter of the cut surface, and 1–4 stems dominate after a year of regrowth. New stems can grow very rapidly and may reach a height of 10 m in 2 years. Individual leaves persist from 4–6 months. They fold at night or under stress.

Other botanical information The common and giant forms of *L. leucocephala* are distinguished taxonomically as *L. leucocephala* var. *leucocephala* (common form, shrubby, less than 5 m tall, small plant parts, pubescent shoot tips, seeding profusely) and *L. leucocephala* var. *glabrata* Rose (giant form, arboreal, up to 20 m tall, with large plant parts, glabrous shoots). Intermediate types, combining vigorous growth (up to 10 m tall) and large leaves of good fodder quality with extensive, low branching are referred to as the 'Peru' form. The giant or 'glabrata' form gives the highest yields of fodder with infrequent cutting, often outperforming the common form by 100%. The best known cultivars in South-East Asia are 'K8', 'K29', 'K67' and 'K636' (now 'Tarramba') which resulted from research work in Hawaii, and the cultivar 'Cunningham' from Australia. Psyllid-resistant cultivars 'KX2' and 'KX3' are interspecific hybrids and are becoming popular in Asia.

Ecology Leucaena is found up to 1000 m elevation, but new hybrids such as 'KX3' greatly extend this range to cooler climates. Leucaena generally requires annual rainfall of 650–1500 mm, but can be found in drier and wetter locations. It thrives under irrigation regimes similar to those used for crops such as maize (i.e. > 1200 mm/year). For optimal growth leucaena requires warm conditions: mean annual temperature ranging from 20–26°C, maximum temperature range of the hottest month 24–32°C and minimum temperature range of the coldest month 16–24°C. Some cultivars of leucaena are sensitive for even light frost, which causes defoliation; others tolerate frost well, provided it is not too severe or too frequent. Severe frost kills all above-ground parts, but below-ground parts survive and plants will regrow vigorously. Some hybrids e.g. with *L. retusa* Benth. are more frost resistant. Growth of leucaena is highly light- and temperature-dependent. Daily dry matter increments in Hawaii ranged from 13.8 kg/ha in winter (average temperature of 21°C and irradiation of 15 MJ/m^2) to 26.9 kg/ha in summer (average temperature 26°C and irradiation of 23 MJ/m^2).

Leucaena favours deep, well-drained soils with pH > 5, and has a low tolerance to soluble Al. It performs optimally on calcareous soils, but can be found on saline soils and on alkaline soils up to pH 8. Leucaena is not suited to acid soils with pH(H_2O) < 4.8 or to waterlogged conditions. Adequate levels of available phosphorus are needed.

Propagation and planting Leucaena can be propagated by directly sowing seed or by transplanting seedlings. Seed must be scarified to improve germination, usually by placing it in water at 80°C for 3 minutes followed by removal and then allowing it to cool. Inoculation using peat cultures of improved rhizobia strains such as CB3060 (TAL 1145) or CB81 is important for early nodulation and growth. In the absence of peat inoculants the soil from under well-established stands of leucaena can be used as inoculant to promote early establishment. This may also promote early infection by mycorrhiza. It is important not to sow the seed more than 2 cm below the soil surface. Where possible, weeds should be controlled either by slashing or by appropriate chemicals, as early growth is severely reduced by competition. In alley cropping, hedges are planted 4–10 m apart with an intra-row spacing of 0.25–1 m, depending on the pruning regime adopted and the associated crops. Spacing is an effective management tool, as it affects diameter growth more than growth in height. Maximum wood yields in 4-year rotations are obtained with 10 000–20 000 trees/ha. For household fuelwood production leucaena is planted at very high densities of up to 40 000 trees/ha and grown in a 3-year cycle, giving stems with a diameter of about 3.5 cm; for timber and fibre production stands are thinned 2–3 years after planting to 1–2 m × 2 m.

For forage, seeds are usually sown in rows 1–5 m apart with a seeding rate of 5–7 kg/ha, using fertilizer where necessary to correct known soil deficiencies. In cut-and-carry systems, closer plant spacing gives higher yields of leucaena. However, in grazed situations the wider row spacings of 2–5 m are more appropriate to enable grass to grow between the rows. Leucaena can also be established by raising seedlings in the nursery in long narrow containers (3 cm × 15 cm) which accommodate the strong taproot without coiling. Transplanting is done when seedlings are 3–5 months old, preferably after a month in the full sun. Bare-rooted seedlings can be transplanted effectively if shoot and roots are topped. Although weed competition strongly reduces early growth, leucaena is often able to survive because of its ability to tolerate some shade, thereby eventually growing above the weed canopy, provided the area is not closely grazed or mown.

Husbandry Leucaena is a suitable tree for alley cropping provided adequate moisture is available and soil acidity and Al content are not limiting. In long-term alley-cropping experiments in Nigeria and Zaire with leucaena and maize, maize yields in the alley-cropped plots gradually increased over time, but could not be maintained in the plots receiving only chemical fertilizer or manure. In an experiment in Kenya half of the leucaena prunings could be removed for fodder without a significant reduction in maize yield, provided the manure of the animals was returned to the field.

Plants in established hedges are pruned to 25–50 cm at the planting of the associated crop. Subsequent pruning intervals of 6 weeks during the cropping season have given good results. Hedges could be maintained under this system even where 2 crops of maize were grown per year. In India root pruning using a local plough increased yield of the associated sorghum by about 25%. However, information on how to manage the balance of competition between leucaena and the associated crop is still incomplete.

Leucaena has been tested as a live support for yam in a trial in Ivory Coast. In spite of regular pruning it reduced yam tuber yields considerably more than live supports of *Flemingia macrophylla* (Willd.) Merrill or *Gliricidia sepium* (Jacq.) Kunth ex Walp. Its stronger branching, denser shade and denser root system made leucaena more competitive than the other species.

For grazing, leucaena can be grown with many grasses. Pangola grass (*Digitaria eriantha* Steudel), guinea grass (*Panicum maximum* Jacq.), signal grass (*Brachiaria decumbens* Stapf) and Sabi grass (*Urochloa mosambicensis* (Hack.) Dandy) are suitable in the tropics. In the subtropics, Rhodes grass (*Chloris gayana* Kunth) and setaria (*Setaria sphacelata* (Schumach.) Stapf & Hubbard ex M.B. Moss) are suitable companion grasses. Leucaena is very palatable and stands can easily be weakened by heavy continuous grazing. Several rotational grazing strategies have been successful, including a simple 2 paddock system of 4 weeks grazing / 4 weeks rest and a 4 paddock system of 2 weeks grazing / 6 weeks rest. The main principle is to move the animals before they graze leucaena regrowth. When adequate leucaena is available, cattle should be capable of weight gains of about 1 kg/head per day provided the Na level in the diet is adequate.

Diseases and pests There are few diseases of leucaena. Seedling rots such as *Phytophthora drechsleri* and *Fusarium semitectum* attack primarily under waterlogged conditions. The root pathogen *Pirex subvenosus* causes dieback on heavy textured soils in some areas (e.g. on some irrigation areas in north-western Australia). Until the mid-1980s leucaena was relatively free of serious diseases and pests. However, since then devastating effects of the leucaena psyllid (*Heteropsylla cubana*), a tiny, jumping plant louse have been experienced in many areas where leucaena is grown. Psyllid damage is rarely seen in leucaena's centre of origin in South and Central America, and damage caused by the psyllid has decreased with time in other areas. Populations of this insect fluctuate through the season and can reduce yield by over 50%. Attempts to use predatory and parasitic insects for control have met with varying success. The pest now limits the further development of forage leucaena in some areas. Other leucaena species show resistance to psyllids, and have been used in the breeding of resistant hybrids 'KX1', 'KX2' and 'KX3'.

Attacks of soft scale (*Cocus longulus*) and an associated sooty mould can be serious on plants allowed to grow tall. Seed crops can also suffer yield reduction through larvae of the moth *Ithome lassula* attacking the inflorescences and young pods. In some areas, notably Central America and more recently in Australia, bruchid beetles can seriously reduce or destroy seed crops.

Seedlings can suffer attack from cutworms and termites, but, provided there is an adequate stand density, subsequent production is usually not reduced.

Harvesting In alley-cropping systems leucaena is generally cut back to 25–50 cm. Pruning is repeated every 6–8 weeks. In cut-and-carry fodder systems the plants are cut back to 0.5–1.0 m height every 6–8 weeks during the growing season and fed fresh to ruminants. In some of the Indonesian islands (particularly Timor), fresh leucaena may form a large part of the diet of tethered animals intended for slaughter. Banana pseudostems are also fed, to provide water. Such a diet is grossly inadequate in Na, and salt supplementation is required for good production.

Wood harvest periods range very widely, from 1–8 years, depending on size of desired product and harvesting equipment. Matchets are commonly used in Asia, but bandsaws and chainsaws can also be used.

Yield Yields of green manure and forage vary with soil fertility, rainfall, altitude and cutting management, from 1–15 t/ha of dry matter per year. Total yields are reduced by frequent cutting, though leaf yield per day may vary little between cutting intervals of 6, 8 or 12 weeks. Highest yields are obtained under wet tropical lowland conditions on deep well-drained, neutral to alkaline soils. Although leucaena is drought tolerant, yields in the dry season are low unless the plants have access to groundwater or are irrigated.

Wood yields compare favourably with the best tropical trees, with annual height increments of 3–5 m and annual wood increments of 20–60 m^3 for the arboreal cultivars.

Handling after harvest Fodder is commonly fed fresh or provided as a browse. Sun-drying is practised for leaf pelleting and marketing, often by placing branches over a trellis or on asphalt to allow the leaflets to drop. Wood handling is similar to that of other fuelwood or pulpwood species.

Genetic resources Three major collections are held at the University of Hawaii (Honolulu, United States), the Australian Tropical Forages Genetic Resource Centre (CSIRO, Australia), and the Oxford Forestry Institute (United Kingdom). They comprise all 17 *Leucaena* species and total 2000 accessions derived largely from expeditions to Mexico, Central and South America. They are identified by K numbers (Hawaii), CPI numbers (Australia) or OFI numbers (United Kingdom). Naturalized populations of leucaena in Asia show limited genetic variation and are not recommended for production as they are outyielded by improved cultivars.

Breeding Breeding of leucaena is in progress at the University of Hawaii and the University of Queensland, Australia, with the key objective of incorporating psyllid resistance and cold-tolerance from other *Leucaena* species (primarily *L. diversifolia* Benth. and *L. pallida* Britton & Rose) into agronomically desirable forms of *L. leucocephala*.

Prospects Over the last 2 decades leucaena has been one of the most promising multipurpose legumes in South-East Asia. The arrival in 1984 to 1986 of the psyllids curbed the previous enthusiasm, but partial control of the problem now occurs with natural or introduced predators. The prospect of new lines or hybrids more tolerant or resistant to the psyllid has renewed interest in this and related species. Newly-bred cultivars widen the climatic range of leucaena to the highlands and subtropical regions, and some of the new hybrids (e.g. 'KX3') are very cold-tolerant. Improved bole shape ('K636'), psyllid resistance

('KX1', 'KX2'), low mimosine content ('KX3') and increased vegetative vigour are among other advances in breeding.
Improved alley-cropping methods of managing leucaena have been developed in Africa, Indonesia, the Philippines and Central America (Haiti). These are expected to improve crop yields in association with leucaena and aid in the stabilization of land-use systems and of fragile tropical soils.

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R.J. Jones, J.L. Brewbaker & C.T. Sorensson

Lupinus L.

Sp. pl.: 721 (1753); Gen. pl. ed. 5: 322 (1754).
LEGUMINOSAE – PAPILIONOIDEAE
$x = 5$ or 6; *L. albus*: $2n = 30, 40, 48, 50$; *L. angustifolius*: $2n = 40, 48$; *L. luteus*: $2n = 46, 48, 50, 52, 104$; *L. mutabilis*: $2n = 42, 48$

Major species and synonyms
- *Lupinus albus* L., Sp. pl.: 721 (1753), synonyms: *L. termis* Forssk. (1775), *L. graecus* Boissier & Spruner (1843).
- *Lupinus angustifolius* L., Sp. pl.: 721 (1753), synonyms: *L. linifolius* Roth (1787), *L. reticulatus* Desv. (1835), *L. opsianthus* Atabekova & Maissurjan (1969).
- *Lupinus luteus* L., Sp. pl.: 721 (1753), synonym: *L. odoratus* DC. (1825).
- *Lupinus mutabilis* Sweet, Brit. flow. gard., Ser. 1, 2. t. 130 (1825), synonym: *L. cruckshanksii* Hooker (1831).

Vernacular names General: Lupin (En, Fr). Lupine (Am).
- *L. albus*: White lupin, Egyptian lupin (En). Lupin blanc (Fr).
- *L. angustifolius*: Blue lupin, narrow leaved lupin (En). Lupin petit bleu, lupin à feuilles étroites (Fr).
- *L. luteus*: European yellow lupin, yellow lupin (En). Lupin jaune (Fr).
- *L. mutabilis*: Andean lupin, South American lupin, pearl lupin (En). Tarwi, chocho (Sp).

Origin and geographic distribution The origin of *Lupinus* is unknown; it is distributed over the Mediterranean region, where it occurs from southern Europe to the highlands of North and East Africa, and the American continent, where it is found in the western parts of North and South America, but not in the Amazon basin. Only 12 species are native to the Old World, including the cultivated species *L. albus*, *L. angustifolius* and *L. luteus*. *L. albus* originates from the Balkan and the Aegean region, *L. angustifolius* from southern Europe and *L. luteus* from the western Mediterranean. *L. mutabilis* is the main cultivated American species, originating from the Andean mountains.
Lupin domestication commenced relatively late: 4000–3000 BC. The cultivated species are grown worldwide, from cool temperate to subtropical and tropical areas.

Uses Lupins are cultivated as green manure, for soil improvement and in pastures. Lupin has been used as green manure since ancient times. Ploughing in lupin at the flowering or early fruiting stage improves soil fertility. Intensive farming and its associated massive use of mineral fertilizers has largely displaced this practice, however. Lupins, especially *L. albus*, *L. mutabilis*, *L. arboreus* Sims and *L. polyphyllus* Lindley play a prominent role in erosion control, e.g. in Brazil, Peru, New Zealand and Germany. *L. arboreus*, the tree lupin, a native of California, is also used to consolidate coastal land and in reclamation of kaolin mine spoils.

The dry seed of sweet, alkaloid-free cultivars and de-bittered seed is used as fodder in concentrates, as fish feed and, to a lesser extent, for human nutrition. The alkaloid extracts obtained in industrial de-bittering of lupin seed are used as biostimulants and biological insecticides. The fat content of *L. mutabilis* is sufficiently high to justify the extraction of edible oil. *L. luteus* is of greatest interest as a protein-rich forage as it resprouts well from axillary buds and becomes woody later than other species. Flowering lupin makes good hay. Dry plants of bitter lupin, mainly cultivars of *L. luteus* with shattering pods, are eaten by sheep in arid zones during dry summers.

Several lupins are used medicinally. A decoction of the seed of *L. albus* is reported to increase the sugar tolerance in diabetic patients. Traditionally, seed of *L. albus* is used for a variety of ailments, e.g. as anthelmintic, carminative, deobstruent, diuretic and pectoral. Burning the seeds is said to drive away gnats. The asparagin-rich seed of *L. angustifolius* has been used in culture media for the production of tuberculin.

Production and international trade About 2 million ha are cultivated with lupins world-wide, of which 60% is mainly for grain production and 40% for forage and green manure. The former Soviet Union (1 million ha) and Poland (285 000 ha), where *L. luteus* is the main species, account for over 90% of the area cultivated for fodder, while Australia is the leading grain producer with 700 000 ha of *L. angustifolius*. Australia and Chile are the main exporting countries of lupin grain, while the Korean Republic, the European Union and Japan are the leading importers. In Korea, lupin seed is mainly used in fish feed, in Japan and Indonesia for human consumption.

Properties Hay from an immature lupin crop contains per 100 g dry matter: crude protein 32 g, fat 5 g, N-free extract 38 g, crude fibre 20 g, ash 4 g, P 0.45–0.5 g, Ca 0.55–0.6 g, Mg 0.35 g.

The most salient feature of lupin grain is its high protein content, ranking among the highest for legumes and ranging from 30–50% (28–38% for *L. angustifolius*). The proteins contain only small amounts of sulphur-containing amino acids. *L. mutabilis* contains 13–23% fat, *L. albus* 10–14%, whereas all other cultivated species contain less than 7%. The carbohydrate content is 20–30%. The fibre content is inversely related to the size of the grain: 15–18% for *L. luteus*, 7–11% for *L. mutabilis* and only 3–10% for *L. albus*. The ash content varies from 2.5–5%, with little difference between species. The content of the major elements per 100 g dry matter is: P 0.6 g, K 1.1 g, Ca 0.3 g, Mg 0.2 g, Na 1 g. Lupin seed also contains appreciable amounts of ß-carotene, niacin, thiamine and, especially, choline.

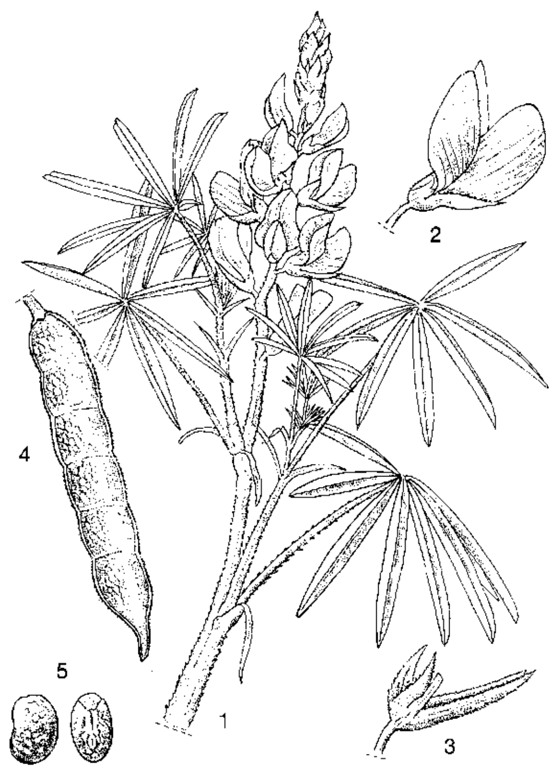
Toxins reduce the nutritional value of lupin plants considerably. Toxic and bitter quinolizidine alkaloids are the main obstacle in using the seed and the rest of the lupin plant. Lupinine and sparteine are the most toxic components. Hydroxyluparine is another lupin alkaloid. The overall alkaloid content of bitter lupin seed per 100 g dry matter ranges from 0.3 g to over 3 g, while selected sweet cultivars contain 0.05–0.2 g. The alkaloids can be removed by boiling or steeping in water. Industrially, they are separated from lupin flour by solvent extraction.

The weight of 1000 seeds is 150–500 g for *L. albus*, 130–200 g for *L. angustifolius*, 110–180 g for *L. luteus* and 120–340 g for *L. mutabilis*.

Description Annual or perennial herbs or shrubs, erect to creeping; habit indefinite; taproot strong, deep. Stem branching to 5th-order laterals, glabrous or pubescent, up to 2 m long. Leaves digitately compound, long-petioled, 5–12 foliolate, heliotrope; stipules adnate to the base of the petiole. Inflorescence a terminal raceme, increasing in size with increasing branching order, 20–30-flowered; calyx bilabiate, divided almost to the base; corolla variously coloured, wings connate at the apex, keel beaked; stamens 10, monadelphous. Fruit a straight, compressed pod, usually constricted between the seeds, dehiscent, 3–12-seeded. Seed variable in shape, size and colour, with sunken hilum. Seedling with epigeal germination.

- *L. albus*. Short-hairy annual, up to 120 cm tall. Leaflets of lower leaves obovate, 25–35 mm × 14–18 mm, those of upper leaves obovate-cuneate, 40–50 mm × 10–15 mm, all mucronulate, nearly glabrous above, sparsely villous beneath, dark green; stipules setaceous. Inflorescence 5–10 cm long, sessile; flowers alternate; calyx 8–9 mm long, both lips shallowly dentate; corolla 15–16 mm long, white or blue. Pod 6–10 cm × 11–20 mm, shortly villous, glabrescent, yellow, 4–6-seeded. Seed orbicular-quadrangular, 8–14 mm in diameter, compressed or depressed, smooth, dull, light yellow, sometimes with dark variegation.

- *L. angustifolius*. Short-hairy annual, 20–80 (–150) cm tall. Leaflets linear to linear-spatulate, 10–50 mm × 2–5 mm, glabrous above, sparsely villous beneath; stipules linear-subulate. Inflorescence 10–20 cm long; peduncle 1–3 cm long; flowers alternate; lower calyx lip 6–7 mm long, irregularly 3-dentate to subentire, upper lip about 4 mm long, 2-partite; corolla 11–13 mm long, blue. Pod 5–7 cm × 1–1.3 cm, shortly hirsute, yellow to black, 4–6-seeded. Seed ellipsoid, 7–8 mm long, smooth, dull, yellow-brown, dark brown or grey with yellow spots.
- *L. luteus*. Hairy annual, 25–80 cm tall. Leaflets obovate-oblong, 40–60 mm × 8–12 mm, mucronate, sparsely villous; stipules dimorphic, those of lower leaves subulate, 8 mm long, those of upper leaves linear-obovate, 22–30 mm × 2–4 mm. Inflorescence 5–16 cm long; peduncle 4–12 cm long; flowers verticillate, scented; lower calyx lip 10 mm long, shallowly 3-dentate, upper lip 6–7 mm long, 2-partite; corolla 13–16 mm long, bright yellow. Pod 4–5 cm × 1 cm, densely villous, black, 4–6-seeded. Seed orbicular-quadrangular, 6–8 mm × 4.5–6.5 mm, compressed, smooth, dull, black marbled with white, with a white curved line on each side.
- *L. mutabilis*. Erect, glabrous annual, 0.5–2.5 m tall. Stem generally slightly woody, more or less glabrous. Leaf (5–)7–9(–12)-foliolate; leaflets ovate to lanceolate or oblanceolate, about 6 cm long, glabrous, yellowish-green; petiole reddish-green to dark green. Inflorescence up to 60-flowered; flowers verticillate, fragrant; corolla 1–2 cm long, blue and/or pink and white, with yellowish eye. Pod up to 12 cm long, densely hairy when young, up to 9-seeded, almost indehiscent. Seed 0.5–1.5 cm in diameter, black, brownish black, white or white with a black or grey halo around the hilum.



Lupinus angustifolius L. – 1, flowering branch; 2, flower; 3, calyx; 4, pod; 5, seeds.

Growth and development During the vegetative phase, leaf rosettes are formed, their longevity depending on species, cultivar and environmental conditions. Flowering is initiated by the influence of vernalization and photoperiod, with major inter- and intraspecific differences. Lupins from the Old World are quantitative long-day plants, *L. luteus* being the most daylength-sensitive. *L. mutabilis* is either a scarcely daylength-sensitive short-day species or a day-neutral species. Flowering is stepwise: inflorescences appear on branches of a given order concomitantly with the flowering of inflorescences on the branches of the immediately preceding order. The length of the flowering period of an inflorescence decreases with increasing branching order. Fertilization is essentially autogamous, but is occasionally allogamous as well in some species and under certain environmental conditions. High temperatures and water stress are decisive in determining the end of flowering. The rate of fruit setting varies with the inflorescence order and usually averages 10–30%. When flowering has ceased, seeds grow rapidly and become ripe virtually simultaneously on all branches.

Lupins nodulate with *Rhizobium lupini* and a crop can accumulate 130–240 kg N/ha. In tests in Australia with *L. angustifolius*, nodules appeared 4–6 weeks after sowing, while nitrogen-fixation started 2 weeks later. Nitrogen-fixation peaked at the beginning of flowering and remained constant until the beginning of seed filling and the onset of water stress; under optimal conditions it may continue until seed maturity and even leaf drop.

Other botanical information Three centres of speciation or origin are distinguished: North and Central America, South America, and the Mediterranean-African region. The number of species in *Lupinus* is disputed. It was long estimated to be about 200, but recent opinion puts it at about 600 or even higher. The majority of the species occur in the Americas and also the new species are described from there. The 4 major cultivated species are quite variable and many cultivars and cv. groups are distinguished. Well-known cultivars of *L. albus* are: 'Kiev', 'Multolupa' and 'Ultra'; of *L. angustifolius*: 'Uniharvest', 'Unicrop' and 'Illyarrie'.

Ecology The mean maximum temperature during the growing season is 15–25°C. Higher temperatures and moisture stress hinder flowering and pod setting. Mediterranean species are cold-tolerant (–6 to –9°C) during the vegetative period. On the other hand, *L. mutabilis* seedlings are cold-sensitive, whereas maturing plants are cold-tolerant. For optimal yield, rainfall should be over 350 mm during the growing period. *L. luteus* has the most modest water requirements (250 mm). Lupins are drought-resistant thanks to their deep roots, but are somewhat sensitive to moisture deficiency during the reproductive period. The best soils for lupin cultivation are well drained, neutral to acid loams. Growth is hampered on clayey and waterlogged soils, while highly calcareous or alkaline soils induce chlorosis and also reduce growth, frequently precluding cultivation. The accepted limiting soil level of $CaCO_3$ is 3–5 g/100 g for *L. albus*, 0.5–1 g/100 g for *L. angustifolius* and 0.5 g/100 g for *L. luteus*. The limestone tolerance of *L. mutabilis* is midway between those of *L. albus* and *L. angustifolius*. Some cultivars of *L. albus* are more tolerant of soil salinity than most crops.

Propagation and planting Lupins require deep soil preparation in order to facilitate root growth. Sowing is done before or after the first rains in autumn in subtropical and warm-temperate regions and in early spring in cool-temperate regions. Early sowing favours growth. Shallow seeding (1–5 cm deep) is advisable. The recommended plant density per ha for sole cropping is 450 000–600 000 for *L. angustifolius* and *L. luteus*, 250 000–800 000 for *L. albus* and 200 000–400 000 for *L. mutabilis*. Lupins are often grown mixed with cereals and other fodder legumes. Inoculation with *Rhizobium lupini* is necessary prior to sowing in fields where lupins have not been cultivated during the last 4–7 years.

Husbandry Cultivated lupins must be weeded, as they compete poorly with weeds during early growth. Pre-emergence herbicides are often advised. *L. angustifolius* and *L. albus* are mostly treated with simazine.

Lupins usually require no N fertilization, but soils containing less than 15 mg P/kg should be supplied with a phosphorus fertilizer at a rate of 30–120 kg P_2O_5/ha, while soils containing less than 40 mg K/kg should be fertilized with 50–120 kg K/ha. *L. angustifolius* is sensitive to magnesium deficiency, which can be corrected by applying 15–30 kg $MgSO_4$/ha. Lupins should never be continuously grown on the same soil, but should be grown in rotation with cereals.

Lupin green manure gives the best yield of the subsequent crop when ploughed in at the grain filling stage. A green manure crop of *L. albus* in Parana (Brazil) had an effect equivalent to 80 kg N/ha and increased the yield of a subsequent maize crop by 25%. Even when lupins are grown for grain, they have a positive residual effect on the subsequent crops. In an experiment with *L. angustifolius* grown for grain in Australia, it yielded 2.5 t/ha, while the 2 following wheat crops yielded 5.4 and 4.7 t/ha, respectively. Three consecutive wheat crops yielded 4.0, 3.9 and 3.9 t/ha. The effect is attributed not only to residual nitrogen but also to a reduction of soil borne diseases. However, long-term use of lupins as green manure may lead to soil acidification.

Diseases and pests Lupins are most commonly affected by brown leaf spot (*Pleiochaeta setosa*) and anthracnose (*Colletotrichum gloeosporioides*), and, to a somewhat lesser extent, root rot (*Fusarium*, *Pythium*, the *Rhizoctonia* complex). The fungus *Phomopsis leptostromiformis* is a serious disease, as it produces a mycotoxin that causes lupinosis, a disease lethal to cattle and even more so to sheep; some lines resistant to this fungus are available now. The most widespread and harmful pests of lupins include army worms (*Heliothis* spp.), which damage buds, flowers and pods. *Phorbia platura* attacks during germination and emergence, and results in plant losses, while the larvae of *Sitona* spp. severely damage root nodules.

Harvesting The habit of lupins, with their rigid stem and high, non-shattering pods, facilitates mechanical harvesting for seed with a conventional cereal harvester. However, such a harvester may damage the seed, so threshing must be done very gently to avoid cracking. Accordingly, the lowest available drum speed and widest possible concave setting should be used.

Yield The average dry matter production of lupins as forage or green manure amounts to 5–10 t/ha. *L. albus* and *L. angustifolius* grain yields can reach 6 t/ha. The typical average grain yield per ha is 1.5–3 t for *L. albus*, 1–2.5 t for *L. angustifolius*, 1.2–2 t for *L. luteus* and 0.75–2 t for *L. mutabilis*.

Handling after harvest Lupin seed should be stored in a dry and cool place and does not require special storage conditions.

Genetic resources Germplasm collections of lupin are maintained at the Western Australia Department of Agriculture, South Perth, Australia; at Campex Semillas Baer, Temuco, Chile; and the Banco de Germoplasma Instituto Nacional de Investigaciones Agraria, Madrid, Spain.

Breeding Since ancient times, farmers have selected plants of *L. albus* and *L. mutabilis* with non-shattering pods and large white seeds that germinate rapidly. Sweet strains of *L. luteus*, *L. angustifolius* and *L. albus* with a low alkaloid content (0.02–0.05 g/100 g) became available in the first 30 years of the 20th Century. Subsequently, strains of *L. luteus* and *L. angustifolius* with non-shattering pods and permeable seeds were developed. Sweet strains of polygenic heredity were recently obtained in *L. mutabilis*.
The current aims of improvement for the Mediterranean region include complete removal of alkaloids, adaptation to winter and spring sowing, increased resistance to cold and diseases, reduced plant height and branching, higher yield levels, higher seed-protein content with more balanced amino acid composition. Selection in *L. cosentinii* Guss., *L. pilosus* L. and *L. atlanticus* Gladst. is currently being directed for use in soil improvement and forage production in clayey or alkaline soils.

Prospects Lupins have great potential for soil improvement, particularly in low rainfall areas with poor acid soils and low phosphate status. They are inexpensive sources of protein for livestock and humans. The wide variation in existing *Lupinus* species and their great ecological adaptability will allow expansion of growing area for various purposes including soil improvement, seed and forage production. Their use in South-East Asia will remain restricted to highland areas. Lupin development has lately been fostered by the establishment in 1980 of the International Lupin Association (Cordoba, Spain) to promote international cooperation and research on lupins.

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L. López-Bellido & M. Fuentes

Maesopsis eminii Engler

Pflanzenw. Ost-Afr. C: 255 (1895).

RHAMNACEAE

$2n = 18$

Synonyms *Maesopsis berchemioides* (Pierre) A. Chev. (1917).

Vernacular names Umbrella tree, musizi (standard trade name) (En). Musizi (Fr). Indonesia: kayu afrika.

Origin and geographic distribution *M. eminii* occurs naturally between 6°S and 8°N in tropical Africa along the Gulf of Guinea (incuding Sao Tomé) from Liberia to Angola and through Zaire, southern Sudan and Uganda to Kenya and Tanzania. It was introduced into Java in the 1920s and is cultivated there and in Sumatra and Kalimantan. From Java, it was introduced into Peninsular Malaysia in 1952. Plantations of *M. eminii* have been established in Africa, India, Indonesia, Malaysia and Fiji, while it has been introduced for testing in Costa Rica, Hawaii, Puerto Rico, the Solomon Islands and Western Samoa.

Uses In Africa *M. eminii* is commonly retained in home gardens for shade, fuel and timber, while the leaves are used as fodder. In Africa and India it is often planted as a shade tree in coffee, tea and cardamom plantations, in Zaire also to shade cocoa trees. Because of its fast growth, it is widely planted for fuelwood, although its light wood is not an ideal fuel. In Java it is commonly planted for this purpose along roads and field boundaries.

Musizi is a good general purpose timber for indoor construction, for joinery, boxes, furniture and millwork, corestock for plywood and particle board. In Uganda, *M. eminii* is used for enrichment planting. The bark is used for roofing and for medicinal purposes in Africa (a decoction is diuretic and purgative).

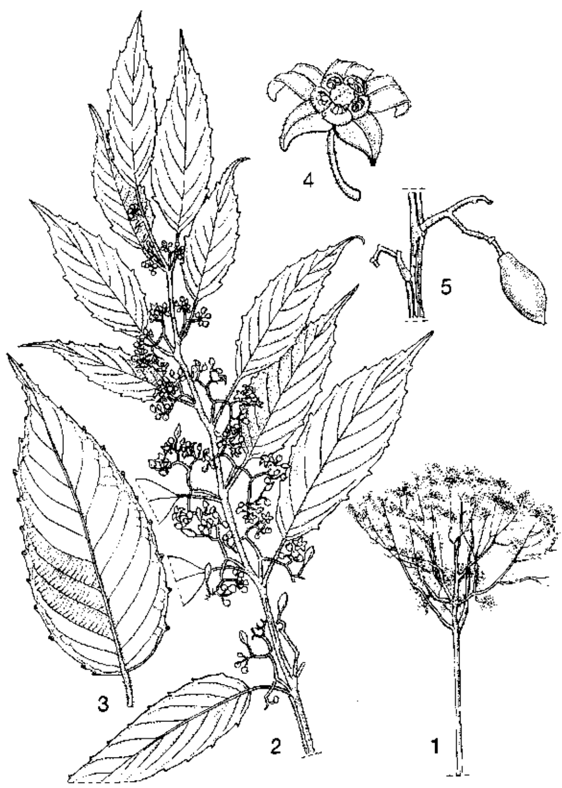
M. eminii is a common ornamental and shade tree planted along roads.

Properties The heartwood is yellowish green when fresh, quickly turning golden to dark brown, the sapwood is white. The heartwood is light with a density of 380–480 kg/m^3, soft, moderately strong and medium to coarse in texture. It dries fairly rapidly with some warp but little checking. Logs have a tendency to split during felling and storage. Timber is easy to saw and works well with machinery, but is difficult to finish. The grain is interlocked. Wood is attacked by termites and is liable to fungal decay, but is highly absorbent and easily treated with preservatives.

The wood of *M. eminii* yields about 50% screened pulp for paper-making, comparable in tearing strength, tensile strength, and bursting strength to commonly used temperate hardwood species.

Analyses of seed from Karnataka, India indicate that the seed of *M. eminii* contains 40–45% of an edible oil, the main components of which are stearic acid (27%), oleic acid (47%), and linoleic acid (15%). Digestibility of the leaves by livestock is excellent and only slightly reduced by heating. The leaves have a dry matter content of 35% and contain per 100 g dry matter: crude protein 26 g, ether extract 3.6 g, ash 5 g, neutral detergent fibre 20 g, lignin 5.4 g, total phenols 2.4 g, tannin (vanilline-HCl method) 5.6 g, tannin (pepsin precipitation method) 0.9 g. The weight of 1000 seeds is up to 200 g.

Description Unarmed, evergreen to deciduous tree, 15–25(–45) m tall with an open, spreading crown. Bole exceptionally straight, cylindrical, up to 15 m tall and 50(–180) cm in diameter; buttresses small or absent; bark pale grey to grey-brown or almost white, smooth or with deep, vertical, often twisted furrows; slash red outside, yellow near the wood. Branchlets with patent short hairs. Leaves mostly subopposite, simple, glandular-serrulate; stipules subulate, 2–6 mm long, puberulent, caducous; petiole 6–12 mm long, puberulent to glabrescent; blade ovate-elliptical to oblong-ovate, 7–14 cm × 2.5–6 cm, lustrous above, paler beneath, glabrous except when young, base rounded to subcordate, apex acuminate, margins with rounded teeth 0.3–5 mm long. Inflorescence a many flowered, axillary cyme, 1–5 cm long; peduncle 4–25 mm long; flowers bisexual, 5-merous, yel-



Maesopsis eminii Engler – 1, habit; 2, flowering branch; 3, undersurface leaf; 4, flower; 5, branchlet with fruit.

lowish-green; pedicel 1–3(–6) mm long; sepals deltoid, 2–6 mm long; petals very strongly concave-convex, hiding the anthers, not clawed; anthers subsessile; style short, dilated; stigma stellately 10-lobed; style and stigma persistent in fruit. Fruit an obovoid drupe, 20–35 mm × 10–18 mm, turning from green to yellow to purple-black when maturing; mesocarp floury, cream-coloured, endocarp creamy-brown.

Growth and development *M. eminii* grows rapidly at 1–3 m per year in height and 1.5–5.5 cm per year in diameter. In Malaysia, it has reached a height of 20 m in 6 years. It flowers from February to May and from August to September in Peninsular Malaysia. Seeds ripen about 2 months after flowering. They are dispersed by birds (especially hornbills in Africa), bats, rodents and monkeys. *M. eminii* is remarkably long lived for a pioneer species attaining over 150 years.

Other botanical information *Maesopsis* A. Engler is a monospecific genus, rather isolated in the *Rhamnaceae* because of the structure of its wood, its number of chromosomes, its protogynous flowers and the morphology of its ovary and style.
M. eminii is sometimes divided into 2 subspecies: subsp. *eminii* (occurring in East Africa and e.g. in South-East Asia; very large trees with large prominent glandular teeth on the leaves), and subsp. *berchemioides* (Pierre) N. Hallé (occurring from Nigeria to Angola; smaller trees with glandular teeth on the leaves much less prominent, about 1–1.5 mm long).

Ecology In Africa, *M. eminii* occurs in association with many other species from lowland tropical rain forest to savanna, extending into submontane forest up to 1500 m altitude, in Rwanda even up to 1800 m. In Java and Malaysia it is mostly planted in the lowland, but it is more vigorous at 600–900 m altitude. It prefers a mean annual rainfall of at least 1200–1300 mm and tolerates a dry season of up to 2 months. In its habitat the mean annual temperature ranges from 22–27°C, the mean maximum temperature of the hottest month from 26–32°C, the mean minimum temperature of the coldest month from 16–24°C. It is very light demanding.
M. eminii grows best on deep fertile soils. It tolerates a wide range of soils, from medium to light and from neutral to very acid, but it does not tolerate waterlogging. In Malaysia, good growth was obtained on alluvial and sedimentary, granite-derived soils.
It was introduced first in German colonial times in the Usambara mountains in eastern Tanzania, then again in the 1930s and 1960s and has rapidly invaded submontane rain forest, to become the dominant species there.

Propagation and planting *M. eminii* is mostly propagated by seed obtained from fresh ripe fruit, after the pericarp has been mechanically removed and the seed has been dried for several days. To improve germination, seed may be soaked in water for 1–2 days, or in concentrated (20 N) sulphuric acid for 20 minutes. Fresh seed has yielded over 90% germination, but viability decreases rapidly after 3 months. Germination generally takes 2–6 weeks, but has been reported to require 100–200 days. Direct seeding is feasible. Because of the strong development of the taproot, polybag nurseries are preferred to raised beds. Seedlings attain plantable size after 2–24 months. Potted striplings and stumps have given good results. Seedling survival rates of 57–84% are reported from Malaysia.

Husbandry Thinning is required after the 5th year to allow a proper crown/stem ratio to develop. For optimal growth, a density of about 125 trees/ha has been calculated in Malaysia. Established plantations may be coppiced. *M. eminii* is self-pruning. It has been proposed as an alternative for *Paraserianthes falcataria* (L.) Nielsen, where the latter is affected by *Xystrocera* wood borers. Rotations in *M. eminii* plantations are kept at 30–40 years, since older trees are often wind-thrown. Rotations are about 8 years for fuelwood, poles and pulp production. In plantations *M. eminii* competes well with weeds but cannot suppress *Imperata* grass.
In agroforestry experiments in Rwanda its growth was not affected by any of the associated crops, but yields of the latter were strongly reduced. Common bean (*Phaseolus vulgaris* L.) did best, yielding about 60% of the unshaded controls.

Diseases and pests Poorly growing trees of *M. eminii* on soils of low fertility or with impeded drainage are prone to canker (in Uganda caused by *Fusarium solani*). Fungal rot may occur during the often long germination period. A bacterial blight may cause damage on poorly drained sites in Malaysia. It is relatively free of pests in South-East Asia, only debarking by squirrels has been reported to cause damage in Malaysia.

Yield Average annual increments of 8–20 m^3/ha are common, but can be as high as 33 m^3. In Malaysia trees planted from seed from Java and Ghana reached harvestable size after 5–8 years. After 5 years at a density of 850 trees/ha the timber yield was about 175 m^3/ha; after 9.5 years the density was reduced in 2 thinnings to 125 trees/ha, while the timber yield was about 300 m^3/ha.

Genetic resources and breeding *M. eminii* appears to be a genetically broad species, reflected e.g. in a significant difference in size between East and West African provenances, the former being much taller. In Malaysia collections of genetic resources are maintained by the Forest Research Institute of Malaysia in four localities in Perak, Kedah and Sarawak.

Prospects Because *M. eminii* can easily be propagated by stumps, requiring little attention after planting and yielding relatively well on poor soils, it may continue to play a role in the reclamation of degraded land and enrichment planting. Given its open crown and long lifespan, *M. eminii* could also continue to play a role as a shade tree for estate crops.

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H.G. Schabel & A. Latiff

Melia azedarach L.

Sp. pl.: 384 (1753).
MELIACEAE
$2n = 28$

Synonyms *Melia sempervirens* (L.) Sw. (1788), *M. dubia* Cavanilles (1789), *M. composita* Willd. (1799).

Vernacular names Chinaberry, Persian lilac, pride of India (En). Indonesia: gringging, mindi (Java), marambung (Sumatra). Malaysia: mindi kecil. Philippines: paraiso, balagañgo (Tagalog), bagaluñga (Bisaya). Singapore: mindi kechil. Cambodia: dâk' hiën, sdau khmaôch. Laos: h'ienx, kadau s'a:ngz. Thailand: lian, lian-baiyai (central), khian (northern). Vietnam: c[aa]y xoan, xoan d[aa]u, s[aaf]u d[oo]ng.

Origin and geographic distribution *M. azedarach* is a widely distributed tree, probably of South Asian origin, occurring widely in tropical, subtropical and warm temperate regions. It is found wild in the Himalayan foothills of India and Pakistan at altitudes of 700-1000 m, widely scattered in China, through Malesia to the Solomon Islands and northern and eastern Australia. It is naturalized in a wide belt in the cooler parts of eastern and southern Africa, in the Americas from Argentina to the southern United States and Hawaii, and throughout the Middle East and the Mediterranean as far north as Croatia and southern France. The most frost-tolerant cultivars can be planted outdoors in sheltered areas in the British Isles.

Uses In South-East Asia, *M. azedarach* is primarily used for fuelwood (e.g. in the Philippines) and is also planted as a shade tree in coffee and abaca (*Musa textilis* Née) plantations and as an avenue tree. It is a well-known ornamental grown for its scented flowers and shade. In South Asia, *M. azedarach* is better known for its medicinal uses. Its various parts have anthelmintic, antimalarial, cathartic, emetic, and emmenagogic properties, and are also used to treat skin diseases. The fruits are so highly valued for their medicinal properties in Malaysia that they are imported from Szechuan (China). However, some toxic components occur in the seed oil, the oral intake of which may cause severe reactions and even death. *M. azedarach* oil may be mistaken for neem seed oil, which is taken orally for medicinal purposes. Aqueous and alcoholic extracts of leaves and seed reportedly control many insect, mite, and nematode pests. However, because they contain toxic components, care is needed in their use.

M. azedarach wood (the 'white cedar' of commerce) is also used to manufacture agricultural implements, carts, tool handles, and furniture, and in construction, because of its termite resistance.

Production and international trade Currently, the use of *M. azedarach* products is almost entirely restricted to the informal sector.

Properties *M. azedarach* contains numerous compounds with anti-feedant and growth-disrupting properties in insects. These compounds are related to those in neem (*Azadirachta indica* A.H.L. Jussieu), but recent information indicates that azadirachtin, the most important compound in neem, is absent in *M. azedarach*. The fruits of *M. azedarach* are highly toxic to warm-blooded animals; the consumption of 6–8 fruits can cause nausea, spasms and death in children. The proximate oral lethal dose for pigs of purified ethanolic extract of fruits was found to be 6.4 mg/kg live weight. Ruminants seem less sensitive and several species of birds eat the fruits. After eating too many fruits, however, these animals sometimes show mild intoxication and temporary paralysis. The leaves are generally much less toxic and in India are fed to goats. They were also used to rid goats and sheep of intestinal worms. The presence of toxic and non-toxic forms is reported from New South Wales. The flowers may cause discomfort to asthma patients and the wood dust sometimes induces dermatitis. The bark exudes a water-soluble gum.

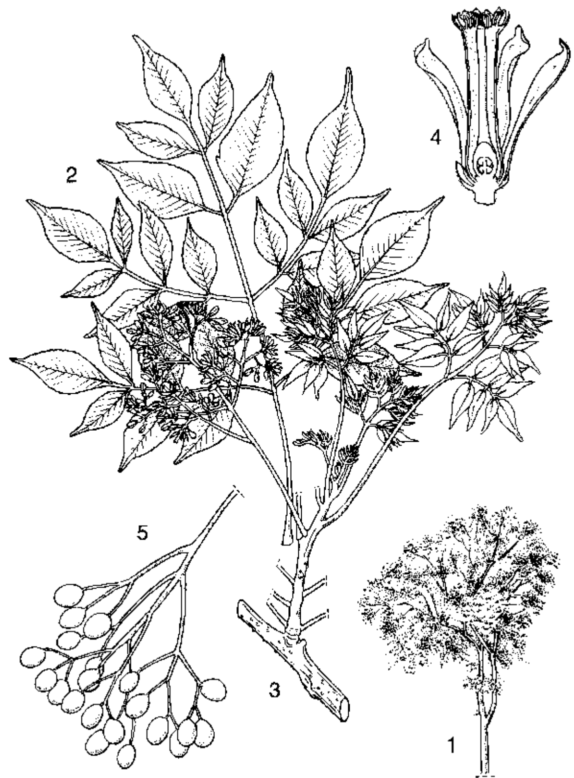
Of the many compounds isolated from the fruit, the triterpenoid melianotriol, desacetylochinolide B, and several nimbolins and sendanins have shown very strong anti-feedant properties in insects. Insecticidal properties are found in the derivatives of vilasinine, meliacin and meliacarpin. The latter are azadirachtin analogues. Many of these compounds are similar to the insect hormones known as ecdysones, which control moulting and metamorphosis. Toosendanin, a triterpenoid related to sendanin has been isolated from the bark and has nematicidal properties. A glycopeptide in the leaves and roots inhibits in vitro replication of several RNA and DNA viruses.

The seed contains an oil high in linoleic acid (65–82%) and oleic acid.

The wood of *M. azedarach* resembles mahogany. It makes good construction timber, durable even in exposed locations and not affected by termites. Its density is 510–660 kg/m³, its energy value 24 000–25 000 kJ/kg.

The weight of 1000 seeds is 75–250 g.

Description Deciduous tree up to 45 m tall; bole fluted below when old, up to 60(–120) cm in diameter. Bark grey-brown, smooth, lenticellate, becoming lightly fissured or scaly with age; inner bark yellowish; sapwood whitish, heartwood rusty brown. Crown widely spreading, with sparsely branched limbs. Twigs upturned at end of drooping branchlets, smooth, brown, lenticellate, with raised cicatrices; leafy twigs with fulvous stellate



Melia azedarach L. – 1, habit; 2, leaf; 3, flowering branch; 4, section through flower; 5, infructescence.

hairs. Leaves bipinnate, occasionally wholly or partly tripinnate, more or less opposite, (15–)23–80 cm long, glabrescent; petiole 8–30 cm long, terete, lenticellate, swollen at base; pinnae in 3–7 pairs, up to 25 cm long; petiolule 3–7 mm long; leaflets in 3–7 pairs, opposite or nearly so, ovate or oblong-lanceolate to elliptical, 2–10 cm × 0.6–3.8 cm, base slightly unequilateral, acute to rounded, apex acuminate, margin entire to variously serrate. Inflorescence a thyrse, axillary or in axil of rudimentary leaves on short shoots, 10–22 cm long, primary branches 5–7.5 cm long, secondary branches up to 2 cm long, bearing fascicles of flowers; bracts 3–10 mm long, filiform, caducous, bracteoles similar but smaller; pedicel 2–3 mm long; flowers purplish, fragrant, bisexual or male, 5-merous; calyx tubular, about 2 mm in diameter, lobes about 2 mm long, exterior stellate and with simple hairs; petals free, narrowly oblong, 6–10 mm × 2 mm, white to lilac or bluish, outside minutely pubescent; staminal tube about 7 mm long, lilac turning deep purple, exterior glabrous, interior with dense simple hairs; anthers 10, sessile; pistil glabrous, stigma clavate, 5-lobed. Fruit a drupe, ellipsoid-globose, 2–4 cm × 1–2 cm, yellow-brown when ripe, glabrous, up to 5-seeded. Seed oblongoid, 3.5 mm × 1.6 mm, smooth, brown.

Growth and development Under optimal conditions *M. azedarach* grows fast. In Uganda it has grown about 1.7 m in height annually for several years after planting. It is generally deciduous, but some forms in the humid tropics (e.g. in Malaysia and Tonga) are evergreen. It flowers from March to May in the northern hemisphere, though some forms flower throughout the summer and even throughout the year. Fruit drop is limited and ripe fruits cling to the branches for several months even when leaves have fallen. The tree resprouts after cutting and regrows after pollarding, making it suitable for pole production.

Other botanical information *M. azedarach* is a variable, complex species, comprising many wild and cultivated forms formerly often recognized as separate forms, varieties or species. Besides the wild trees, two groups of cultivars are recognized: Chinese and Indian. The wild tree is taller (up to 45 m), its leaflets are entire, its flowers are sweetly scented to malodorous, the petals white or pale mauve and the fruits up to 4 cm long. It is sometimes grown for wood (e.g. in the Philippines). The Chinese cultivars are smaller, with entire leaflets, fragrant, mauve, pink or blue flowers and larger fruits than the Indian cultivars. In South-East Asia, trees of Chinese cultivars are rare. The Indian cultivars are more common in South-East Asia; they are smaller trees, with irregularly serrate leaflets and sweet, fragrant, pink or blue flowers. Well-known cultivars in the Indian group are 'Floribunda', a precocious form, flowering when only a few m tall and used as bedding plants, and 'Umbraculifera', a mutant found in Texas with a flattened crown. *M. azedarach* L. var. *australasica* (Juss.) DC. which occurs naturally in eastern Australia and is planted in the Philippines, grows into a large tree, to 45 m tall and 1.2 m in diameter under humid conditions.

M. azedarach is often confused with the neem tree (*Azadirachta indica*). Neem can easily be distinguished: it never has stellate hairs, it has pinnate leaves (not bipinnate), 3-lobed stigmas (not 5-lobed), and 1(–2)-seeded drupes (not up to 5-seeded).

Ecology The natural habitat of *M. azedarach* is seasonal forest, including bamboo thickets, *Tamarindus* woodland and *Eucalyptus* savanna. Its natural occurrence from the Himalayan foothills of Baluchistan (Pakistan) and Kashmir (India) to the lowland of Papua New Guinea indicates that it is highly adaptable and tolerates a wide range of conditions. The mean maximum temperature of the hottest month may reach 39°C, the mean minimum temperature of the coldest month –5°C, although many forms tolerate a narrower range only. In eastern coastal Australia *M. azedarach* occurs where the mean maximum temperature of the hottest month is 26–32°C and the mean minimum temperature of the coldest month 3–10°C. Young trees are sensitive to frost, but old ones tolerate up to –15°C. It is generally found from 0–1200 m altitude, in the Himalayas up to 1800(–2200) m. Annual rainfall in its natural habitat ranges from 600–2000 mm. In Africa it is planted as a drought-tolerant shade tree and ornamental. *M. azedarach* is widely distributed in the drier parts of the southern and south-western United States, while in humid Florida it is self-sowing and considered a weed. Where annual rainfall is less than 600 mm, as in parts of the Middle East, it performs well on wet soils along rivers and under irrigation. *M. azedarach* tolerates seasonal waterlogging and is even reported from permanently waterlogged sites. Strong winds may break off limbs.

Although optimal growth is obtained on well-drained, deep, sandy loams, *M. azedarach* tolerates shallow soils, saline and strongly alkaline soils, but not very acid soils. Reports on its tolerance of heavy clays are contradictory. It is found on poor, marginal, sloping, and stony land, even in crevices in sheer rock.

Propagation Although successful vegetative propagation through stem cuttings, root suckers and air layering has been reported, propagation is usually by seed. Drupes need to be macerated until the seed can be gently eased out. Seeds are soaked in water for 1–2 days, depulped, and dried in the shade. They can be stored in a cool and well-ventilated place, in cloth or gunny bags. Plastic and other airtight containers should not be used for seed storage. Seed should be planted within two weeks after harvesting, as viability drops rapidly thereafter. Sowing is mostly done in a nursery at 15 cm × 2.5 cm in a sunny place, keeping the seed lightly covered with soil or mulch. Seedlings may be thinned to 15 cm × 15 cm when 2 months old, and transplanted when 7–10 cm tall.

Husbandry A few weedings are required during the first 2 years after planting. When grown for timber, stems are pruned to a height of about 6 m to obtain a branch-free bole. In Paraguay, *M. azedarach* grown in small woodlots for timber, is often interplanted with a variety of food crops. It is planted at a spacing of 4 m × 3 m, thinned after 3 years to 400 trees/ha and after 6 years to 200 trees/ha.

Diseases and pests Although some bacterial and fungal diseases have been observed on leaves, twigs, and fruits, no serious damage has been reported. Generally, *M. azedarach* is also little affected by pests.

Harvesting Pollarding of *M. azedarach* for fuelwood and poles is usually done on 5–10-year-old trees.

Yield In Thailand, timber yields of 10-year-old stands of *M. azedarach* are estimated to be about 85 t/ha. In Paraguay, 12–15 years after planting, woodlots yield about 100 m^3 posts and small-sized wood and 175 m^3 logs. Under natural conditions, *M. azedarach* fruit yield is higher than neem's, but there are no data on this.

Handling after harvest Fruits should be depulped immediately after collection, and the seed dried in the shade and stored in a well-ventilated, cool place.

Genetic resources and breeding No substantial germplasm collections of *M. azedarach* are known to exist. Neither are any breeding programmes known. Breeding work may lead to e.g. improved burning quality, drought tolerance, and higher fruit and oil yields.

Prospects Its quick growth and small dimensions make *M. azedarach* a good choice for fuelwood production for household needs. Its ability to grow under suboptimal conditions makes *M. azedarach* suitable for reforestation and reclamation of marginal land in semi-arid areas in tropical highland and temperate regions. *M. azedarach* may provide excellent prospects for exploitation as a natural pesticide.

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S. Ahmed & Salma Idris

Melilotus Miller

Gard. Dict., abr. ed. 4 (1754).
LEGUMINOSAE – PAPILIONOIDEAE
$x = 8$; *M. alba*: $2n = 16, 24, 32$; *M. indica*: $2n = 16$; *M. officinalis*: $2n = 16, 32$; *M. suaveolens*: $2n = 16$

Major species and synonyms
- *Melilotus alba* Medikus, Vorlesungen Churpfälz. Phys.-Ökon. Ges. 2: 382 (1787), synonyms: *M. alba* Desr. (1796), *Trifolium vulgare* Hayne (1807).
- *Melilotus indica* (L.) All., Fl. Pedem. 1: 308 (1785), synonyms: *Trifolium melilotus-indica* L. (1753), *Melilotus parviflora* Desf. (1799).
- *Melilotus officinalis* (L.) Pallas, Reise russischen Reichs 3: 537 (1776), synonyms: *Trifolium melilotus-officinalis* L. (1753), *Melilotus officinalis* (L.) Lamk (1778).
- *Melilotus suaveolens* Ledeb., Ind. Sem. Hort. Dorpat, suppl. 2: 5 (1824), synonym: *M. graveolens* Bunge (1833).

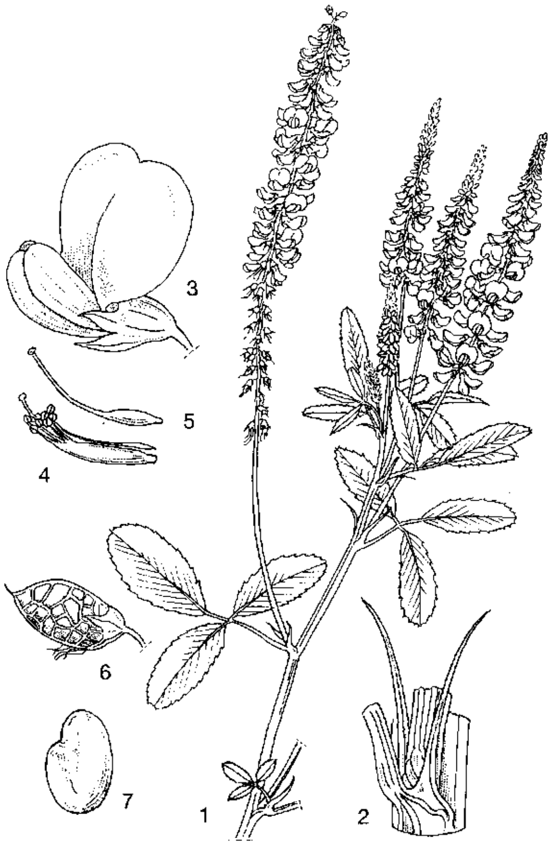
Vernacular names General: sweetclover (En). Mélilot (Fr).
- *M. alba*: White sweetclover, white melilot, bokhara clover (En). Mélilot blanc (Fr).
- *M. indica*: Sourclover, Indian clover, senji (India) (En).
- *M. officinalis*: Yellow sweetclover, yellow melilot (En). Mélilot officinal (Fr).
- *M. suaveolens*: Daghestan sweetclover (En). Vietnam: nh[ax]n h[uw][ow]ng.

Origin and geographic distribution Sweetclovers are widely distributed throughout Europe and Asia, mainly in temperate and subtropical areas, extending into North Africa, India (*M. indica*), Indo-China and Taiwan (*M. suaveolens*). *M. alba* and *M. officinalis* are cultivated extensively in North America, where they have attained their greatest importance in the Corn Belt and Great Plains of the United States and Canada, and in Eastern Europe and the Russian Federation. They have been introduced into Australia, South America and into eastern and southern Africa. *M. indica* is cultivated in India (mainly in the northern parts), in Pakistan and the United States. *M. suaveolens* is occasionally cultivated in China and North America.

Uses Sweetclover is used for green manure, soil improvement and forage. It is said to have no equal as a soil-improving crop in the United States. As a forage crop, the use of sweetclover as a pasture crop far exceeds its uses for either hay or silage. Good quality hay can be made from the first-year growth. Because hay from the second-year growth is rather coarse, forage is often converted into silage. *M. suaveolens* is grown as a cover crop and forage plant on saline soils in China.
Seed oil is used in paint and varnish, and seed meal as protein supplement in cattle feed. Sweetclover is prized as a good honey plant, yielding large quantities of good quality, pale honey with a mild flavour. The honey has been used since the ancient Greeks for flavouring foods and for medicinal purposes, having astringent and narcotic properties. In Vietnam, *M. suaveolens* is used in lotions to treat eye diseases.

Properties The composition of *M. alba* green fodder per 100 g is: moisture 79.2 g, protein 4.1 g, crude fibre 4–9 g, total digestible nutrients 12.8 g. Chemical analysis of green material showed per 100 g: N 0.83 g, P 0.07 g, K 0.67 g, and Ca 0.50 g. The silage is similar to maize silage in nutritive value, but is not as palatable, containing per 100 g: moisture 72 g, protein 4.5 g, crude fibre 9.6 g, total digestible nutrients 15.7 g. Good quality *M. alba* hay can approach the chemical composition and feeding value of lucerne hay, containing per 100 g: moisture 8.2 g, protein 16.5 g, crude fibre 24.6 g, total digestible nutrients 50.3 g. Sweetclover contains coumarin, hydrocyanic acid, malonic acid, and melilotin. Coumarin reduces the palatability to livestock. Feeding spoiled hay or silage from high-coumarin cultivars may lead to 'sweetclover bleeding disease'. Affected animals may bleed to death from small wounds or internal haemorrhages.
The weight of 1000 seeds is 150–200(–390) g.

Description Annual or biennial, sometimes scented herbs. Leaves trifoliolate; stipules adnate to the petiole, subulate; leaflets dentate. Inflorescence an axillary raceme; flowers small; bracts small; bracteoles absent; calyx campanulate with 5 subequal teeth; corolla yellow or white, rarely purple, glabrous, caducous, standard usually longer than keel and wings, keel shorter than wings, obtuse, not adnate to stamens; stamens diadelphous, anthers uniform. Fruit a small pod, straight, ovoid to nearly globose, with persistent pedicel and calyx, 1–4-seeded. Seed smooth or nearly so.
- *M. alba*. Erect, ascending or decumbent, sparsely branched, scented, annual herb, up to 1.5(–2.5) m tall, with long taproot. Stipules lanceolate to setaceous, 4–6 mm long; petiole 0.5–2 cm long, petiolule up to 5 mm; leaflets obovate to oblong-obovate, 1–2.5 cm × 5–12 mm, serrate-dentate almost to the base. Raceme 5–20 cm long, on an up to 4 cm long peduncle; flowers



Melilotus alba Medikus – 1, flowering branch; 2, stipules; 3, flower; 4, stamens and pistil; 5, pistil; 6, pod; 7, seed.

white, calyx about 2 mm long, corolla 4–6 mm long, style 1.7–2.3 mm long. Pod obovoid to ovoid, 4 mm long, reticulately veined, greyish to blackish-brown when ripe. Seed ovoid, about 2 mm long, yellow-brown.

- *M. indica*. Erect, annual herb up to 60 cm tall. Stem pubescent. Stipules lanceolate to setaceous, 5–8 mm long; petiole up to 4.5 cm long, petiolule up to 5 mm; leaflets oblong to obovate, 0.8–2.5 cm × 2–9 mm. Raceme 10–16-flowered; peduncle up to 3 cm long; flowers yellow; calyx about 1.5 mm long, teeth triangular-lanceolate; corolla 2–3 mm long; style 0.9–1.2 mm long. Pod 1-seeded, 1.5–4 mm long, prominently reticulately veined, olive-green. Seed ovoid, about 2 mm long, yellow-brown, finely verrucose.
- *M. officinalis*. An erect, much branched, scented annual or biennial with stout stem up to 1.5(–3) m tall and thickened roots. Stipules 3–6 mm long; petiole up to 3 cm long, petiolule up to 6 mm; leaflets obovate to oblong-lanceolate, 1–2.5 cm × 4–15 mm. Raceme up to 10 cm long, peduncle about 2 cm long; flowers 4.5–8(–10) mm long; calyx teeth equal, acute; corolla yellow; style 1.7–2.3 mm long. Pod ovoid, 3–6 mm long, glabrous, brown when ripe, transversely reticulate or irregularly rugose, usually 1-seeded. Seed ovoid, about 2 mm long, yellow-green.
- *M. suaveolens*. Annual to biennial herb, up to 1.5 m tall, pubescent to subglabrous, with thickened roots. Stem erect, angular, glabrous. Stipules 8–10 mm long; petiole up to 2 cm long, petiolule up to 1 mm; leaflets narrowly elliptical to obovate, 1–3 cm × 3–8 mm. Raceme 10–15 cm long, densely flowered, elongate after anthesis; peduncle 2–5 cm long; flowers pale yellow, 3–4 mm long; style 1.7–2.3 mm long. Pod ellipsoid, about 3 mm long, finely reticulate. Seed ellipsoid, 2 mm long, reddish.

Growth and development Well-ripened, mature seed is hard. Seed can be stored for long periods. After storage for 40 years in stoppered glass bottles, 60% of the seed still germinated in a trial in the United States. During the first year, biennial cultivars form a primary stem which becomes much branched under favourable conditions, a deeply penetrating taproot and, as the season progresses, a crown. When sweetclover is cut early, regrowth is from buds higher up the stem. Top growth reaches maximum development during late summer when a rapid increase in the size of the taproot begins which continues during autumn. Growth in the second year starts quickly and largely consists of rather coarse stems, which may reach to nearly 3 m in *M. officinalis*. Root thickening does not occur in annual cultivars. Control of flowering and taproot thickening is not fully understood. The flowering of biennial cultivars is initiated by long days. Under a daylength of 18 hours, flowering starts within 3 months after sowing. Vernalization seems to be of only minor importance.

Sweetclover fixes atmospheric nitrogen and is an aggressive colonizer, quickly invading roadsides, railways and fence lines. Around 1900 it was listed as a noxious weed, but by 1910 its value as a cover crop and green manure plant was well established in North America.

Pollination is by insects, mostly honey bees. Flowers of *M. alba* and *M. officinalis* only set seed when tripped by visiting insects. *M. alba* and *M. indica* are self-fertile; self-incompatibility is common in *M. officinalis*.

Other botanical information *Melilotus* comprises about 25 species found chiefly in the Mediterranean region and central Asia. The following characteristics may be useful to easily distinguish between the 4 species described here: *M. indica*: style length 0.9–1.2 mm (other species 1.7–2.3 mm); *M. alba*: flowers white (other species yellow); *M. officinalis*: pod strongly transversely veined (other species irregularly veined); *M. suaveolens*: style 1.7–2.3 mm long, flowers yellow, pod irregularly veined, plant very fragrant.

M. alba and *M. officinalis* are closely related and sometimes hybridize naturally. Some authors prefer to write *M. albus* and *M. indicus* instead of *M. alba* and *M. indica*.

Well-known annual cultivars of *M. alba* are 'Emerald', 'Floranna', 'Hubam' and 'Israel'. Biennial cultivars are 'Arctic', an early maturing, winter-hardy cultivar, 'Polara', which is low in coumarin, but produces lower yields, both from Canada, "Denta', from the United States, which is low in coumarin and late, 'Chermasan' and 'Medet' from Russia. 'Goldtop', 'Madrid' and 'Norgold' are cultivars of *M. officinalis* commonly used in North America, 'Katek' and 'Omskii Skorospelyi' are used in the Russian Federation.

Ecology Sweetclover is adapted to a wide range of climatic and soil conditions. It occurs in grassland, arable fields, wasteland and along roadsides, especially in calcareous soils. It is frost-hardy and grows well from sea level up to 2000 m altitude in the United States and China. Sweetclover is drought tolerant, requiring enough moisture for germination, after which it will survive under dry conditions. It comes up well under irrigated conditions, but does not give a good ratoon. For optimal growth it requires a well drained, fertile soil of pH 6.5–7.5 and adequate moisture. Heavy clays and light sands will produce a successful crop. Acid soils are not tolerated. In China, *M. suaveolens* is grown on saline soils.

Propagation and planting Propagation is by seed, but propagation by cuttings is also possible. Due to a hard testa, seed must be scarified. Seed rate varies from 11–17 kg/ha. Inoculation with effective *Rhizobium* strains is recommended in fields not previously sown with sweetclover. It has been suggested that it is worthwhile using inoculated seed at each planting. Seeds are small, thus the seedbed should be fine and seed placed no deeper than 1–2 cm in the soil.

Husbandry Sweetclover is often sown in mixtures with cereals grown for forage or grain, with grasses, or grown in rotation with cereals. When grown in mixtures with cereals it is left to cover the soil in winter and is ploughed in early next spring. The strong taproot opens up the subsoil, providing favourable conditions for growth in succeeding crops. Roots break down and release nutrients rapidly at maturity. Sweetclover is particularly susceptible to injury from herbicides, especially 2,4-D.

Diseases and pests Sweetclover is affected by several diseases in the more humid parts of its area of cultivation in the United States and Canada. *Phytophthora cactorum* causes root rot and crown injury in the spring of the second year. *Ascochyta caulicola* and *Cercospora davisii* cause 'black stem', characterized by stunted, blackened stems, poor flowering and reduced seed set. The sweetclover weevil (*Sitona cylindricollis*) is the main insect pest in North America. Seedlings are most vulnerable, adult plants may be defoliated, but generally survive and outgrow the damage.

Harvesting Timing and intensity of grazing or cutting are very important in sweetclover. Intensive grazing or mowing in the first season before the formation of a crown may lead to poor regrowth if there are a limited number of buds on the stem. Grazing or mowing in autumn can prevent adequate development and accumulation of assimilates in the root, leading to poor growth in the second year. Second-year growth is vigorous and heavy grazing is essential when tops are 20–25 cm tall, to keep plants palatable. Good quality hay, equal in palatability and feeding value to lucerne, may be produced from first-year growth. Second-year growth is less satisfactory for hay, as leaves become brittle and shatter in handling. The best quality of silage is obtained from crops cut prior to flowering.

Yield Yield of hay varies from 2.2–5.5 t/ha during the first year to 2.2–8.1 t/ha during the second year in the United States. In India, *M. alba* 'Hubam' has yielded 9.0–10.5 t/ha in 2 cuttings. As a green manure crop, 'Hubam' adds about 80 kg/ha N to the soil. Seed yield averages about 225 kg/ha in the United States, but it has been estimated that about 40% of the seed is lost due to shattering.

Genetic resources and breeding A germplasm collection of some 1300 accessions is maintained at the Canada Department of Agriculture, Brandon, Canada. The development of strains with large seed, resistance to seedling diseases, winter hardiness, drought resistance, tolerance to acid and saline soils, and a higher proportion of permeable seed are objectives for improving these crops. Breeding work is being done in Canada, the

United States and the Russian Federation. Cultivars with low coumarin content have been bred, following the discovery of a low-coumarin gene in *M. dentata* (Waldst. & Kit.) Pers. and its transfer into *M. alba* and *M. officinalis*.

Prospects Sweetclover may regain its former importance in North America and Europe as a green manure and honey crop as more land is left fallow. These 4 *Melilotus* spp. all occur occasionally naturalized in the tropics, especially in highland areas. Their qualities as soil-improving crops in temperate areas warrant their testing in tropical highland areas.

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R.K. Arora & P.N. Mathur

Mikania Willd.

Sp. pl. ed. 4, vol. 3(3): 1742 (1803).

COMPOSITAE

$2n = 36$ (*M. cordata*); 36, 38, 72 (*M. micrantha*)

Major species and synonyms
- *Mikania cordata* (Burm.f.) B.L. Robinson, Contrib. Gray herb. 104: 65 (1934), synonyms: *Eupatorium cordatum* Burm.f. (1768), *Mikania volubilis* (Vahl) Willd. (1803).
- *Mikania micrantha* Kunth, Nov. gen. sp. pl. vol. 4: 105 (1820), synonyms: *M. orinocenis* Kunth (1820), *M. subcrenata* Hooker & Arnott (1836), *M. umbellifera* Gardner (1845).

Vernacular names General: mikania (En).
- *M. cordata*: Mile-a-minute (En). Indonesia: brojo lego (Javanese), blukar (Sumatra), hila hitu lama (Ambon). Malaysia: akar lupang, ceroma, selaput tunggul. Philippines: bikas (Bagobo), detidid (Igorot), uoko (Bontok). Thailand: khikaiyan.
- *M. micrantha*: Bitter vine (En). Liane-serpent (Fr).

Origin and geographic distribution Most species of *Mikania* are native to the Americas; the most widely distributed species *M. cordata*, however, is native to and widespread in South-East Asia including Hainan and Taiwan. *M. micrantha* is native to Central and South America; it was first observed in Fiji in 1907, in Java in 1951 and is now found in India, Sri Lanka, Malaysia, Indonesia, the Philippines, New Guinea and several Pacific Islands.

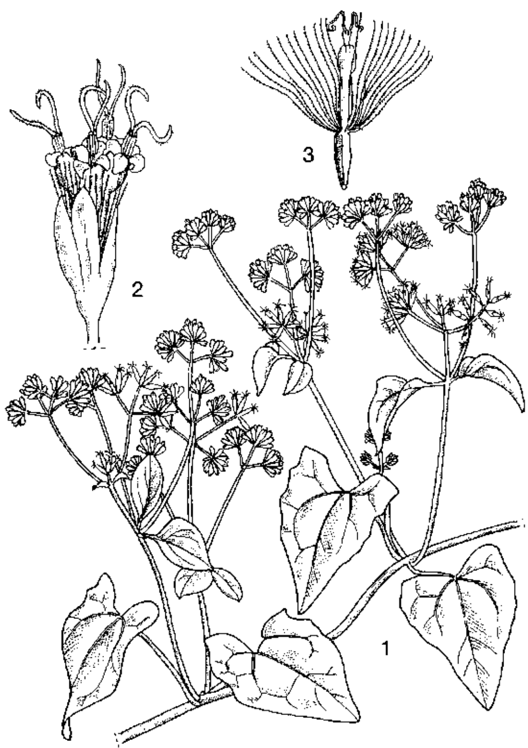
Uses Although often considered a nasty weed, *Mikania* is sometimes tolerated as a spontaneous soil cover in plantation crops e.g. rubber and oil palm, where its growth is limited by shade or where it can be controlled by herbicides. In plantation crops that transmit more light, and to a lesser extent in annual crops, it is considered one of the most noxious weeds. It is especially troublesome in young plantations, where it can quickly overgrow the main crop.

Leaves of *M. cordata* constitute a highly palatable forage, especially to sheep. They are also used as a poultice for swellings (Taiwan), itches (Malaysia) and wounds (Indonesia).

Properties The dry matter digestibility of *M. cordata* is about 50% and N concentrations range from 2.6–3.4%, Ca concentrations from 1.5–1.9% and P concentrations from 0.6–0.9%. It has high concentrations of Cu, about 18 mg/kg. It has been reported from Malaysia that *Mikania cordata* contains phenolic or flavonoid substances that inhibit the growth of other plants e.g. rubber, tomato and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), and depress nitrification in soils.

Description Perennial, trailing or climbing herbs. Stems branched, terete or angular. Leaves opposite, usually petiolate, simple and entire. Inflorescence composed of corymbosely or cymosely clustered, peduncled heads; head 4-flowered, homogamous; involucral scales 4, oblong, narrow, subequal; corolla campanulate, 5-fid, tube narrow; receptacle small, naked; anthers obtuse at base, apex with appendages; style branches 2, slender, long exserting the corolla, pubescent, subobtuse at apex. Fruit an oblongoid, 5-angular achene, usually glabrous; pappus bristles numerous, uni-seriate, equal, scabrid or barbellate.

- *M. cordata*. Scandent herb, often forming a dense tangled mass. Stem subterete or irregularly angular, ribbed, up to 6 m × 2–3 mm, internodes 8–20 cm long, nodes thickened, sometimes with short hairs. Leaf blade triangular-ovate, 2.5–10 cm × 2.5–7 cm, base cordate or shortly contracted, margin crenate-dentate, sinuate or entire, apex acutely acuminate, subglabrous, dotted with glands beneath; petiole 1–4 cm long. Inflorescence composed of peduncled heads, combined into small dense corymbs, at the top of short lateral branches and in the axils of leaves; peduncle of corymbs very variable in length; peduncle of heads up to 6 mm long; head 6.5–7.5 mm × 1.5–2 mm; involucral bracts elliptical-oblong, 6 mm long; corolla 3.5–4 mm long, yellowish-white; style branches 2.5 mm long, white. Achene 2–3 mm long, glandular, black-brown; pappus of 40–45 bristles, 3–4 mm long, white to reddish.



Mikania cordata (Burm.f.) B.L. Robinson – 1, flowering plant part; 2, flower head; 3, achene with flower.

- *M. micrantha*. Creeping or twining herb. Stem terete to ribbed, pubescent to glabrous; internodes 5–20 cm long. Leaf blade ovate, 2–13 cm × 3–10 cm, base cordate, margin undulate-dentate to subentire, apex acuminate, glabrous; petiole up to 8 cm long. Inflorescence an axillary or terminal panicle of corymbs; peduncle about 6 mm long; flower head 4–6 mm long; involucral bracts ovate-oblong 3–4 mm long, glabrous, apex acute; corolla 2.5–3 mm long, white to greenish. Achene 2 mm long, black, with very small glands between the ribs; pappus of 33–36 bristles, 2–3 mm long, white.

Growth and development *Mikania* spreads by seed or by rooting at nodes touching the soil. Even small pieces of stem, spread by people or animals, may grow into new plants. Flowering occurs throughout the year. Seeds are produced in large numbers and the pappus enables effective wind dispersal over long distances. With its rampant growth it can rapidly smother young tree crops and other plants, hence the common name of *M. cordata*: 'mile-a-minute'. It can rapidly form a tangled mass to a depth of 0.6–1 m. If undisturbed, it often spreads in massive circular patterns.

Other botanical information *Mikania* comprises about 400 species, many of which are quite variable and difficult to identify. The 2 species treated here have long been considered as one species: *M. scandens* (L.) Willd. *M. scandens*, however, only occurs in the Americas. References to *M. scandens* from Asia usually refer to *M. cordata*. Distinctive characters of the 2 species are:

- *M. cordata*: heads 6.5–7.5 mm long; involucral bracts elliptical-oblong, 6 mm long; corolla yellow-white; achene 2–3 mm long.
- *M. micrantha*: heads 4–6 mm long; involucral bracts ovate-oblong, 3–4 mm long, shortly acute at apex; corolla white; achene up to 2 mm long.

Ecology *M. cordata* is adapted to hot, humid tropical environments with 1500 mm or more annual rainfall and plenty of sunlight, at altitudes ranging from sea level to 1600 m. Hence it is commonly found in young secondary jungle, forest clearings, abandoned ground, secondary regrowth areas, ravines, mountain slopes, roadsides, water courses, fallow land, low-lying areas along streams and rivers and open plantations. Howev-

er, it can also persist with reduced vigour in plantations. It may even be found under closed canopies of 4–5-year-old rubber and oil palm, but it is then markedly etiolated and weakened. It is rarely found in plantations 5–15 years old.
M. micrantha is usually found in damp clearings in lowland forest, but occurs up to 3000 m altitude. In Indonesia, it is only found below 700 m altitude. It grows along streams and roadsides, on disturbed sites as well as in forests. In Latin America it is only rarely a weed, but in parts of Asia it is considered the most aggressive species.

Agronomy *Mikania* can be a devastating weed in crops of tea, coconut, cocoa, rubber, oil palm, coffee, banana and sugar cane, and can smother leguminous cover crops. Spraying with herbicides can reduce its vigour and spread. Mechanical weeding may contribute to the distribution of *Mikania* by spreading pieces of stem. As a cover crop, *Mikania* quickly covers the soil, but produces only small amounts of organic matter or leaf litter compared with leguminous or grass covers. Yields of associated rubber and oil palm are often lower than with a bush or legume cover. This is attributed not only to competition for nutrients and water, but also to allelopathic compounds diffusing from the roots. It has been reported as being susceptible to parasitic growth of dodder, *Cuscuta chinensis* Lamk in Sri Lanka and *C. australis* R. Br. in Fiji and Malaysia. *M. cordata* is palatable to livestock, particularly to sheep. Where present, it is the first species to be eliminated when sheep graze pastures. It should not be the main component of forage for sheep. Instances of abortion, death of newborn lambs and of older sheep have been recorded in rubber plantations where it comprised more than 50% of the diet. There is evidence that these problems relate to the high Cu concentrations. In Africa, *M. cordata* is reported to be less palatable to cattle and intensive grazing may lead to disappearance of grasses in mixed swards. There is very little information about the productivity of *Mikania*. Dry matter yields of 4 t/ha have been found in Mauritius.

Genetic resources and breeding It is unlikely that any germplasm collections or breeding programmes of *Mikania* exist.

Prospects *M. cordata* and *M. micrantha* are aggressive herbs that are primarily noxious weeds. They should only be used as a cover crop if a legume cover can not be economically maintained. *M. cordata* and *M. micrantha* are highly acceptable, aggressive forages, but further study should be given to their agronomy and to feeding systems using these species, so that grazing may contribute to the biological control of these serious weeds.

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I.B. Ipor & H. Sutarno

Mimosa diplotricha C. Wright ex Sauvalle

Anal. Acad. Cienc. Med. Fis. & Nat. Habana 5: 405 (1869).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 24$

Synonyms *Mimosa invisa* Martius (1837), non Martius ex Colla (1834).

Vernacular names Giant sensitive plant (En). Giant false sensitive plant (Am). Indonesia: simeduri-dura (Malay), jukut borang (Sundanese). Malaysia: duri semalu. Philippines: makahiang lalake (Tagalog). Cambodia: bânla: sâ-'ôt. Laos: hnha:z khè:wz ngu:. Thailand: maiyarap-thao. Vietnam: c[aa]y trinh n[uwx] m[os]c.

Origin and geographic distribution *M. diplotricha* is native to tropical and subtropical America from north-eastern Argentina and south-eastern Brazil to south-western Mexico and the Greater Antilles; its distribution is now pantropical. It was probably accidentally introduced into South-East Asia in the 19th Century. In the early 20th Century it was taken into cultivation in Java and Sumatra and from there to other countries in South-East Asia. A true-breeding, spineless form was discovered in Java in 1942 and soon taken into cultivation; this form spread to most countries of South and South-East Asia and to a lesser extent to Africa.

Uses The typical, spiny form of *M. diplotricha* used to be cultivated as a green manure, fallow crop and cover crop. However, it is now considered a noxious weed because it aggressively colonizes open spaces, produces large amounts of easily distributed seed and may pose a fire hazard. Because of its spines, it is especially notorious in hand-harvested sugar cane. The spineless form is still cultivated. It is an excellent soil improver, cover crop and soil binder against erosion in humid areas, but is somewhat less effective in smothering weeds than the spiny form.

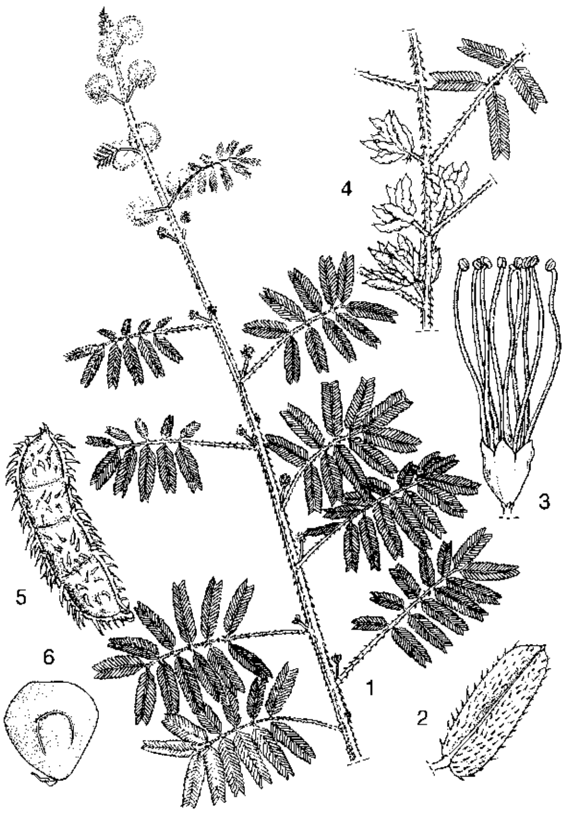
Until 1940, *M. diplotricha* had been used as a fallow crop in wrapper tobacco cultivation in Deli, Sumatra, because it significantly reduced the incidence of Granville wilt or slime disease caused by *Pseudomonas solanacearum*. As it was difficult to eradicate the fallow crop later and it slightly reduced the quality of the tobacco leaves, this use has been discontinued.

In the Philippines the Italian honeybee, *Apis mellifera*, collects large amounts of pollen of *M. diplotricha* and *M. pudica* L. during the distinct 'Mimosa pollen season' (October–March). At this time over 80% of the pollen collected originates from *Mimosa* species.

Properties Information on the properties of *M. diplotricha* is scanty. Mature spiny plants discourage animals from grazing them, although buffaloes are said to eat young shoots. Pigs are reported to be poisoned by ingesting large amounts, probably of the spineless form.

The weight of 1000 seeds is about 6 g.

Description A straggling or scrambling, short-lived perennial woody shrub or semi-woody herb, with branches to over 5 m long, rooting at the base and with a strong, elaborate rooting system. Stem 4–5-angular, prostrate or ascending, up to 1–2 m tall, slightly purplish to brown, hirsute, on the angles with strong, recurved, sharp, yellow spines 3–4 mm long. Leaves bipinnate, with 3–10 pairs of evenly distributed, opposite pinnae; petiole 2–7 cm long, thickened at the base; rachis 6–11 cm long, thickened at the base; petiole and rachis furrowed, hirsute, armed with 4 rows of recurved prickles; stipels transformed into prickles at the bases of the pinnae; pinnae 1–4.5 cm long, hirsute, with recurved prickles abaxially; leaflets opposite, in 11–30 pairs per pinna, oblong, acute, (2–) 3.5–5(–7) mm × 1–2 mm, sensitive to the touch or movement, with scattered hairs on both surfaces. Inflorescence a glomerule (globose head), mostly (1–)2(–3) together in the axil of a young leaf; peduncle 0.5–2 cm long, densely and subpatently villous with recurved spines; bracts spathulate, with ciliate tips, 0.4–1 mm long; flower bisexual, sub-



Mimosa diplotricha C. Wright ex Sauvalle – 1, flowering branch; 2, leaflet; 3, flower; 4, fruiting branch; 5, pod; 6, seed.

sessile, actinomorphic, 4-merous; calyx campanulate, small, up to 0.4 mm long; corolla narrowly funnel-shaped, 1–2.8 mm long, whitish, finely puberulous or glabrous, with 4 ovate, 1 mm long lobes that are greenish with purplish margin; stamens 8, filaments free, pale purplish-pink, 8–16 mm long, strongly exserted; pistil with puberulous ovary, style purplish-red and as long as the stamens. Pod borne in umbelliform clusters, sessile, flattened oblongoid, slightly curved, 1–3.5 cm × 4–5 mm, acuminate at apex, 3–8-seeded, sharply bristly, at maturity breaking into free-falling, 1-seeded articles, sutures persistent. Seed flattened rhomboid or ovoid, 2–5 mm in diameter, glossy yellowish-brown.

Growth and development *M. diplotricha* has a robust growth and scrambles over other plants forming spreading, tangled masses or thickets of undergrowth up to 2 m tall, eventually forming pure stands. The duration of growth is 1.5–2 years, at the end of which time the plant dies. With fast-growing *Rhizobium* similar to the form infecting *Leucaena leucocephala* (Lamk) de Wit it forms root nodules and fixes atmospheric nitrogen. In Indonesia, Malaysia and the Philippines it flowers and fruits throughout the year.

Other botanical information *M. diplotricha* has long been known as *M. invisa* Martius, and the latter has long been thought to be identical with *M. invisa* Martius ex Colla which, however, is a different species from South America with larger leaves (4–21 pairs of pinnae, 17–50 pairs of leaflets), with spiciform inflorescences and larger fruits (up to 14.5 cm long). *M. diplotricha* has been subdivided into 3 varieties:

- var. *diplotricha*: spiny; fruits 1–2.5(–3.2) cm long, containing 2–8 seeds; distributed all over tropical America and pantropically as a weed;
- var. *odibilis* Barneby: spiny; fruits 4–7 cm long, containing 12–16 seeds; only known from Mexico;
- var. *inermis* (Adelb.) Veldkamp (synonym: *M. invisa* Martius var. *inermis* Adelb.): spineless, for the rest like var. *diplotricha*; the spineless form originated in Indonesia, where it gradually replaced the spiny forms as soil cover in plantations; spineless forms have also been discovered in other tropical areas, but unlike the Javanese form, most of them do not breed true.

Ecology *M. diplotricha* is an aggressive colonizer on light and heavy, moist, often poor soils, in sunny to lightly shaded locations, along drains, water courses and roadsides, in ravines, in annual and perennial crops and in secondary forest. In drier areas it is restricted to depressions and other damp sites. The plant may die during prolonged dry spells. It occurs at various altitudes, from 0–2000 m above sea level. Although it prefers light, permeable soils, it can also be grown on heavy clay soils.

Propagation and planting *M. diplotricha* is propagated by seed. Seed kept in 98°C hot water for 1.5 minutes or in 98% sulphuric acid for 20–30 minutes showed a high percentage of germination. Dry heat has also given a high germination rate. Seed is sown in rows about 5 m apart at a rate of 6–8 kg/ha.
Pods of the spiny forms have spiny surfaces and are easily distributed by animals and farm machinery. The seed may germinate immediately or remain dormant in the soil for a long period. Seed collected about 50 days after flowering gives the highest direct germination rate.

Husbandry As a cover crop in tree plantations the spineless forms will last for 1.5–2 years (under favourable conditions 4 years) and then gradually die. It is cheaper to establish, covers the soil more quickly and can be better established on poorer soils than most other leguminous cover crops. The spiny forms are most effective in suppressing *Imperata cylindrica* (L.) Raeuschel but do not kill it and the grass may recover after *M. diplotricha* is phased out. The spineless form is less effective in smothering weeds. In rubber estates in Indonesia and Malaysia *M. diplotricha* was prevented from climbing trees and its growth was checked by pulling its branches back and beating them down with bamboo sticks. Rubber trees in Sri Lanka and coconut palms in India grew better with a cover crop of *M. diplotricha* than with a natural cover, but in coffee plantations in Cameroon its use is not recommended because of the risk of fire in exceptionally dry periods. In replanting experiments in tea conducted in Tocklay (India), a soil cover of *M. diplotricha* for 2 years followed by subsoiling resulted in much faster establishment and better growth of tea plants than direct planting or planting of tea after subsoiling alone. In tests in Thailand maize yields gradually increased in a rotation with leguminous green manure crops and moderate fertilizer applications, while fertilizer alone could not maintain yields. *M. diplotricha* and *Lablab purpureus* (L.) Sweet gave the best results. *M. diplotricha* is a host of crickets and grasshoppers that feed on coconut palm and oil palm. The main disadvantage of *M. diplotricha* var. *inermis*, however, is that it may cross with spiny forms and thus contribute to the spread of the latter. In Cameroon a cover crop of var. *inermis* was kept free of spiny forms by roguing them twice per year during weeding rounds. As a weed, *M. diplotricha* is effectively controlled by cultivation and hand weeding when plants are still young. It can be controlled by foliar spraying with a wide range of herbicides. The experimental use of larvae of the cerambycid insect *Milothris irrorata* as biological control against *Mimosa pigra* L. gave promising results. The larvae tested also attacked *M. diplotricha*. The larvae attack by boring the stems, while the adults girdle some of the shoots causing them to dry out.

Diseases and pests Few diseases and pests have been reported, but *M. diplotricha* is sensitive to *Meloidogyne* nematodes.

Genetic resources and breeding No substantial germplasm collections or breeding programmes are known to exist.

Prospects Although its ease of establishment and effectiveness against *Imperata cylindrica* are very favourable attributes, the difficulty of controlling its spread and regrowth and the risk of getting spiny forms through crossing with wild plants have limited the use of *M. diplotricha* var. *inermis* as a cover crop and green manure. It will probably continue to be used on a minor scale only, because good alternatives, such as *Pueraria phaseoloides* (Roxb.) Benth., have been selected.

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C. Doungsa-ard & C.S. Tawan

Mucuna pruriens (L.) DC. cv. group Utilis

M. pruriens: Prodr. 2: 405 (1825); cv. group Utilis: Westphal, Pulses in Ethiopia, their taxonomy and agricultural significance: 121 (1974).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 20, 22, 24$

Synonyms *Mucuna utilis* Wall. ex Wight (1840), *M. pruriens* (L.) DC. var. *utilis* (Wall. ex Wight) Baker ex Burck (1893), *M. pruriens* (L.) DC. f. *utilis* (Wall. ex Wight) Backer (1963).

Vernacular names Velvet bean (En). Cowitch (Am). Pois mascate, pois velus (Fr). Indonesia: kara benguk (Javanese), kowas (Sundanese), kekara juleh (Moluccas). Malaysia: kacang babi, kekaras gatal. Philippines: sabawel. Cambodia: khnhaè. Laos: tam nhè. Thailand: mamui (central). Vietnam: d[aaj]u m[ef]o r[uf]ng.

Origin and geographic distribution Velvet bean is probably a native of tropical South or South-East Asia, and has been widely distributed throughout the tropics. It was introduced into Florida in 1876, from where its range was extended into temperate and subtropical areas by breeding. In the south-eastern United States it used to be the most important cover crop grown in combination with maize in an area of about 1 000 000 ha around 1920. Later, soya bean and commercial fertilizers rapidly replaced it and it disappeared from agricultural statistics in 1965. As a cover crop, it is now most important in Australia, Hawaii, the Fiji Islands, Indonesia, Malaysia and the Philippines.

Uses Velvet bean is mainly grown as a cover crop and green manure and is one of the most suitable crops for reclaiming land infested with weeds, especially with *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L. and *Imperata cylindrica* (L.) Raeuschel. It is recommended for use in rotation with cotton in Brazil to limit *Fusarium oxysporum* and *Meloidogyne incognita* infestation. In Central America, it is widely grown either relay planted with maize or as a rainy season fallow crop in rotation with dry season maize. It was formerly an important cover crop in citrus and banana plantations. In Georgia and northern Florida and in Mauritius it is used as a forage and as a component in pastures. Boiled seeds of velvet bean are occasionally eaten as a pulse. In Java the seeds are fermented and flattened into a kind of cake ('tempe benguk'), while immature pods and young leaves are sometimes boiled as vegetables. In the southern United States it is often grown as an ornamental.

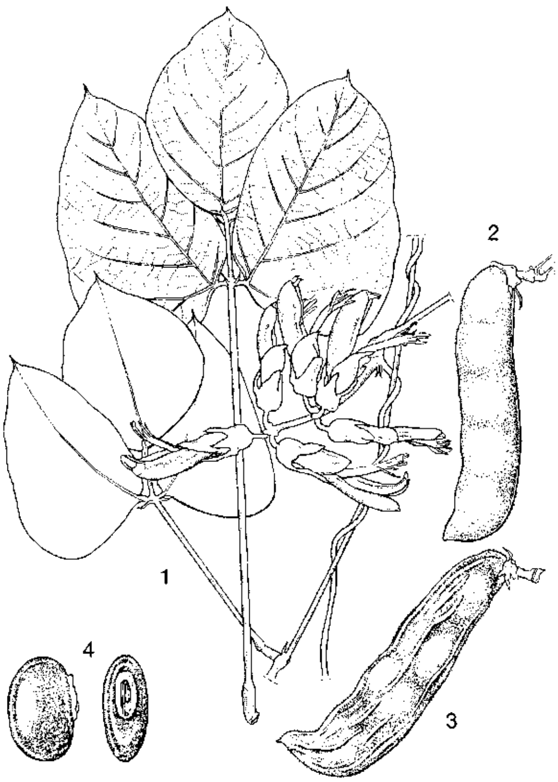
In traditional medicine the pod hairs mixed with syrup, molasses or honey are taken as an anthelminthic, but the effect seems to be only minor. Ethanol extracts of the pod-hairs and leaves have an analgesic and anti-inflammatory effect in rats. The amino acid L-dopa used in the symptomatic relief of Parkinson's disease is extracted from the seed. Starch from the seed has been tested in Brazil in the preparation of food thickeners and adhesives.

Production and international trade Annual world seed production has been estimated to be 900 000 t. There is local trade in seed for consumption and in pod hairs. In Java, seed is currently (1996) sold at about US$ 1.00 per kg. No statistics are available on trade and production of seed for manufacturing L-dopa.

Properties Analysis of the aboveground organic matter indicates the following composition per 100 g dry matter: protein 15–24 g, ether extract 2 g, N-free extract 49 g, crude fibre 19 g, ash 15 g. Velvet bean plants decompose fairly rapidly, the rate may amount to 50% loss of dry weight in about 4 weeks.

Per 100 g dry matter seed contains: protein 23–33 g, crude fat 6 g, N-free extracts 52–57 g, fibre 7 g, ash 3.5 g, K 1.5 g, P 1 g, Ca 0.2 g, vitamin A 50 IU. The in vitro protein digestibility in cattle is about 72%. The nutritive value of the seed, either raw, boiled or roasted, is not very high, similar to e.g. Lima bean (*Phaseolus lunatus* L.), but better than sword bean (*Canavalia ensiformis* (L.) DC. When fed to pigs in large quantities, seed causes severe vomiting and diarrhoea, probably due to the presence of L-dopa. Two important non-protein amino acids are found in the seed and in smaller amounts in the stems and leaves: L-dopa (L-3.4-dihydroxyphenylalanine) from which dopamine, an important medicine to relieve the effects of Parkinson's disease, is prepared, and DMP (N-dimethyltryptamine) which has hallucinogenic properties. The L-dopa content varies from 1.6–3.3% and is sufficiently high for commercial extraction. The seed also contains a number of alkaloids, the most important of which being mucunaine, prurienine and serotine. The stinging hairs of velvet bean, used as an anthelmintic, contain a pruritogenic, proteolytic enzyme and granular matter, tannic acid and resin. The weight of the seed varies greatly between cultivars, and ranges from 550–850 g per 1000 seeds.

Description A vigorous, climbing, pubescent annual herb, 2–18 m long. Roots numerous, 7–10 m long, taproot with many laterals. Stem slender, terete, slightly pubescent with white, straight, short and long hairs, glabrescent. Leaves alternate, 3-foliolate; stipules caducous, subulate, about 0.5 cm long, white-hairy outside, glabrous inside; petiole (3–)4–9(–13.5) cm long, slightly grooved above, generally slightly pubescent, pulvinus pubescent; rachis (0.5–)1–2 cm long, grooved above, slightly pubescent; stipels filiform; lateral leaflets conspicuously asymmetrical, obovate, rhombic, ovate or elliptical, (5–)7–15(–19) cm × (3–)5–12(–17) cm, terminal leaflet symmetrical and as a rule smaller, apex acute to acuminate-mucronate, base rounded, covered with appressed, grey or silvery hairs turning black when dry. Inflorescence an axillary raceme, up to 32 cm long, 1–many-flowered, silvery pubescent; rachis tubercled without lateral branchlets; bracts early caducous, narrowly triangular-elliptical, 5–10 mm long; pedicel 1.5–10 mm long, with 2 bracteoles 10 mm × 2 mm, near the base of the calyx; calyx campanulate, tube 4–7 mm long, 5-lobed, appressed silvery pubescent outside, glabrous inside, upper pair of lobes connate, the other 3 lobes subequal, triangular, 3–9 mm long, acute; corolla blackish-purple, pale lilac or white; petals clawed, auricled; standard hood-shaped, much shorter than other petals, 17–22 mm × 11–15 mm, fleshy especially towards the base, rounded at the top; wings narrowly obovate, 32–35 mm × 8–10 mm, fleshy especially towards the base, rounded at the top, finely and patently pubescent at base; keel about 35 mm × 5 mm, narrow in the middle, entirely split dorsally, ciliolate at the edges, glabrescent towards



Mucuna pruriens (L.) DC. cv. group Utilis – 1, climbing branches with inflorescence and leaves; 2, young pod; 3, mature pod; 4, seeds.

the top, ventrally split near the base and apex, apical part hard and ending in a horny tip; stamens 10, diadelphous. Fruit an oblong, (1–)3(–7)-seeded pod with oblique top, somewhat compressed laterally, slightly bulging over the seeds, 4–13 cm × 1–2 cm, finely pubescent with white to light brown hairs; valves thick and leathery, with prominent, complete rib and 2–3 partial, less prominent ribs. Seed oblong-ellipsoid, somewhat laterally compressed, about 15 mm × 10 mm × 5 mm, colour variable, light or pinkish-brown often with dark brown mosaic, mottled with grey, purple or black background, almost entirely black, grey, greyish-black or white; hilum oblong, lateral, eccentric, about 4 mm long, surrounded by a prominent, cream-coloured aril, with scale-like extension at the rim. Seedling with hypogeal germination.

Growth and development Young plants of velvet bean have a purplish, pubescent epicotyl; the first 2 leaves are opposite, simple, deeply cordate. They grow very fast and can cover the ground in 2–3 months, forming a thick even blanket about 60 cm deep, smothering most weeds. Its climbing habit further contributes to its capacity to suppress the growth of weeds. Distribution of the roots tends to be very shallow and concentrated in the fertile topsoil. Roots form where creeping stems touch the soil. Velvet bean forms root nodules with slow-growing *Rhizobium* and fixes atmospheric nitrogen. Flowering commences 90–145 days after sowing and pods begin to ripen 2–3 months after flowering. Self-pollination is the rule. The first harvest of dry seed may be expected after 200–230 days. Rapid growth declines in most cultivars at an age of 5 months when stems begin to dry and defoliate and roots begin to rot. Maximum survival is generally 8–10 months, but some velvet bean cultivars (Mauritius bean) may cover the ground for over 2 years.

Other botanical information *M. pruriens* has often been classified in the genus *Stizolobium* P. Br., but at present *Stizolobium* is generally considered a subgenus or section of *Mucuna* Adans. Wild forms of *M. pruriens* have pods covered with irritating bristly hairs which are absent, or nearly so, in cultivated forms. Several cultivated forms of *M. pruriens* have been described as distinct species: *M. aterrima* (Piper & Tracy) Merrill, Mauritius bean, grown as a cover crop and green manure in Australia, Brazil, Mauritius and the West Indies; *M. capitata* (Roxb.) Wight & Arnott, cultivated in India and Indonesia for its seed; *M. deeringiana* (Bort) Merrill, Florida or Georgia velvet bean, grown for fodder; *M. hassjoo* (Piper & Tracy) Mansf. (synonym *Stizolobium hassjoo* (Sieb.) Piper and Tracy), Yokohama velvet bean, an early maturing type from Japan; *M. nivea* Wight & Arnott (synonyms *M. lyonii* Merrill and *M. cochinchinensis* (Lour.) A. Chev.), Lyon bean, cultivated for the immature pods eaten as a vegetable in South-East Asia; *M. pachylobia* (Piper & Tracy) Rock (synonym: *Stizolobium pachylobium* Piper & Tracy), cultivated in India as a green fruit vegetable; *M. utilis* Wall. ex Wight, Bengal bean, cultivated in India and *M. velutina* Hassk. All these species, mainly distinguished by the nature of their hairs and colour of flowers and seed are now considered cultivars of *M. pruriens* cv. group Utilis. A clear classification of the different cultivars into cv. groups is badly needed.

Several cultivars differing in plant type and time to maturity have been released in the United States. The best known are: '120-Day Florida', a cultivar with medium-sized, mottled seed, usually requiring over 120 days to mature in the United

States; 'Early Jumbo', a large-seeded cultivar maturing in about 175 days, easy to harvest for seed because the pods grow in clusters that can be picked together; 'Osceola', a white-flowered heavy seed producer with pods almost devoid of stinging hairs; 'Victor', maturing in about 190 days, producing about 1400 kg seed per ha.

Ecology Velvet bean tolerates a wide range of annual rainfall from 400–3000 mm, but is not drought resistant because of its shallow root system. Only Mauritius bean shows better drought tolerance. Velvet bean grows best at an average annual temperature of 19–27°C. Plants are sensitive to frost and exposure to a temperature below 5°C for more than 24 hours is fatal even for cultivars from Florida. A night temperature of over 21°C is said to stimulate flowering. Velvet bean requires a high light intensity and yields poorly when intercropped with cassava or maize. It grows best on well-drained sand and clay soils and on ultisols with a pH of 5–6.5, but also grows vigorously on acidic sandy soils. It does not tolerate waterlogging. In soils with a fertile topsoil and an acidic subsoil, the latter being low in P and high in Al, root growth is concentrated in the topsoil. If a fertile topsoil is absent an extensive root system develops even in acidic soils.

Propagation and planting Propagation is mostly by seed. Seed requires no scarification, but dry seed requires soaking in water for 24 hours. The germination rate of fresh seed is 90–100%, declining with time. Seed stored in a cool dry place remained viable for about 2 years, but seed stored in a sealed jar for 3 months lost its viability. Germination takes 4–7 days. In South-East Asia, sowing is done from January to May, at the onset of the rainy season. Seed is placed 2 cm deep with 2–4 seeds per hole. For cover crops in rubber plantations in Indonesia and Malaysia, a spacing of 2 m × 1 m or 1.5 m × 1.5 m is recommended, requiring about 15 kg seed per ha. In sugar-cane plantations in Mauritius, a spacing of 60–100 cm × 60–100 cm is used. When planted as a green manure crop in Indonesia, it is sown at a spacing of 30 cm × 20–30 cm with 2 seeds per hole, while elsewhere it is also broadcast. When intercropped with maize in the United States, it is sown in rows 90–120 cm apart at a seed rate of 4–15 kg/ha.

Husbandry After sowing, velvet bean requires 1–2 weedings. Hand weeding is most common, but both pre- and post-emergence herbicides are applied effectively. When grown as a cover crop in tree plantations, velvet bean is mostly grown in combination with other cover crops, because of its short life span. Species commonly used in such combinations are *Calopogonium mucunoides* Desv. and *C. caeruleum* (Benth.) Sauv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth.

Velvet bean is currently being tested in a number of cropping systems, mainly in combination with maize. It is either intercropped, relay planted 15–40 days after sowing of the maize, or grown in rotation. When grown as a green manure crop, velvet bean tends to become weedy when the seed is left to mature. In tests in Nigeria, mowing velvet bean before maturation of the seed followed by zero tillage planting of maize effectively solved this problem.

Diseases and pests Velvet bean is little affected by diseases, although in Zimbabwe, it is very susceptible to a vine rot of unknown cause that can wipe out the crop. It is resistant but not immune to root-knot nematodes and is attacked by several other *Meloidogyne* spp. Very few insect and small mammals attack velvet bean possibly because of its high L-dopa content. The velvet bean caterpillar (*Anticarsia gemmatalis*) in Florida is one of the few insects reported to cause damage. In Malaysia, green bugs (*Brachyplatys* spp.) feed on the leaves. *Striga gesnerioides* (Willd.) Vatke parasitizes the velvet bean.

Harvesting The optimum time for harvesting velvet bean for green manure is at flower initiation, attained 55–145 days after sowing, depending on the cultivar. Plants are pulled up by hand or by hoe and buried in the soil. Grown for forage in the United States, it may be harvested 90–120 days after sowing, when the pods are still young. In Malaysia, the first harvest for fodder can take place 2 months after sowing. A cutting interval of 5 weeks and cutting at a height of 30 cm provide a reasonable yield of forage of adequate quality. Harvesting for pod production can start as soon as the pods start changing colour from green to dark brown or black; in Malaysia this is possible at 215–255 days after sowing. Pods are harvested by hand. When intercropped with maize, cutting velvet bean below the level of the maturing maize cobs facilitates harvesting the latter.

Yield On good soils in the southern United States, seed yields of 900–1200 kg/ha and even of 1500 kg/ha in Hawaii have been obtained. In India, seed yields range from 250–1150 kg/ha. Green forage yields in the United States are 3–6 t/ha 90–120 days after sowing and 18 t/ha at the end of a growing season. When grown as a cover crop in rubber plantation a fresh organic matter yield of about 2 t/ha can be obtained in about 6 months.

Handling after harvest Green manure should be buried in the soil immediately after harvesting. If left to dry above the ground, the nitrogen content may be reduced by as much as 50%. Dried pods are threshed with a regular grain thresher or by hand. In Java and Africa, threshing is done by beating the pods put in sacks. Only the best seed is used to make 'tempe'. It is washed and boiled for 2–3 hours. After cooling, seeds are dehulled and soaked in ample water for 1–2 days, changing the water 2–3 times a day to ensure that all toxic substances have been removed. The cotyledons are then chopped into smaller pieces and steamed. When cool, the beans are sieved and inoculated evenly with the fungus *Rhizopus arrhizus* or *R. oryzae*, flattened and wrapped in banana leaves or a similar material for 24–40 hours at 31°C. The product is a cake covered with mats of mycelium. It is consumed fried, or mixed with vegetables in a soup.

Genetic resources Natural populations of wild forms of *M. pruriens* are no longer common in Indonesia, while other species of *Mucuna*, such as *M. acuminata* R. Grah., *M. gigantea* (Willd.) DC. and *M. macrophylla* Miq. are also threatened. Hybridization of cultivated genotypes with these species may become important in breeding programmes. Germplasm collections of *Mucuna* spp. are maintained, for example at the Southern Regional Plant Introduction Station of the United States Department of Agriculture, Griffin, Georgia, which has 32 accessions of velvet bean.

Breeding A number of cultivars have been released in the United States, but no current breeding programmes are known to exist.

Prospects Velvet bean covers the soil quickly, is very productive, resists most diseases and pests, and is adapted to a wide range of environmental conditions. It is one of the few cover crops and green manures that yield valuable byproducts, making it attractive to small-scale farmers. Its resistance to diseases and pests also make it an attractive vegetable and pulse crop. Its future importance as a source of L-dopa depends on the existence of alternative plant sources and methods of producing this compound synthetically.

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Paraserianthes falcataria (L.) Nielsen

Bull. Mus. Natn. Hist. Nat., 4e sér., sect. B, Adansonia 5: 327 (1983).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26$

Synonyms *Albizia moluccana* Miquel (1855), *A. falcata* sensu Backer (1908), *A. falcataria* (L.) Fosberg (1965).

Vernacular names Paraserianthes (general), batai (timber trade name) (En). Peacock's plume (Am). Brunei: puah. Indonesia: jeungjing (Sundanese), sengon laut (Javanese), sikat (Banda). Malaysia: batai (Peninsular, Sabah), kayu machis (Sarawak). Papua New Guinea: white albizia. Philippines: Moluccan sau, falcata.

Origin and geographic distribution *P. falcataria* is native to the Moluccas, New Guinea, the Bismarck Archipelago including the Admirality Islands and the Solomon Islands. It is widely planted throughout the humid tropics.

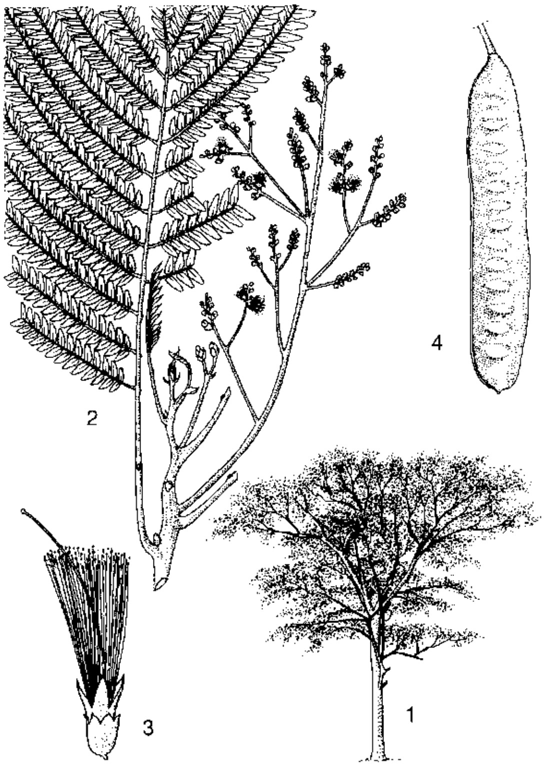
Uses *P. falcataria* is planted extensively for reforestation and afforestation of denuded and eroding land. Because it is very fast- growing, the wood is widely used for fuelwood and charcoal pro-

duction in spite of its low density and energy value. It is an important shade tree for tea and other crops, its fast growth and good shading properties outweighing its sensitivity to strong winds and its relatively short life. It is being tested in alley-cropping systems, although its tolerance of coppicing is limited.
P. falcataria is a major source of paper pulp and has been used for the manufacture of viscose rayon. The comparatively soft timber, called batai in trade, is suitable for general utility purposes such as light construction, furniture and cabinet work, lightweight packing materials and pallets. It is a well-known source for match wood. 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 particle board, wood-wool board and hardboard, and has recently also been used for blockboard.
The bark yields a gum, has tanning properties, and it is also used for packing. The leaves are fed to poultry, goats and sheep. *P. falcataria* is also planted as an ornamental.

Production and international trade In Japan there is a great demand for batai wood for manufacturing lightweight furniture and furniture components (e.g. drawer sides); particularly the butt log portion is used for these purposes. Timber from natural and plantation-grown trees is imported in Japan, but no statistics are available.

Properties In Cameroon, the mineral composition of the leaves of 1-year-old trees per 100 g was approximately: N 2.5 g, P 0.15 g, K 0.7 g, and Ca 1.17 g; the composition of the wood: N 0.9 g, P 0.1 g, K 0.4 g, and Ca 0.3 g. In an alley cropping experiment in Western Samoa, *P. falcataria* was pruned 4 times per year, each pruning producing about 1 t/ha total dry matter. The mineral composition of the prunings was: N 5.3 g, P 0.6 g, K 0.8 g, Ca 0.6 g, and Mg 0.3 g.
The density of the wood of *P. falcataria* is (230–)300–500 kg/m^3 at 12% moisture content. The energy value of the wood is 19 500–20 600 kJ/kg. 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 pale coloured sapwood, but it is more distinct in older trees. The grain of the wood is straight or interlocked, texture moderately coarse but even. Batai wood usually air-dries fairly rapidly without serious degrade, and the kiln-drying properties are satisfactory. It is easy to work with machines and hand tools, but is reported to be abrasive to saws. Sharp knives are needed to produce smooth surfaces in planing, otherwise grain may pick up badly. 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. Glueing is no problem. Batai can be peeled and sliced easily into veneer of good quality. It is very suitable for particle boards, while its pulp is rated among the best of tropical woods, comparable to good-quality eucalypt pulp, and requiring only minimal bleaching.
The wood is not durable when used outdoors, with an average service life in contact with the ground of 0.5–2 years in graveyard tests. It is very vulnerable to termites, powder-post beetles and fungi. The wood can be treated easily with preservatives, e.g. a mixture of creosote and diesel fuel. Stake tests showed an average life of treated wood in contact with the ground of 15 years under tropical conditions.
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.
Preliminary test results indicate that the leaves of *P. falcataria* are a good fodder: daily liveweight gains of 57 g were found in sheep, about 50% higher than from leaves of *Calliandra calothyrsus* Meisn. and *Gliricidia sepium* (Jacq.) Kunth ex Walp.
The weight of 1000 seeds is 16–26 g.

Description A medium-sized to fairly large, unarmed tree up to 40 m tall, bole straight and cylindrical in dense stands, branchless for up to 20 m and up to 100 cm or sometimes more in diameter; 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, up to 40 cm long, with (4–)8–15 pairs of pinnae, each pinna with (8–)15–25 leaflets, rachis and pinnae with extrafloral nectaries; stipules linear or filiform, caducous, 3–5 mm × 0.5–1 mm; petiole 2–8 cm long, with a raised gland in the distal half; leaflets oblong-falcate, 6–15 mm × (2–)3–6 mm, sessile, densely appressed puberulous. Inflorescence a paniculate raceme, up to 30 cm long; flowers bisexual, 5-merous, sub-



Paraserianthes falcataria (L.) Nielsen – 1, tree habit; 2, flowering twig with part of leaf; 3, flower; 4, pod.

tended by bracts; calyx valvate, tubular to cup- or bell-shaped, 1.5–3 mm long; corolla valvate, funnel- or bell-shaped, 4–6.5 mm long, creamy to yellowish, sericeous all over; stamens numerous, 10–15 mm long, white, filaments fused into a 3.5 mm long tube at base, anthers quadrangular, minute; ovary solitary, glabrous. Fruit a chartaceous, flat, straight pod, 7.5–10.5 cm × 1.3–1.7 cm, narrowly winged along the ventral suture, dehiscent along both sutures, puberulous, usually glabrescent, many-seeded. Seed oblongoid, flat, 6–7.5 mm × 3–4 mm, olive-green, with oblong areole about 5 mm long.

Growth and development *P. falcataria* grows so fast that it is sometimes called the 'miracle tree'. It 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 and 40.5 cm after 9 years, 38 m and 54 cm after 12 years, and 39 m and 63.5 cm after 15 years, respectively. Growth of young trees in a P-deficient soil is promoted by inoculation with the mycorrhizal fungi *Gigaspora margarita* and *Glomus fasciculatum*. Inoculation with *Bradyrhizobium* has proved to be effective, and especially beneficial in combination with mycorrhizal infection.

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 Three subspecies are recognized in *P. falcataria*. 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 central mountains of New Guinea; the latter subspecies has densely puberulous to tomentose pods and a woolly leaf rachis.

Ecology As a pioneer species, *P. falcataria* occurs in primary but more characteristically in secondary lowland rain forest, and also in light montane forest, grassy plains and along roadsides near the sea. It is adapted to per-humid and monsoonal climates with a dry season of up to 2(–4) months and an annual rainfall ranging from 2000–4000 mm, averaging 2800 mm. In its natural habitat it occurs from 0–2300 m altitude. The optimum temperature range is 22–29°C, with mean minimum temperatures of the coldest month of 22–24°C and mean maximum temperatures of the hottest month of 30–34°C. It is found on well-drained sandy and lateritic soils. In natural stands in Irian Jaya *P. falcataria* is associated with e.g. *Agathis labillardieri* Warb., *Celtis* spp., *Diospyros* spp., *Pterocarpus indicus* Willd., *Terminalia* spp., and *Toona sureni* (Blume) Merrill.

When planted, *P. falcataria* can grow on comparatively poor sites and survive without application of fertilizers. However, it does not thrive in poorly drained, flooded or waterlogged soils. It is sensitive to fire and easily damaged by strong wind.

Propagation and planting *P. falcataria* is strongly light-demanding and regenerates naturally only when the soil is exposed to sunlight. In the forest, wildlings sprout in abundance 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. They are usually collected by cutting down branches bearing ripe brown pods. The seeds can be easily 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, seed can be soaked in boiling water for 1–3 minutes, or by immersion in concentrated sulphuric acid for 10 minutes and then washing and soaking in water for 18 hours. The germination rate can be as high as 80% to almost 100%.

For storage, seeds are air dried for 24 hours and then packed in polythene bags. Stored at 4–8°C, the germination rate after 18 months may still be 70–90%.

Seed is usually sown by broadcasting, pressed gently into the soil, and then covered with a layer of fine sand up to 1.5 cm thick. 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 20–25 cm. The seedlings are usually planted into the field at a spacing of 2–4 m × 2–4 m. The average annual production of seedlings in the Philippines was 2.1 million in the period 1979–1982. Seed tissue has been successfully used for propagation by tissue culture in the Philippines.

Husbandry As initial growth of *P. falcataria* in plantations is remarkably fast, weeding generally can be limited to 1 complete weeding and 3 spot weedings during the first year. The application of fertilizers may improve the yield; application of 12.5 kg/ha of P has been found satisfactory.

In agroforestry systems a cutting cycle of 10–15 years is normally used, in combination with annual crops in the first year and grazing by livestock in subsequent years. Pure stands give a good protective cover to prevent erosion on slopes, and they are recommended for this purpose in Indonesia and the Philippines in catchment areas sheltered from typhoons. *P. falcataria* coppices fairly well, which is advantageous for pulpwood production, but frequent coppicing as in alley-cropping systems quickly exhausts the trees and results in a high mortality rate and poor regrowth. For timber production, the original stand can be thinned to a density of 250 trees/ha when 4–5 years old, and to 150 trees/ha after 10 years. Trees grown for timber must be pruned, 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.

Diseases and pests Nursery seedlings are susceptible to damping-off caused by fungi of the genera *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia* and *Sclerotium*. Sterilizing the soil before sowing and applying fungicides to soil and seeds may control the disease. The fungus *Corticium salmonicolor* causes 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. 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.

Plantation pests in Indonesia, Malaysia and the Philippines include stem-borers such as the longicorn beetle *Xystrocera festiva* and the red borer *Zeuzera coffeae* (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 infestation by fungi. The wood is particularly prone to sap-staining attack.

Yield *P. falcataria* 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 and breeding *P. falcataria* is planted on a large scale throughout the tropics and the genetic resources are quite comprehensive.

Prospects Breeding programmes should be conducted to obtain superior trees in respect to bole shape (preferably long and straight without a tendency to fork) and resistance to diseases and pests. Superior trees can be mass-produced by tissue culture.

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Peltophorum dasyrhachis (Miquel) Kurz

Journ. As. Soc. Beng. 45(2): 128 (1876), 293 (1877).

LEGUMINOSAE – CAESALPINIOIDEAE

$2n$ = unknown

Synonyms *Caesalpinia dasyrhachis* Miquel (1861), *Peltophorum grande* Prain (1897), *P. tonkinense* (Pierre) Gagnep. (1913).

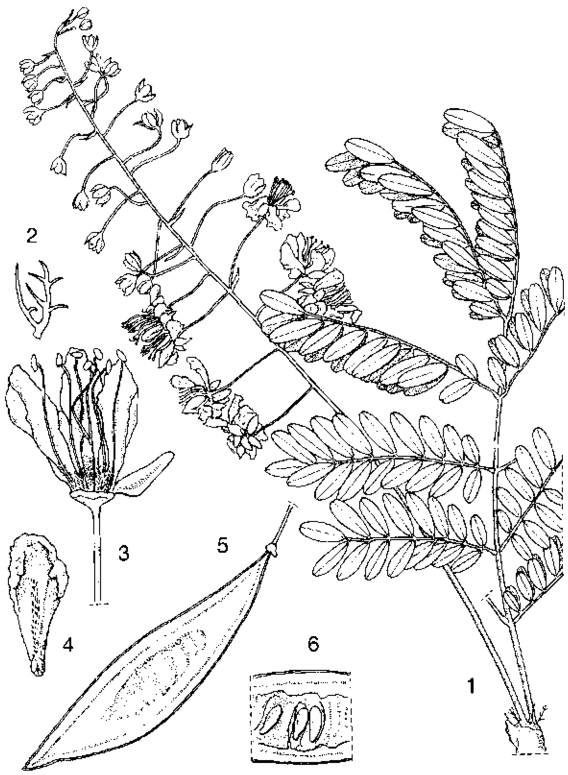
Vernacular names Peltophorum (En). Indonesia: soga (Palembang), petaian (Lampung). Malaysia: batai, jemerelang. Cambodia: trâse:k. Laos: s'a:z kha:m, sa: f'ang, sa: ph'ang. Thailand: nonsi (central), arang (north-eastern). Vietnam: lim x[ej]t, lim v[af]ng.

Origin and geographic distribution *P. dasyrhachis* is found in Thailand, Indo-China, Peninsular Malaysia, Sumatra and Borneo. It is also cultivated in many other tropical regions, e.g. in Java.

Uses In the first half of the 20th Century, *P. dasyrhachis* was used as a shade tree mainly in coffee in Java. In central Thailand it is maintained after bush fallow as a shade tree for fruit trees and for its role in soil improvement. Its use in the reclamation of *Imperata cylindrica* (L.) Raeuschel grasslands is being tested; in Indonesia and Malaysia, young trees planted in tall *Imperata* grassland and left untended after planting remained alive, but grew slowly. The red-yellow wood is locally used for planks in house-building, but is of little market value. It is suitable as firewood. Medicinally, the bark is used in an infusion for coughs.

Properties Due to a fairly high content of polyphenolic substances, leaf litter decomposition is slow, allowing a humus layer to build up in the soil. The yellowish-red heartwood is heavy, but brittle and is attacked by termites and boring insects. The weight of 1000 seeds is about 37 g.

Botany A usually deciduous tree, up to 30 m tall, with a straight trunk and rather diffuse crown; root system with well-developed taproot and few superficial lateral roots; trunk up to 70 cm in diameter; bark up to 10 mm thick, reddish-brown inside; young branches reddish-tomentose, glabrescent. Leaves bipinnate, with 5–9 pairs of pinnae and 6–16 pairs of leaflets per pinna; stipules large, bipartite, branches pinnatifid or bipinnatifid; petiole up to 7 cm long, rachis up to 40 cm long, both reddish-pubescent; leaflets oblong-elliptical, 10–25 mm × 4–10 mm, sessile, base acute, obtuse or rounded, apex rounded-emarginate,



Peltophorum dasyrhachis (Miquel) Kurz – 1, flowering branch; 2, stipule; 3, flower (2 sepals and petals removed); 4, petal; 5, pod; 6, opened fruit part with seeds.

finely pubescent, glabrescent, rather glaucous below, shiny above. Inflorescence an axillary, unbranched raceme, 15–30 cm long; bracts linear, 10–12 mm long, persisting until flowers open; pedicel 1.7–4 cm long; calyx deeply 5-lobed, lobes ovate, 10–15 mm × 5–6 mm, densely velvety outside, glabrous inside; petals 5, obovate, 15–25 mm × 10–12 mm, spreading, yellow, hairy towards the base inside; stamens 10, free, filaments 10–15 mm long, woolly at base, anthers dorsifixed; ovary sessile, 5 mm long, hairy, 4–8-ovuled, style filiform, 12 mm long. Pod elliptical, sharp-pointed, 10–15 cm × 2–4 cm, flat, with a wing-like extension 4–5 mm broad on each suture, dull-brown when ripe, later blackish, 4–8-seeded, indehiscent, often hanging in bunches below the leaves. Seed flattened oblongoid, 10–12 mm × 5 mm, transversely positioned. Seedling with epigeal germination; hypocotyl 4–6 cm long; cotyledons stalked, 3-nerved, glabrous.

In Malaysia, trees may grow up to 7 m tall with a stem diameter of 5 cm in 2 years. Upon pruning, trees resprout abundantly and form a dense hedge. In Lampung (Indonesia), it does not shed its leaves, flowering takes place during the dry season (September–October) and fruits ripen 1 year later. In Indo-China, flowering is from February to April, while new leaves are formed and fruits ripen from May to November. Seed germinates in abundance after a bush fire.

P. dasyrhachis (often erroneously spelled 'dasyrrhachis') is related to *P. pterocarpum* (DC.) Backer ex K. Heyne, an important source of 'soga' dye. *P. dasyrhachis* can be distinguished by its crown that is uneven and not umbrella-shaped, its branched stipules, and its thick, reddish tomentum. The two species have occasionally been confounded in the literature. In northern Vietnam, a form of *P. dasyrhachis* occurs with unbranched stipules and early falling bracts, named var. *tonkinense* (Pierre) K. & S.S. Larsen.

Ecology *P. dasyrhachis* is found in secondary, deciduous or evergreen forest below 800 m altitude with an annual rainfall of 1500–2500 mm. It is mainly found on ultisols. Due to its relatively deep rooting system, it is drought tolerant. Its hairiness and fairly thick bark have been associated with its tolerance of fire.

Agronomy *P. dasyrhachis* is propagated by seed or cuttings. It has been tested as a tree in alley-cropping systems. When unpruned, it provides a rather dense shade to control weeds during fallow periods, and can be managed in hedges without too much shading of inter-row crops. Because its growth rate is slower than that of *Leucaena leucocephala* (Lamk) de Wit and *Gliricidia sepium* (Jacq.) Kunth ex Walp., it requires less frequent pruning. When hedges were pruned 2–4 times per year, an annual yield of prunings of 8 t/ha was found in Lampung (Indonesia), containing 200 kg nitrogen. The slow rate of decomposition of the leaves reduces erosion and contributes to the suppression of weeds. Seeds of *Imperata cylindrica* hardly germinate in soil covered by the leaves.

Few insects have been recorded as damaging the leaves, whereas large stem-boring insects attack older trees.

Genetic resources and breeding No germplasm collections or breeding programmes are known to exist for *P. dasyrhachis*.

Prospects Preliminary research has indicated the potential of *P. dasyrhachis* as an initial tree-cover in *Imperata* grasslands and as a first step in the reclamation of degraded land. This needs confirmation by further experimentation. Its possible suitability as a tree for alley cropping also requires further investigation.

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M. van Noordwijk & Rudjiman

Pongamia pinnata (L.) Pierre

Fl. For. Cochinch.: t. 385 (1899).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 20, 22$

Synonyms *Pongamia glabra* Ventenat (1803), *Millettia novo-guineensis* Kanehira & Hatusima (1942), *Derris indica* (Lamk) J.J. Bennett (1971).

Vernacular names Pongam, Indian beech (En). Pongame oil tree (Am). Arbre de pongolote (Fr). Indonesia: bangkong (Javanese), ki pahang laut (Sundanese), kranji (Madurese). Malaysia: mempari, kacang kayu laut (Peninsular), biansu (Sarawak). Philippines: bani (general), balikbalik, balok (Tagalog). Singapore: seashore mempari. Laos: (do:k) ko:m ko:y. Thailand: khayi (Chumphon), yi-nam (peninsular). Vietnam: d[aa]y m[aas]u, d[aa]y kim, kh[oor] s[aa]m hoa.

Origin and geographic distribution *P. pinnata* probably originated from India and occurs naturally or naturalized from Pakistan, India and Sri Lanka throughout South-East Asia to north-eastern Australia, Fiji and Japan. It has been introduced in Egypt and the United States (Florida, Hawaii).

Uses *P. pinnata* provides two sources of energy: the wood is burnt as a cooking fuel, while the seed-oil is used for illumination. The wood also provides timber for cabinet work and cartwheels and paper pulp. The oil is applied as a lubricant, as a leather dressing in the traditional Indian tanning industry, and in manufacturing soap, varnish and paint. *P. pinnata* is used in reforestation of marginal land, its extensive root system making it valuable for checking erosion. In Sri Lanka it is grown as a wind-break. The leaves, flowers and seed-cake are used as green manure, the leaves and seed-cake also as fodder. The flowers are a good source of pollen and nectar, yielding a dark honey. The bark can be made into rope. Medicinally, extracts from the leaves, bark and seed are applied as anti-septic against skin diseases and rheumatism. Pounded and roasted seeds used to be utilised as a fish poison. In rural areas, dried leaves are stored with grain to repel insects. *P. pinnata* is used as a host of the lac insect and of the hemi-parasitic sandalwood *Santalum album* L. It is occasionally planted as an ornamental because of its attractive flowers. However, the large amounts of flowers, leaves and pods that it regularly sheds make it not very suitable for this purpose.

Properties The energy value of the wood is 19 000–20 000 kJ/kg, its specific gravity about 650 kg/m^3. The yellowish-white wood is coarse, strong, hard and beautifully grained, but not durable. It has a tendency to warp and split in seasoning. Wood fibre is 1000–1200 μm long, 20 μm in diameter and its wall about 4 μm thick. Air-dried seed contains per 100 g: moisture 19 g, protein 18 g, oil 28 g and the flavonoids karanjin 1.25 g and pongamol 0.85 g. The seed-oil has a disagreeable odour, is difficult to refine and is inedible. It contains about 70% oleic acid and 11% linoleic acid. The oil and soap made from it have a characteristic reddish-brown colour due to the compound isolonchocarpin.

The seed-oil is being tested as an anti-feedant and insecticide against several insects, e.g. *Oryzaephilus surinamensis* and *Tribolium castaneum* (both storage pests of rice) and *Nephotettix virescens* (a vector of the virus causing tungro disease in rice). The oil and its components are being tested as synergists to increase the potency of other insecticides.

Botany Evergreen or briefly deciduous, glabrous shrub or tree with spreading branches, 15–25 m tall, trunk up to 80 cm in diameter. Bark smooth or faintly vertically fissured, grey. Branchlets with pale stipule scars. Leaves imparipinnate, pinkish-red when young, glossy dark green above and dull green with prominent veins beneath when mature; leaflets 5–9, ovate, elliptical or oblong, 5–25 cm × 2.5–15 cm, obtuse-acuminate at apex, rounded to cuneate at base. Inflorescence raceme-like, axillary, 6–27 cm long, bearing pairs of strongly fragrant flowers; calyx campanulate, 4–5 mm long, truncate, finely pubescent; corolla white to pink, purple inside, brownish veined outside; standard rounded obovate, 1–2 cm long, with basal auricles, often with green central blotch, thinly silky hairy; wings oblong, oblique, slightly adherent to obtuse keel; stamens 10, monadelphous, vexillary one free at base, joined to the tube in the middle. Pod short-stalked, oblique-oblongoid to ellipsoid, flat, 5–8 cm × 2–3.5 cm × 1–1.5 cm, smooth, thick-leathery to subwoody, beaked, indehiscent, 1–2-seeded. Seed compressed ovoid, 1.5–2.5 cm × 1.2–2 cm × 0.8 cm, with a brittle coat.

Pongamia pinnata (L.) Pierre – 1, flowering branch; 2, flower; 3, pods.

Growth of young trees is fairly slow; a growth of 1.3 m in height and 0.4 cm in diameter in 13 months was found in India. In Florida, it sheds its leaves in April and develops new leaves and flowers from May onwards. In India, seed ripens from February to May. Pods do not open naturally and must decay before seed can germinate. *P. pinnata* nodulates and fixes atmospheric nitrogen with *Rhizobium* of the cowpea group.

The taxonomy of the genus *Pongamia* Ventenat is confused. It is closely related to and is sometimes included in the genera *Millettia* Wight & Arnott or *Derris* Lour.

Ecology In its natural range, *P. pinnata* tolerates a wide temperature range. Mature trees withstand light frost and tolerate temperatures of over 50°C. Its altitudinal range is from 0–1200 m. It is fairly tolerant of shade, at least when young. Annual rainfall required is 500–2500 mm, with a dry season of 2–6 months. It occurs naturally in lowland forest on limestone and rocky coral outcrops on the coast, along the edges of mangrove forest and along tidal streams and rivers. Best growth is found on deep sandy loams, but it will also grow on sandy soils and heavy swelling clay soils. It is very tolerant of saline conditions and tolerant of alkalinity.

Agronomy *P. pinnata* can easily be propagated by seed and cuttings. Even branches stuck in moist soil develop roots readily. Seed remains viable for a long time. No seed treatment is required. Germination takes 10 days to 1 month. In the nursery, it can be planted at a close spacing and tolerates shade well. In India, a spacing of 7.5 cm × 15 cm is recommended. Seedlings reach a height of 60 cm about 1.5 years after sowing and are easy to transplant. Direct sowing is common and mostly successful. Trees coppice well and can also be pollarded. Spontaneous seedlings and root suckers are produced in large numbers and may create serious weed problems. *P. pinnata* is host to a large number of fungi and insects, but serious damage has not been reported. Pod production starts 5–7 years after sowing. Individual trees yield 9–90 kg of pods annually. Ripe pods are collected in India from April–June and are subsequently dried in the sun. Seeds are easily extracted by light hammering or by splitting the pod with a knife along the sutures and winnowing out of the husks. Mature trees yield 8–24 kg seed annually.

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

Prospects *P. pinnata* is likely to remain important as a reforestation and fuelwood tree because of its adaptability to poor and saline soils, its many useful products and ease of planting. More research attention to develop its potential as insecticide and as medicine seems warranted.

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L.P.A. Oyen

Prosopis juliflora (Swartz) DC.

Prodr. 2: 447 (1825).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26, 28, 52, 56$

Synonyms *Mimosa juliflora* Swartz (1788), *Prosopis vidaliana* Naves (1877).

Vernacular names Mesquite (En). Bayahonde (Fr). Algarrobo, mesquite (Sp).

Origin and geographic distribution *P. juliflora* probably originates from Peru and occurs naturally in dry areas of northern South America and Central America, Mexico and the southern United States. It has been introduced into many dry tropical areas, including north-eastern Brazil, Africa, Australia, South-East Asia and the Indian subcontinent. In Malesia, it is cultivated in Java, Papua New Guinea and the Philippines. In Brazil, cultivation is becoming very important.

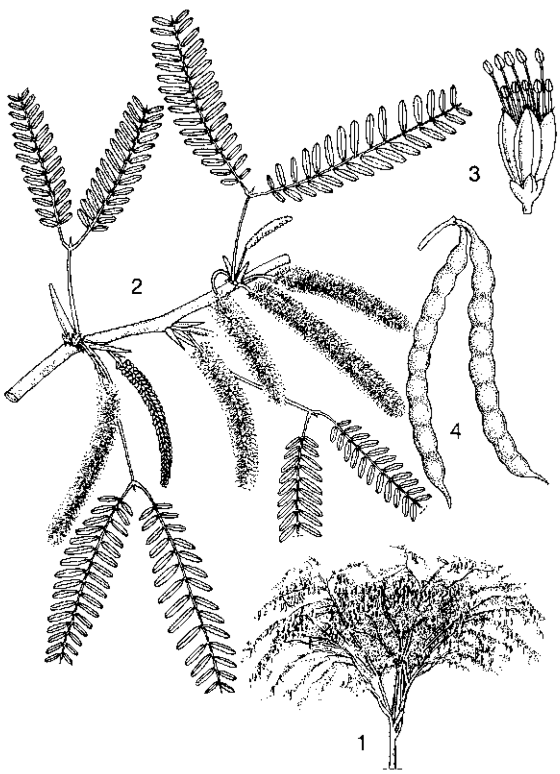
Uses *P. juliflora* is widely planted for land reclamation, being an aggressive colonizer, tolerant of very poor, degraded, saline and alkaline soils. It controls soil erosion, stabilizes sand dunes and is planted in wind-breaks and shelter-belts. However, because of its aggressive nature, it is considered a noxious weed in more humid areas, e.g. the southern United States. The generally crooked stems and branches make a good firewood and provide excellent charcoal. The wood is durable and can be used for quality furniture, doors and flooring, but the small trees rarely produce marketable logs. A reddish-amber gum, similar in properties to gum arabic produced by *Acacia senegal* Willd., often exudes from the stem and older branches. The protein and sugar-rich pods are valuable livestock fodder, and serve as security food for people during famine. In Argentina, Chile and Peru the pods are an important human food item used in making bread, syrup, sweets and alcoholic drinks such as cocktails. The pods must be processed, to improve the flavour. Sugars and sweeteners can be produced from the pods. Roasted seeds are used as a coffee substitute. Flour prepared from the pods can replace wheat bran in animal feed. For dairy cows, the flour may make up 40–60% of concentrate rations, while in South Africa, it is fed unmixed to sheep. The short-fibred parts are also suitable for pigs and poultry. The leaves of most selections are unpalatable to livestock. *P. juliflora* is also a valuable honey plant. Medicinally, the pods are used (as tea or syrup) against digestive disturbances and skin lesions.

Production and international trade The fruits of *P. juliflora* are of great economic importance locally in Argentina, Brazil, Chile and Peru, but no statistics are available. Potential agro-industrial uses are being investigated and are promising. Charcoal made from *P. juliflora* wood is used extensively as a barbecue fuel in the United States, where about 30% of the charcoal sold for this purpose originates from *P. juliflora* from the Sonora desert in northern Mexico.

Properties The wood of *P. juliflora* is hard and durable and burns evenly. The basic density of sawlogs is about 935 kg/m^3, of fuelwood about 750 kg/m^3. The energy value of fuelwood is

17 000–19 000 kJ/kg. Pods of *P. juliflora* contain per 100 g: crude protein 14 g, ether extract 3 g, nitrogen-free extract 50 g, crude fibre 28 g, ash 5 g; the flour has more protein and less fibre and carbohydrates. Seed contains per 100 g dry matter: crude protein 41 g, ether extract 5 g, nitrogen-free extract 43 g, sugars 8 g, starch 1 g, crude fibre 7 g, ash 4 g. Fresh leaves contain per 100 g dry matter: crude protein 19 g, ether extract 3 g, nitrogen-free extract 48 g, crude fibre 22 g, ash 9 g. Leaves are quite rich in essential amino acids, but lack the sulphur-containing ones. The leaf litter persists much longer than that of some other legumes. The litter suppresses the growth of soil bacteria and fungi and soils covered with *Prosopis* litter are often agriculturally poor. The weight of 1000 seeds is 35–45 g.

Description A flat-topped, evergreen (sometimes deciduous) shrub or small tree with twisted stem, up to 13(–20) m tall, armed with axillary, stipular spines 1–5 cm long or unarmed. Bark rough, dull-red; inner bark yellowish. Leaves with 1–2(–4) pairs of pinnae; petiole 1–4 cm long, rachis 3–14 mm long, ending in a spine 2–3 mm long; pinnae 3–11 cm long; leaflets in (6–)12–25(–29) pairs, sessile, elliptical-oblong, 6–16(–25) mm × 1.5–3(–6) mm, rounded to truncate at apex, mucronulate, usually glabrous, submembranous. Inflorescence an axillary, pendent, densely flowered, cylindrical, spiciform raceme, 5–15 cm long; flowers 4–5 mm long, yellow to creamy-brown; calyx broadly campanulate, about 1.5 mm long, teeth 5, slightly ciliate; petals 5, sharply acute, about 3 mm long, greenish-yellow, pilose within; stamens 10. Fruit a pendent, straight or slightly falcate, compressed pod, 8–29 cm × 9–17 mm × 4–8 mm, surface irregular, light yellow to brown; stipe up to 2 cm long, beak 3–7 mm long; valves thick, indehiscent, enclosing seeds in cavities when ripe. Seed broadly ovoid, 6 mm × 4 mm, brownish, embedded in a whitish, slightly sweet pulp.



Prosopis juliflora (Swartz) DC. – 1, habit; 2, flowering branch; 3, flower; 4, pods.

Growth and development In tests in Petrolina, Brazil, *P. juliflora* reached a height of 4 m, a diameter at breast height of 4.5 cm and a crown diameter of 5.4 m in 2 years. It normally grows to a height of about 10 m, while under very favourable conditions it may reach 20 m. In Brazil, it flowers profusely in December–February and pods are mature in February–May. In India, flowering and fruiting is from August–October. *P. juliflora* coppices readily.

P. juliflora moderately enriches the soil with atmospheric nitrogen obtained through symbiosis with cowpea-type *Rhizobium*. The roots also form mycorrhizal associations with *Glomus* fungi. Plants with both mycorrhizal and *Rhizobium* associations show significantly higher nitrogen fixation rates than those lacking the mycorrhiza.

Other botanical information The taxonomy of *Prosopis* L. is confused and in great need of a worldwide revision. *P. juliflora* is a highly polymorphic species and many varieties have been described. Several varieties such as var. *glandulosa* (Torrey) Cockerell and var. *velutina* (Wooton) Sargent are often considered separate species, denoted *P. glandulosa* Torrey (honey mesquite, in the southern United States) and *P. velutina* Wooton (velvet mesquite, in Mexico and Arizona, United States), respectively. Var. *torreyana* L. Benson is also classified as *P. glandulosa* Torrey var. *torreyana* (L. Benson) M.C. Johnston. These varieties are difficult to distinguish, having only larger leaflets and flower spikes than var. *juliflora*.

Ecology The value of *P. juliflora* lies in its exceptional tolerance of drought and marginal soils. In its natural habitat in Peru, average annual rainfall ranges from 250–500 mm, but plants bearing leaves and fruits can be found in locations receiving as little as 50 mm. An annual rainfall of about 800 mm is required for optimal growth. It is grown successfully on sandy soils in Brazil, in locations with 1000 mm annual rainfall, where most vegetation remains green all year. *P. juliflora* tolerates a dry season of 8 months or even longer. In Peru, it is found up to 100 m altitude, while elsewhere its range extends to 1500 m altitude. The mean maximum temperature of the hottest month is 22–34°, the mean minimum temperature of the coldest month 14–22°. Some selections tolerate light frost. *P. juliflora* is tolerant of highly saline and alkaline soils. When grown experimentally on a 20 g/l NaCl nutrient solution, it not only survived and continued to grow, but also continued to fix atmospheric nitrogen. The roots are able to exclude NaCl; the NaCl content of the ash increasing much slower than that of the nutrient solution or soil. *P. juliflora* survives and even flourishes in soils more saline than 2 S/m (13 g/l NaCl) if it can obtain water from a portion of the rootzone with lower salinity and its roots continue to extract water from soils with salinities greater than 2.8 S/m (18 g/l NaCl). Fair growth is also obtained on poor sandy and rocky soils.

P. juliflora is sometimes said to dry out the soil and compete with grasses, particularly in dry years, hence in some areas (e.g. the United States) it is considered a weed. The tree naturalizes easily in many regions, such as India and Australia and may become a weed in humid areas.

Propagation and planting Propagation is possible by seed, root cuttings and grafting. Establishment by seed is feasible, although seed is difficult to extract from the pods. For small amounts, pods are cut open with a knife and seeds are removed manually. For larger amounts, pods are kept in a damp place and allowed to degrade by fermentation, releasing the seeds. Alternatively, pods are fed to goats and the manure containing the undamaged seeds is used for sowing. Treatment of seed with concentrated sulphuric acid for 30 minutes is reported to improve germination, in other cases mechanical scarification was better. Aerial seeding is applied successfully to quickly cover remote, extensive and poorly accessible areas. In the United States, aerial seeding of a mixture of *P. juliflora*, *Nicotiana glauca* Graham and several *Eucalyptus* species is used to revegetate abandoned copper mines. It is common practice to grow plants in plastic bags in nurseries. Inoculation with *Rhizobium* and mycorrhizal fungi is advantageous.

Seedlings withstand watering with saline water up to EC 0.8–1.0 S/m, and at 18 months brackish water of EC 0.4–0.6 S/m and pH 7.0–7.85 still suffices.

Spacing depends on the use of the trees. When grown for fuelwood, a spacing of 2 m × 2 m or wider is used in South America. In rangeland in association with grasses and other crops, spacing may be up to 10 m × 10–15 m. When the emphasis is on pod production, the spacing used ranges from 5 m × 5–10 m.

Husbandry After planting, *P. juliflora* benefits from weeding around the stem. Young plants also need protection from grazing animals. For older plants little care is needed. Thinning and pruning are needed to avoid *P. juliflora* becoming a weed and to keep the plantation accessible. In rangeland in South America, all but the large trees with a stem diameter of 30–50 cm are thinned out and the remaining trees are pruned to 30% of their canopy. The best species to grow in association with *P. juliflora* are *Cenchrus ciliaris* L., *Panicum maximum* Jacq. and *Opuntia* spp. Although better growth of *Opuntia* and grasses under *P. juliflora* trees is often reported, there have been reports that the total fodder yield may be lower than the yield from a well managed grass pasture.

Diseases and pests In South America the wood sawyer insect *Oncideres saga* which cuts off young branches causes considerable damage. Other pests reported from South America are the Lycainid butterfly *Hemiargus ramon* damaging the flowers and the Lonchaeid fly *Silba pendula* and *Bruchus* beetles attacking the pods. The membracid treehopper *Otinotus oneratus* is reported to cause damage in India.

Harvesting Firewood is generally cut in an 8–10-year cycle. Pods are either left for animals to browse or harvested manually. Prompt harvesting and processing of pods may alleviate *Bruchus* beetle attack, while delaying collection of pods fallen on the ground may result in heavy losses. Where pods are stored for later use or marketed, manual harvesting is required.

Yield Wood and pod yields strongly depend on the selection used and on the environment. No difference in yield between planted trees and coppice growth is reported. When cut in an 8–10-year cycle, a firewood plantation may yield 50–60 t/ha; in a 15-year rotation, the expected yield is 75–100 t/ha. Pod production starts in the third year after planting and peaks between 15 and 20 years, provided trees are well managed. Average annual pod yield is about 15 kg per tree, but yields of 100 kg from individual trees are also reported. An annual production of 10 t/ha is possible; the average production in the United States is 8.7 t/ha.

Handling after harvest Pods are often attacked by insects and need careful storage. Traditionally, they are stored in sealed rooms or in layers alternating with layers of sand. Alternatively, they are fumigated and stored in a well ventilated room.

Genetic resources and breeding Various collections exist, e.g. in the United Kingdom at the Commonwealth Forestry Institute in Oxford. Genetic variation exists between populations, e.g. in Pariba, Brazil. Selection work in Haiti found spineless, erect growing forms with unpalatable foliage. Selection is being carried out e.g. in Banthra, Lucknow, India. Most research in Asia is reported from the Indian subcontinent.

Prospects *P. juliflora* is considered very useful for afforestation of saline and alkaline wasteland and for the production of fuelwood and dry season fodder. Its role as a rangeland tree deserves further research attention. It is suitable for stabilizing peripheral bunds around mangrove creeks used for fish culture. On the other hand, warnings are issued against introduction into new locations, as it may become weedy on good soils and in moist locations.

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L.J.G. van der Maesen & L.P.A. Oyen

Psophocarpus scandens (Endl.) Verdc.

Taxon 17: 539 (1968).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 18$

Synonyms *Psophocarpus palustris* auct., non Desv. (1826), *P. longepedunculatus* Hassk. (1842), *Mucuna comorensis* Vatke (1878).

Vernacular names Psophocarpus (En). Indonesia: kecipir monyet (Javanese), jaat monyet (Sundanese).

Origin and geographic distribution *P. scandens* is a native of tropical Africa and widely distributed from Cameroon to Angola and from Tanzania to Mozambique and Madagascar. It is cultivated in Zaire, Brazil, the West Indies, India, Sri Lanka, Burma (Myanmar), Vietnam and Indonesia. It has naturalized in Brazil.

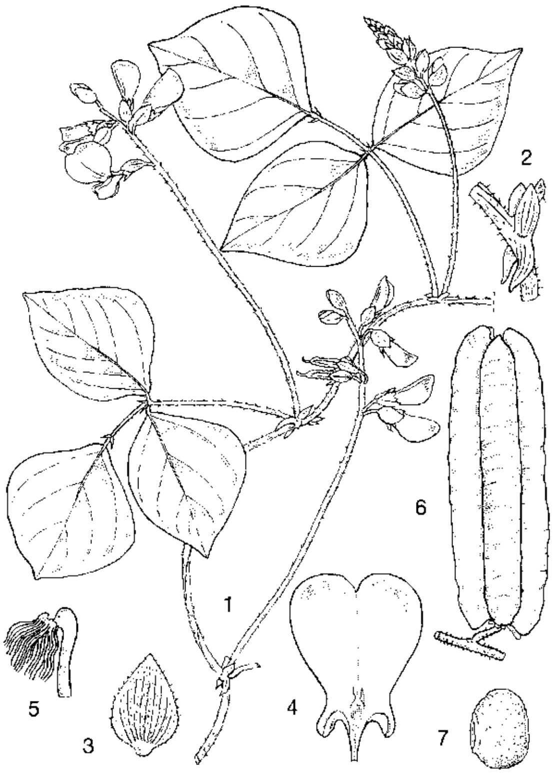
Uses *P. scandens* is grown as a cover crop and green manure in Central Africa, Asia and tropical parts of the New World. In Indonesia, it is grown as a cover crop in rubber and oil-palm plantations, while the leaves are used as a fodder in a mix with grasses and other legumes. In West Africa, the pods are used as a famine food. In Zaire, the primary use is as a vegetable; in the market of Kinshasa, Zaire, bundles of young shoots and pods are sold and eaten after boiling in water or milk. The pods are given to nursing mothers to stimulate milk production. In Zaire, it is also grown as a fodder for livestock and for fish raised in ponds. In traditional medicine, bruised leaves are applied as a compress for open cuts, wounds, and haemorrhoids. Fresh and dried leaves are consumed after boiling or as a tea to relieve the discomfort of stomach inflammations. In Zaire, *P. scandens* is also a source of tannin.

Properties In Indonesia, immature pods of *P. scandens* contain per 100 g: 88–95 g water and 1.2–3.1 g protein. In Zaire, foliar analyses indicated per 100 g dry matter: protein 31–39 g, lipids 12 g, carbohydrates 32 g, P 0.35 g, K 1.2 g, Ca 2.1–3.1 g, Mg 0.4–1.4 g, S 0.5 g; analyses of pods indicated per 100 g dry matter: protein 7.1–27.9 g, lipids 2.7

g, carbohydrates 56.4 g, P 0.1–0.5 g, Ca 0.5–2.3 g, Mg 0.1–1.5 g. Analyses of the leaves in Sumatra (Indonesia) indicated per 100 g dry matter: C 25.9 g, N 4.5 g, P 0.26 g, K 1.0 g, Ca 1.3 g, Mg 0.3 g; analysis of the stems indicated per 100 g dry matter: C 27.2 g, N 1.85 g, P 0.14 g, K 1.6 g, Ca 1.1 g, Mg 0.3 g; analysis of the roots: C 27.5–30.6 g, N 2.3–2.4 g, P 0.2 g, K 0.8–1.0 g, Ca 1.0–1.3 g, and Mg 0.2 g. The protein content of the seed is higher than in other legumes, except for groundnut, soya bean and winged bean.

P. scandens produces a nectar that is rich in sucrose from glands in the flowers and on the pedicels. The weight of 1000 seeds is 90–100 g.

Description Perennial climbing or twining herb, 1–6 m long, with a tuberous main root and glabrous or sparsely hairy to glabrous stems. Leaves trifoliolate; stipules oblong-lanceolate, persistent, spurred, 0.8–1.7 cm long including the spur; petiole 5–18 cm long; rachis 0.8–5 cm long; petiolule 3–6 mm long; leaflets ovate-rhomboid to broadly rounded, 2.5–12 cm × 1.8–10 cm, acute or acuminate at the apex, cuneate to truncate at the base, occasionally 3-lobed, glabrous or glabrescent on both surfaces, margin often ciliate. Inflorescence a several to many-flowered pseudo-raceme; peduncle 3–40 cm long; rachis 5–12 cm long, pubescent; pedicel 2–6 mm long, pubescent; bracts semi-caducous, ovate-lanceolate or elliptical, 5–11 mm × 2–4 mm; bracteoles persistent, ovate-oblong or elliptical, 7–14 mm × 5–8 mm, nearly as long as or longer than the calyx, glabrous or glabrescent; calyx glabrous or puberulous, tube 5–7 mm long, lower lip with median triangular lobe 2.5–3.5 mm long, and 2 lateral very broadly deltoid lobes 1.5 mm long, 2 upper lobes fused into an emarginate lip; standard pale-blue or mauve, obovate-oblong, 1.5–2.1 cm × 1.2–1.5 cm, emarginate; wings blue-lilac or with blue or violet margin; keel 5.5–7 mm wide, blue-lilac, whitish or with blue or violet margin, not prominently beaked. Fruit an oblong pod, square in cross-section, 3.5–8 cm × 6–7 mm, 4–8-seeded, glabrous, prominently 4-winged, wings 2.5–6.5 mm wide, slightly serrate, often striate, sometimes puberulous along the margins. Seed oblong or sub-cylindrical, (5–)6–7.5 mm × (3.5–)5–6 mm, blackish-purple, with minute granular, orange, easily removable tomentum or brown silky hairs on the edges. Seedling with epigeal germination, first leaves blotched.



Psophocarpus scandens (Endl.) Verdc. – 1, flowering branch; 2, stipules; 3, bracteole; 4, standard; 5, stigma; 6, pod; 7, seed.

Growth and development After germination, initial growth is slow; once well established, growth is vigorous. When grown mixed with other cover crops, *P. scandens* may overgrow and suppress the companion crops within a year, remaining as the sole cover crop after two years. Planted as a ground cover, the ends of the shoots rise and twine. In dense stands, they may find mutual support and intertwine, forming loose strands or conical heaps rising well above the rest of the cover crop. These heaps become top-heavy, bend and are then taken up in the cover crop. The sprouts of new shoots may form similar heaps which intermingle with the older ones forming an airy, but closed soil cover. Branches may root at the nodes where they touch the soil. Nodules with abundant leghaemoglobin may form on these adventitious roots.

In Sumatra, flowering starts about 115 days after sowing, taking place from January to March, while fruits mature from April to May. Some further flowering and fruiting may take place from October to December. In Hawaii, flowers are initiated during late October and early November and flowering continues until mid-February to early March. Seed can be collected from plants any time of the year since pod shattering is low in humid locations. In Bogor (Indonesia), bumble bees (*Xylocopa confusa*) have been observed to visit open flowers. Only the lower flowers in an inflorescence usually develop into fruits; the upper flower buds abort unless the lower ones are damaged.

Other botanical information *P. scandens* used to be included in *P. palustris* Desv. and is still often confounded with it. Most agronomic information on *P. palustris* should be attributed to *P. scandens*. *P. palustris* is restricted to Africa, occurring from Senegal to the Sudan. It differs from *P. scandens* in the following characteristics: is a pubescent herb; leaflets ovate-elliptical, never 3-lobed, terminal leaflet broadest in the middle, with cordate base; bracteole 4.5–6.5 mm × 3–5 mm, approximately half the length of the calyx; keel beaked at apex, 6.5–9 mm wide; pod 2.3–5.5 cm long, 3–5-seeded. *P. scandens* is sparsely pubescent to glabrous; leaves ovate, occasionally 3-lobed, terminal leaflet broadest near the base, base more truncate; bracteole 7–14 mm × 5–8 mm, equal in length or longer than the calyx; keel not prominently beaked, 5.5–7 mm wide; pod 3.5–8 cm long, 4–8-seeded. *P. palustris* also differs from *P. scandens* in having a chromosome number of $2n$ = 22. At the edges of their natural areas of distribution some introgression occurs. A few specimens show bracteole characteristics of *P. palustris* and leaflet characteristics of *P. scandens*.

Ecology In Zaire, *P. scandens* grows well in locations with average annual rainfall of 1200–1800 mm, and mean annual temperature of 25°C. It thrives in full sunlight, but tolerates some shade. It prefers damp sites near lakes, marshes, ponds, rivers and streams, but also occurs in drier environments. It is found in disturbed habitats such as grassland, fallow land, riverine thickets, savanna edges, in periodically flooded forest, swamp forest edges, semi-deciduous forest and secondary forest up to 950 m altitude. It grows well on heavy, swamp soils. In East Java, it is grown on gley soils of low humus content, with a loamy-clay texture.

Propagation and planting *P. scandens* is propagated by seed, but vegetative propagation by cuttings or tuberous main roots is also possible. Stem and root cuttings may be successful, if rainfall is sufficient, but they require much labour. After harvesting, the germination rate of the seed declines rapidly; only 15% of seeds stored in gunny-bags will germinate after 3 months' storage. Seed can best be stored in the pod in a ventilated room where pods can be fumigated regularly. In this way about 90% of the seed remains viable and germinates after 6 months' storage.

In Sumatra, seed matures during the dry season and can be sown in the field in the subsequent short rainy season. This requires adequate rainfall during the germination stage. Alternatively, seed is sown in nurseries, requiring daily watering for 1 month. Seedlings may then be transferred to polythene bags and can be planted out in the field after 1–2 months. Transplanting is preferably done at the beginning of the main rainy season. As a sole crop, a planting distance of 75 cm between rows is commonly practised, needing about 25 kg seed per ha.

Husbandry Intensive and frequent weeding is necessary until the crop cover closes. A sole crop of *P. scandens* may cover the ground in 8–16 months after planting. It requires plenty of water and may compete with the main crop during the dry season. When interplanted between rubber trees, rubber yields were found to increase by up to about 165%. It is better to sow a mixed cover crop of *P. scandens*, *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth. than to sow a sole crop, as the mixture may cover the soil already in 4 months after planting and may persist for several years.

Once established, *P. scandens* competes well with weeds and suppresses *Imperata cylindrica* (L.) Raeuschel under high rainfall conditions.

A sole cover crop of *P. scandens* may reach fresh weight yields per ha of approximately 4.6 t leaves, 11.3 t stems, 1.85 t roots, and 15 t litter. In Nigeria, *P. scandens* has been tested as a permanent cover crop, interplanted with maize. Maize planted in cleared strips in between the cover crop gave higher yields than zero tillage planting or conventional tillage. Applying N fertilizer increased yields; the highest maize yield (2.6 t/ha) was obtained with a *P.scandens* cover and an application of 60 kg N per ha. After 5 years, the cover crop was ploughed in and maize was sown, yielding 3.9 t/ha. This was almost double the yield of the best, conventionally planted, fertilized treatment.

Diseases and pests *P. scandens* is generally little affected by diseases and pests. It is resistant to several diseases and pests affecting the closely related *P. tetragonolobus* (L.) DC. such as false rust (*Synchytrium psophocarpi*), yellow mosaic virus, leaf spot and leaf curl. It is also less susceptible to necrotic mosaic and flower blight.

The nematode *Heterodera marioni* attacks *P. scandens* in Sumatra (Indonesia) and Mauritius.

In Zaire, weevils (Bruchidae) attack the seed.

Genetic resources Strains of *P. scandens* are available at the International Institute of Tropical Agriculture, Ibadan, Nigeria and from the Southern Regional Plant Introduction Station, Griffin, Georgia, the United States.

Breeding Efforts to cross *P. scandens* with *P. tetragonolobus* which has the same chromosome number, using *P. tetragonolobus* as the female or male parent, have failed, probably because of differences in karyotype. If interspecific hybrids can be obtained, they will probably be sterile, so it will not be easy to transfer genes for disease and pest resistance from *P. scandens* to *P. tetragonolobus*.

Prospects *P. scandens* is a useful cover crop in humid areas, especially in rubber plantations; it deserves wider attention. Because of the very high protein content of the leaves, it may be a useful fodder grown as a component in pastures or as a sole crop. More research is needed on propagation, husbandry, and breeding.

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N. Wulijarni-Soetjipto

Pueraria phaseoloides (Roxb.) Benth.

Journ. Linn. Soc. 9: 125 (1865).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22, 24$

Synonyms *Dolichos phaseoloides* Roxb. (1832).

Vernacular names Tropical kudzu, puero (Australia) (En). Kudzu tropical, puero (Fr). Indonesia: kacang ruji, krandang (Javanese), fuo banga (Ternate). Malaysia: kacang hijau hutan, tampong urat. Philippines: singkamasaso (Tagalog), bahay (Bikol), vaay (Ivatan). Burma (Myanmar): pe ying pin. Laos: pièd, s'üak pièd. Thailand: thua-sianpa (central). Vietnam: d[aa]u ma, d[aa]u dai, d[aa]u r[uf]ng.

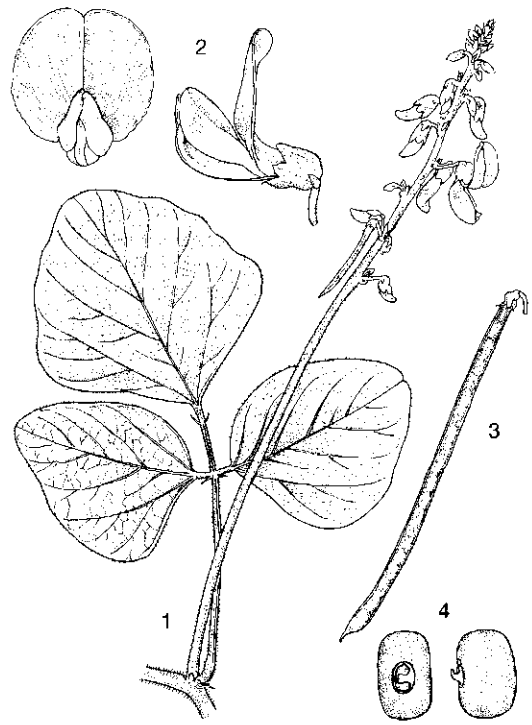
Origin and geographic distribution Tropical kudzu is indigenous to the lowlands of East and South-East Asia where it occurs on river banks and roadsides, fallow fields and young secondary forest. It has been introduced into other tropical regions and is now cultivated and naturalized throughout the wet tropics.

Uses Tropical kudzu is especially important as a component of grazed and ungrazed cover crop mixtures in rubber, oil-palm and coconut plantations in South-East Asia, Africa and tropical America. In East Africa, it is grown as a cover crop in plantations of sisal (*Agave sisalana* Perrine). In South-East Asia, tropical America and Australia it is also used as a pasture legume. Its ability to smother weeds makes it a useful pioneer legume often grown in combination with other more permanent species. It is planted on sloping sites to control soil erosion and in rotation with annual crops as a green manure.

The tuberous roots are edible. Strong fibres from the stem are used for rope making. In Malesia, the plant is used in traditional medicine to cure boils and ulcers.

Properties Chemical analysis of a pure tropical kudzu cover crop under oil palm grown on a Selangor-series soil in Malaysia, producing a living biomass of 4.9 t/ha dry matter in 18 months, indicated a nutrient content per 100 g dry matter of: N 2.35 g, P 0.20 g, K 2.14 g, Mg 0.20 g. A similar cover on a Serdang-series soil in Malaysia produced a living biomass of 5.8 t/ha dry matter in 12 months, containing per 100 g: N 3.01 g, P 0.32 g, K 2.02 g, Mg 0.14 g. Litter of tropical kudzu decomposes fairly slowly. In a litterbag experiment in Colombia at an average temperature of 26°C, the half-life of organic matter was about 110 days during the rainy season and 220 days during the dry season. On average, about 75% of K was leached out of the litter after 1 month, while the concentration of N and P in the remaining litter was approximately constant.
Tropical kudzu is very palatable, although its wet-season palatability is reported to be low in tropical America. Nutrient concentrations typically range from 2–4% N, 30–40% crude fibre, 0.15–0.45% P and 0.4–1.6% Ca.
The weight of 1000 seeds is 10–12 g.

Description Deep-rooting perennial herb with climbing or twining, hairy stems. Roots subtuberous. Main stems about 6 mm in diameter, extending 4.5–10 m, rooting at nodes if in contact with moist soil, lateral stems branching from nodes; young shoots densely covered with brown hairs. Leaves large, trifoliolate; stipules triangular to ovate, 4–11 mm × 2–3 mm, pubescent; petiole 3–11 cm long, hairy; stipels lanceolate to setaceous, 3–7 mm long; petiolule 2–5 mm long; top leaflet symmetrical, triangular or ovate, 2–20 cm × 2–16 cm, thin, base broadly cuneate or subrhomboidal and very shallowly lobed, apex acuminate, lateral leaflets oblique, (4–)6–7(–14) cm × (3–)6–7(–12) cm, thinly hairy on upper surface, greyish-green and densely pubescent on lower surface. Inflorescence an axillary, unbranched raceme, 10–46 cm long, pubescent; peduncle about 13 cm long; bracts 2–5 mm long, pubescent; flowers 10–23 mm long, mauve to deep purple, borne in pairs; bracteoles lanceolate, 1–3 mm long; pedicel 2–6 mm long; calyx campanulate, 6 mm long, hairy, upper teeth broad, lateral ones triangular, the lower lanceolate and all terminating in a bristle; standard orbicular, 1–2.5 cm in diameter, spurred, greenish on outside and white on the inner side with a mauve violet central blotch; stamens 10, diadelphous. Fruit a straight or slightly curved, terete or compressed cylindrical pod, 4–12.5 cm × 3–5 mm, thinly clothed with stiff appressed hairs, black when mature, 10–20-seeded. Seed cylindrical to cubic with rounded corners, about 3 mm × 2 mm, brown to brownish-black.



Pueraria phaseoloides (Roxb.) Benth. – 1, flowering branch; 2, flower, frontal and side view; 3, pod; 4, seeds.

Growth and development Seedling growth of tropical kudzu is only moderately vigorous during the first 3–4 months. Seedling vigour is superior to other cover crops such as centro (*Centrosema pubescens* Benth.) and calopo (*Calopogonium mucunoides* Desv.). Once established, it is very vigorous and quickly smothers weeds. Unless regularly controlled, it tends to climb the stems of trees and to get entangled in the fronds of young palms. In Malaysia, it reaches 60–70% cover after about 4 months and 90–100% after 8 months. It can form a tangled mat of vegetation 60–75 cm deep. Flowering in Java is from May to October.

Other botanical information Three botanical varieties are distinguished within *P. phaseoloides*:
- var. *javanica* (Benth.) Baker (synonym: *Pueraria javanica* (Benth.) Benth.): leaflets mostly entire, rarely somewhat lobed; flowers 15–23 mm long; bracts and calyx pubescent, lateral calyx

lobes obtuse, lower calyx lobe acute; fruit 7–11 cm × 4–5 mm. Worldwide it is the most common variety, also introduced into tropical Africa and America. Its most probable origin is in Java and Peninsular Malaysia.
- var. *phaseoloides*: leaflets entire, lobed or sinuate; flowers 7–15 mm long; bracts and calyx short-pubescent, lateral calyx lobes acute, lower calyx lobe acuminate-lanceolate; fruit 5–9 cm × 3–4 mm. It occurs mainly in South and South-East Asia. Its most probable origin is in south-eastern China.
- var. *subspicata* (Benth.) van der Maesen (synonym: *Pueraria subspicata* (Benth.) Benth.): leaflets large, entire to deeply lobed; flowers 15–23 mm long; bracts and calyx densely long-pubescent, lateral calyx lobes acute, lower calyx lobe lanceolate-subulate; fruit 7–12.5 cm × 4–5 mm. It occurs mainly in India, Bangladesh, Burma (Myanmar) and Thailand. Its most probable origin is in north-eastern India.

The ecological requirements of the 3 varieties are the same. Sometimes overlapping morphological characteristics occur. Named cultivars exist in South America and Tanzania, but seed is mostly traded without cultivar name.

Ecology Tropical kudzu is best suited to the humid lowland tropics up to 1000 m altitude with an annual rainfall in excess of 1500 mm. In an experiment under controlled conditions, an optimum temperature of 32/24°C (day/night) was found and dry matter yields were reduced by 35% with a change in temperature regime to 26/15°C. Few reports are available on photoperiod responses. In Puerto Rico (latitude 18°N), flowering and seed set occur in the short daylength period from January to March, suggesting that it may be a short-day plant. In Papua New Guinea and Africa, it only sets seed under dry conditions.

In comparison with other legume species tropical kudzu has been ranked highly as a shade-tolerant plant. When grown under 50% shade in coconut plantations in the Solomon Islands it was the most productive legume and it even suppressed the accompanying grasses. This characteristic makes it suitable in integrated livestock/plantation production systems. Under a regime of more than 50% shade, tropical kudzu is still comparatively productive, but in mixtures it gives way to other species like centro (*Centrosema pubescens*) or desmodium (*Desmodium heterocarpon* (L.) DC. subsp. *ovalifolium* (Prain) Ohashi).

Tropical kudzu is tolerant of very wet and waterlogged sites. It prefers heavy soils and is well adapted to acid soils. It is particularly susceptible to Mg and S deficiencies and has moderate to low Ca and P requirements, but it responds to fertilizer application. On poor oxisols and ultisols *P. phaseoloides* also requires K and Mg fertilizer. It is not tolerant of salinity.

Propagation and planting Tropical kudzu is usually established from seed. Having a high proportion of hard seed, germination can be increased by hot water, acid or mechanical scarification. Commercially available seed is often scarified by abrading the seed-coat in a hexagonal drum, lined with sandpaper, rotating at 7.5 rpm for 24 hours.

Tropical kudzu usually nodulates with native cowpea rhizobia but inoculation with an appropriate strain of *Bradyrhizobium*, such as RRIM 768 in Malaysia, is recommended for new areas. Seed is usually broadcast or drilled in rows 1 m apart. It can also be established by oversowing into an existing pasture if the pasture is disked or burnt beforehand. When seed is scarce, tropical kudzu can be propagated vegetatively, one recommendation being to plant two rooted cuttings, 0.7–1 m long, at each point on a 1–2 m grid. In Africa, a tropical kudzu cover can sometimes be established by selectively weeding the natural regrowth after land clearance. Standard seed mixtures for cover crop contain a 5:4:1 ratio of calopo, centro and tropical kudzu or a 4:1 mixture of centro and tropical kudzu. Seeding rates for these mixtures are 5–10 kg/ha in the inter-row areas between rubber or oil-palm trees.

Husbandry When planted under palm and other tree crops on former forest land, some initial control of natural regrowth of forest plants is necessary to establish tropical kudzu. Manual weeding gives the best results, but several herbicides have been used successfully (e.g. oxyfluorfen as a post-emergence herbicide at 0.5 kg/ha). During the subsequent two years, tropical kudzu has to be cutlassed or beaten down to a height of 30 cm. Circles around trees are clean-weeded to prevent tropical kudzu from climbing the trees. In sisal plantations in East Africa its vigour is reduced by low rainfall (800 mm) which checks its climbing habit. It competes with oil palm for moisture during dry periods and it has been recommended to check the growth of tropical kudzu at the start of the dry season. The largest effect of tropical kudzu on associated tree crops occurs when it dies off 3–4 years after planting. Marked increases in tree growth and rubber yield are found during that period, not during the first 3 years. Tropical kudzu responds well to added P; linear responses to up to

50 kg/ha of P have been obtained on infertile soil. Tropical kudzu is very palatable to animals and this can lead to selective grazing and poor persistence. Grazing experiments in Malaysia have shown that under continuous grazing at stocking rates of 2–6 head of local cattle per ha, the proportion of tropical kudzu was significantly reduced with increased stocking even after one year of grazing. Farmers using grass–legume mixtures have also reported excellent growth of tropical kudzu in the first two years, and rapid decline under grazing. The lack of persistence of tropical kudzu is probably also influenced by physical soil characteristics and related to the poor development of rooted stolons on some soils.

Diseases and pests Tropical kudzu is remarkably free from diseases, although leaf-eating caterpillars can damage ungrazed swards and pod-borers reduce seed production.

Harvesting Tropical kudzu is usually directly grazed in mixed pastures but can be cut for hay, silage or for feeding as fresh forage.

Yield Annual dry matter yields of up to 10 t/ha from tropical kudzu swards have been recorded in cutting experiments, with some 65–75% of the yield from the wet season and 25–35% from the dry season. Dry matter yields of up to 23 t/ha have been measured in tropical kudzu–grass swards, 40% of this being tropical kudzu. In tropical America, tropical kudzu–grass pastures have produced live weight gains of 313 kg/ha per year (with *Andropogon gayanus* Kunth) and 542 kg/ha per year (with *Panicum maximum* Jacq.)

Genetic resources and breeding The largest germplasm collection is maintained by the Centro Internacional de Agricultura Tropical (CIAT), Colombia and a smaller collection is held at the Australian Tropical Forage Genetic Resource Centre (ATFGRC), CSIRO, Australia. There are no known breeding programmes with tropical kudzu in South-East Asia.

Prospects Tropical kudzu is, and will probably remain, the most widely grown cover crop throughout the humid tropics, especially in tree plantations. Its main features as a forage legume are its vigorous initial growth on fertile soils and its high palatability. Improvements should primarily be aimed at improving its persistence under grazing.

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R.A. Halim

Rhizophora apiculata Blume

Enum. pl. Javae 1: 91 (1827).

RHIZOPHORACEAE

$2n = 36$

Synonyms *Rhizophora candelaria* DC. (1828), *R. conjugata* Arnott (1838), non L. (1753).

Vernacular names Brunei: bakau minyak, bakau. Indonesia: bakau minyak (general), bako (Javanese), babakoan laut (Sundanese). Malaysia: bakau minyak, bakau tandok, bakau akik. Papua New Guinea: abia (Gulf Province), bahkweh (Northern Province), pana (Central Province). Philippines: bakauan (lalaki), uakatan (Tagalog), bakhau (Samar). Singapore: bakau minyak, red-tree. Burma (Myanmar): pyoo. Cambodia: kaông ka:ng nhi:. Thailand: kongkang-bailek, kongkang. Vietnam: c[aa]y d[uw][ows]c.

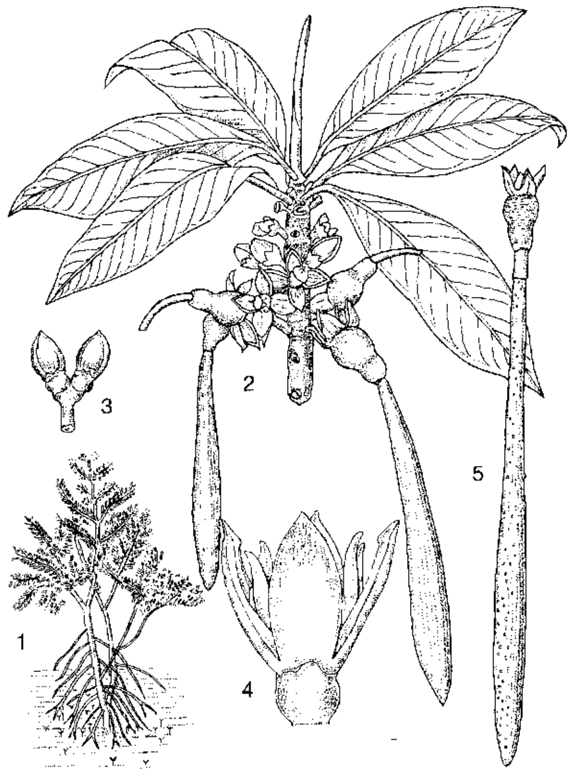
Origin and geographic distribution *R. apiculata* is commonly found in most mangrove swamps in tropical Asia, from the delta of the Indus in Pakistan to Vietnam and Hainan. It occurs throughout the Malesian region and reaches southwards to the Tropic of Capricorn in Queensland, and eastwards as far as New Caledonia and Ponape (Micronesia).

Uses The wood of *R. apiculata* can be split easily and has a high energy value, making it in great demand as firewood and for making charcoal. In recent years it has been extensively harvested for production of wood chips in East Malaysia and Indonesia. *R. apiculata* is the preferred species in replanting programmes in most mangrove regions in South-East Asia. Poles are used for piling and construction purposes, and as fishing stakes. The timber is suitable for making furniture. The branched stilt roots weighted with stones serve as anchors. The bark is rich in tannin, used for tanning leather and to toughen and dye fishing lines, ropes and nets. The bark provides a medicine against dysentery.
Rhizophora hypocotyls can be eaten after extraction of the tannin, but this is probably only of importance in times of famine.

Production and international trade In all parts of tropical Asia, *R. apiculata* is cultivated on a commercial scale for production of firewood and particularly charcoal, poles and tannin. Few production statistics from natural or planted stands are available. In Vietnam, annual wood production is about 60 000 t.

Properties The energy value of the stems, branches and prop roots is 15 000–19 000 kJ/kg, of charcoal 32 200 kJ/kg. The ash content is about 1 g per 100 g wood of the stem and prop roots, and 2 g in branch wood. Leaf samples in the Matang Mangrove Forest which consists of almost pure stands of *R. apiculata* contain per 100 g dry matter: N 0.4–1 g, P 0.1 g, K 0.9–1.2 g, Ca 1.1–2.0 g, Mg 0.4–0.8 g, Na 1.6–1.9 g. The quantity of tannin in the bark is very variable, 8–40% in air-dried bark. The tannin of *Rhizophora* is associated with a substance which darkens gradually; it is used as a deep brown or black dye. The bark, according to some analyses, contains large quantities of pentosans and furfurol. After extraction of the tannins, the ash mainly consists of calcium carbonate (70%) and lime (18%) and can be used as fertilizer. The wood of *R. apiculata* is hard, strong and heavy with an air-dry density of 960–1170 kg/m^3. The sapwood is light yellow, 3–5 cm thick, and very distinct from the heartwood which is reddish-brown and darkens with age. Growth rings and parenchyma are indistinct. Pores are small, circular, fairly numerous, straight, solitary and in short radial groups, mostly in pairs, and frequently with dark gummy deposits. Rays are numerous, straight, forming conspicuous silvery grains, narrower than the pores, and visible to the naked eye.

Description Evergreen tree, up to over 30 m tall and with trunk up to 50 cm in diameter, generally much smaller in exploited forests; bole 10–12 m; stem supported by numerous, lateral, much branched stilt roots; aerial roots sometimes develop from the lower branches; taproot usually abortive; branching primarily sympodial. Bark grey, almost smooth or with vertical fissures. Branchlets swollen at the nodes, solid and pithy. Leaves decussate, rosette-like at the end of twigs; stipules lanceolate, 4–8 cm long, conspicuous, caducous; petiole 1.5–3 cm long, reddish; blade entire, elliptical-oblong to sublanceolate, 7–18 cm ×



Rhizophora apiculata Blume – 1, habit; 2, leafy branch with flowers and seedling fruits; 3, pair of flower buds; 4, flower; 5, fruit with seedling.

3–8 cm, leathery, green and shiny, apex acute to apiculate, base cuneate, veins distinct above, obscure beneath, glabrous with minute, scattered black corky warts on the lower surface, visible on older or dried leaves. Inflorescence axillary (in leaf scar below the leaf rosette), 2-flowered; peduncle thick, 0.5–1.5 cm long; bracteoles at the base of flower, cup-shaped, fleshy, crenulate; flowers bisexual, sessile, yellow; calyx deeply 4-lobed, coriaceous, accrescent and reflexed in fruit, lobes ovate, 10–14 mm × 6–8 mm, concave, acute, brown-yellow to reddish, persistent; receptacle with a disk; petals 4, free, lanceolate, 8–11 mm × 1.5–2 mm, membranous, glabrous, early caducous; stamens mostly 12, sessile, anthers 6–7.5 mm long, acute, multi-loculate, opening with a large ventral valve; ovary semi-inferior, 2-celled, superior part enclosed by the disk, bluntly conical, 1.5–3.5 mm long; style 0.5–1 mm long, 2-lobed. Fruit an ovoid or inversely pear-shaped berry, 2–3.5 cm long, rather rough, brown. Hypocotyl cylindrical to club-shaped, up to 40 cm × 1.2 cm before falling, often slightly curved, more or less blunt, smooth and shining, green tinged with red.

Growth and development The stem of *R. apiculata* is upright and cylindrical in closed forest, but plants develop a straggling or semi-prostrate habit in unfavourable sites. Flowers are self-compatible and usually wind-pollinated. Insects have occasionally been observed foraging for pollen. Vivipary is characteristic for *Rhizophora* species. One-seeded fruits start to germinate when still hanging on the tree. The root protrudes from the fruit, producing a green, spindle-shaped rod (hypocotyl) of up to 40 cm long. Eventually, the seedling falls from the fruit, floats with the high tide and establishes if it reaches a suitable site. Seedlings may retain their viability for several months.

Average annual increase in diameter over a 30-year period in Matang, Malaysia, was 0.32 cm. Litterfall varies with stand vigour and age. Estimates of annual litterfall vary from 6–11.5 t/ha.

Other botanical information In South-East Asia 3 *Rhizophora* species occur: *R. apiculata*, *R. mucronata* Poiret and *R. stylosa* Griffith. *R. apiculata* is slightly more common than *R. mucronata* to which it is closely related. They can be distinguished in the field by some easily observed characters: bark grey, almost smooth, with vertical fissures in *R. apiculata*; in *R. mucronata* the bark is nearly black or reddish, rough or sometimes scaly. Inflorescence in *R. mucronata* longer, forked 2 or 3 times, with more numerous flowers; hypocotyl longer (35–65(–90) cm). *R. stylosa* has broadly elliptical leaf blades, up to 12 cm × 7 cm, flowers with styles 4–6 mm long and the hypocotyl up to 30 cm long. A few specimens have been collected with characters intermediate between *R. apiculata*, *R. mucronata* and *R. stylosa* in western Malesia and western New Guinea.

Ecology *R. apiculata* is the most common mangrove species. It grows gregariously in swamps flooded by normal high tide, on deep soft mud of estuaries, often consolidated and sheltered from surf and currents by pioneer species of *Avicennia* L. and *Sonneratia* L.f. *R. apiculata* avoids hard soils and develops well in per-humid regions where it can form almost pure stands, sometimes in association with *Bruguiera* spp. or *R. mucronata*. It does not occur in fresh water swamps. It is killed by frost and by extended periods of near-freezing temperatures.

Propagation and planting The best way to regenerate a mangrove stand at the least cost is to encourage reproduction in the period before the final harvest by thinning and by minimizing damage to young plants during harvesting. Damaged young trees are capable of recovering by sprouting from dormant buds and bending upwards to form another erect stem. Additional planting and planting in denuded areas mostly succeeds well, provided the ecological conditions are suitable. Natural regeneration is often good, provided sufficient seed trees are left after harvesting.

In nurseries shade is neither advantageous nor harmful. Seedlings tend to be taller in shade and produce fewer roots.

Planting programmes often coincide with the fruiting season. Mature propagules that remain viable for 4–5 months are gathered from the forest floor. The planting procedure is simple, involving inserting the propagules vertically into the muddy soil along predetermined lines and spacings. In sites where attempts at planting had previously failed due to pest problems, planting nursery-raised seedlings and transplanting of wildings proved successful. Wildings are readily available, as natural regeneration is often profuse.

More intensive site preparation is required where flooding is limited due to large numbers of crab mounds and where there is severe infestation of *Acrostichum* ferns.

Husbandry In Peninsular Malaysia it takes 35 years for *R. apiculata* to reach a stem diameter of 19 cm at breast height. Judging by the greatest volume production of firewood, a 40-year rotation is preferable. Current rotations vary from 15 years (in firewood plantations in Thailand) to 20–30 years, but may be even shorter. Thinning is important for good stand development. Three thinnings are prescribed in Matang, Malaysia (at 15, 20, and 25 years of age), one thinning in Indonesia. In practice, thinning is irregular, incomplete and selective, and poorly accessible stands are often neglected. As thinning is a commercial operation, its timing, as well as the selection of tree species and stem diameter are influenced by market demand.

Diseases and pests Propagules of *Rhizophora* spp. are sometimes attacked by a scolytid beetle (*Poecilips fallax*). Occasionally, bagworms and larvae of the moth *Strelote lipara* cause localized defoliation of trees and seedlings. In some plantations, long-tailed macaques (*Macaca fascularis*) and grapsid crabs (*Sesarma* spp.) have been reported to be the major pests of newly planted propagules.

The ferns *Acrostichum aureum* L. and *A. speciosum* Willd. may occur throughout South-East Asia as a low, tufted ground cover under the canopy. With the opening of the canopy, the ferns may form up to 4 m tall, dense, continuous thickets, making it impossible for propagules of *Rhizophora* to enter the area. Large areas of formerly productive *Rhizophora* stands have been made unproductive in this way. Uprooting the ferns manually with iron bars or spraying with a herbicide can solve the problem, unless the inundation regime has changed. *Derris trifoliata* Loureiro can also be a serious strangling weed.

Harvesting Felling of *R. apiculata* for poles is essentially a thinning operation in which straight pole-sized individuals are cut. If cut at least 20 cm above the stilt roots, regeneration is without problems. The poles are carried out of the swamp. In Malaysia, stick thinning is practised. This process involves selecting a well-formed tree and felling all pole-sized trees around it within a radius drawn by a stick 1.2–1.8 m long. The system of final harvesting of trees for fuelwood varies between countries. Thailand and Indonesia adopt strip-felling, the Philippines and East Malaysia practise minimum diameter harvesting, while clear-felling has been traditionally carried out in Peninsular Malaysia. Minimum diameter for charcoal production varies from 20.5 cm in Sabah to 4 cm in Vietnam. Felled trees are bucked into billets of about 1 m long, and sometimes debarked before they are transported out of the swamp forest. In large concessions of 2000–4000 ha for wood chipping in Sabah, a diameter limit of 10.2 cm is used, provided that 100 seed trees per ha are left. Large concessions in Indonesia require felling of trees down to a stem diameter of 7 cm in 50 m wide strips interspaced with 20 m undisturbed strips in a proposed 20-year rotation. Thailand has prescribed the maintainance of a 10 m uncut strip along waterways to reduce the effects of waves and currents on regeneration.

Yield A stand of *R. apiculata* in southern Thailand had an annual leaf production of 7 t/ha and 20 t/ha of wood. Total aboveground dry matter has been estimated to be 160–190 t/ha in 15-year-old stands in Thailand and 257 t/ha in a 28-year-old stand in Peninsular Malaysia.

Genetic resources and breeding It is unlikely that any substantial germplasm collections of *R. apiculata* are being maintained. There are no known breeding programmes.

Prospects *Rhizophora* forests are being heavily exploited for fuelwood and poles. Recently, they have also been extensively harvested for woodchips or converted for agricultural and aquacultural purposes. Long-term, multiple-use management plans have to be developed and implemented to ensure sustainable use of the remaining resource. *R. apiculata*, being among the most easily regenerated and widely planted species, will play an important role in those sustainably managed systems.

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D. Hou & H.T. Chan

Samanea saman (Jacq.) Merrill

J. Wash. Acad. Sci. 6: 47 (1916).

LEGUMINOSAE – MIMOSOIDEAE

$2n = 26$, 14 also reported

Synonyms *Mimosa saman* Jacq. (1800–1809), *Pithecellobium saman* (Jacq.) Benth. (1844), *Enterolobium saman* (Jacq.) Prain (1897).

Vernacular names Rain tree, monkeypod, cow tamarind (En). Arbre de pluie, saman, zamang (Fr). Indonesia: trembesi, kayudan (Javanese), ki hujan (Sundanese). Malaysia: hujan-hujan, pukul lima (Peninsular Malaysia). Philippines: acacia. Cambodia: 'âmpül barang'. Laos: (do:k) sa:m sa:. Thailand: kampu, chamchuri (central), chamcha (northern). Vietnam: me t[aa]y.

Origin and geographic distribution *S. saman* is a native of northern tropical South America. It is now cultivated and naturalized throughout the tropics, including South-East Asia.

Uses *S. saman* is commonly grown as a shade tree and as ornamental. It has been planted as a shade tree in cocoa, coffee, vanilla, and in young nutmeg and teak plantations. It can be used as a hedge tree, if lopped heavily. In north-eastern Thailand, mature trees are highly valued as a host for the lac insect (*Laccifer lacca*). Green leaves of *S. saman* are a high quality feed for sheep, goats and cattle and are used as a supplement during the dry season. The sweet pods are nutritious and relished by ruminants and pigs, who also take advantage of the shade provided in pastures. Because of its prolific flowering, *S. saman* is also profitable for honey production.

The wood, which is not durable, produces a high quality timber for carving, furniture and panelling. It provides a good quality firewood and charcoal, although it produces much smoke, even when very dry. Where a market for wood carvings exists, it is too valuable to be used as firewood.

Production and international trade The production and trade of *S. saman* is mainly local and no statistics are available. The famous 'monkeypod' bowls from Hawaii are made of *S. saman* wood. As the wood is getting scarce, it is now imported in considerable quantities from Indonesia and the Philippines.

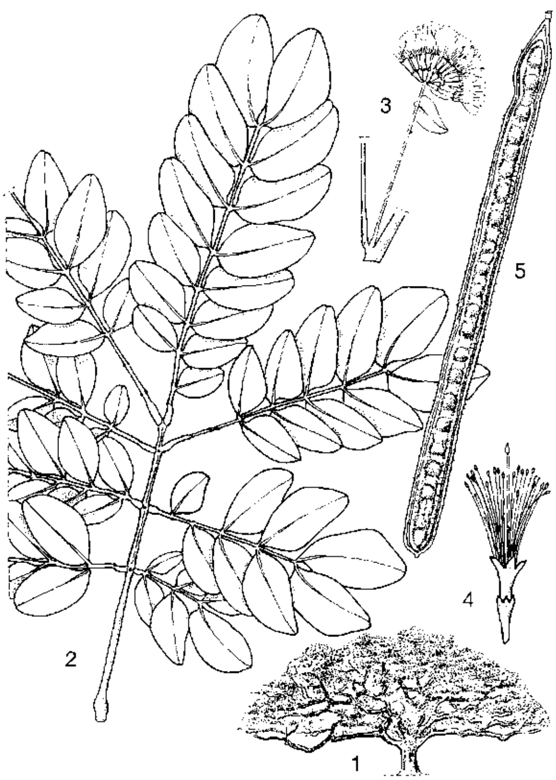
Properties Per 100 g dry matter the leaves and twigs of *S. saman* contain 22–27 g crude protein and 44–53 g neutral detergent fibre, the pods and seeds 12–18 g and 38 g respectively. The in vitro digestibility of the leaves is 58–68%, that of the pods is 40%. The mineral content of leaf litter per 100 g dry matter is: N 2.0 g, P 0.3 g, K 0.15 g, Ca 1.16 g, and Mg 0.01 g. Firewood has an energy value of 25 000–27 000 kJ/kg.

Dry leaves have the heavy scent of coumarin, reminiscent of newly mown hay. The bark lacks tannins, but yields an inferior gum. The bark and seeds contain a minor, saponin-like alkaloid, pithecolobine.

The heartwood of *S. saman* is dark walnut to dark chocolate-brown, turning to light brown or golden-brown with darker streaks when seasoned. The sapwood is whitish. The wood has a basic density at 12% moisture content of 550–700 kg/m^3 and is strong and hard. Shrinkage is extremely low and green wood can be carved out without risk of warping or splitting. It is resistant to dry wood termites.

The weight of 1000 seeds is 125–225 g.

Description A large, evergreen, unarmed tree, up to 25(–40) m tall at maturity with a trunk diameter at breast height up to 2 m, with wide-spreading crown up to 25–30 m in diameter. Bark finely fissured, light grey to greyish-brown. Branchlets puberulous to tomentose. Leaves bipinnate, not sensitive to the touch; stipules lanceolate, small, not spinescent, caducous; rachis up to 40 cm long; pinnae 3–9 pairs, up to 11 cm long; concave circular glands present just below the basal pair of pinnae, between all other pairs of pinnae, and at the junction of the leaflets; leaflets opposite, 2–10 pairs per pinna, oblique-ovate to elliptical or subrhomboid, 1.5–6 cm × 0.7–4 cm, apex obtuse-rounded, often emarginate, mucronate, base asymmetrical, upper surface glabrous, lower surface densely short pubescent, main vein diagonal, lateral veins forming a prominent, dense reticulate pattern. Inflorescence a corymb, 2–5 together in the axils of distal leaves; peduncle erect, 5–10 cm long, densely, shortly, yellowish pubescent; corymb with dimorphic flowers, consisting of a larger, 7–8-merous central flower, surrounded by smaller 5-merous marginal flowers; central flower up to 2.5 cm long, sessile, calyx broadly cylindrical, 8–9 mm × 4–5 mm, corolla up to 12 mm long, staminal tube longer than the corolla; marginal flowers up to 3.5 cm long, on short (3 mm) pedicels, calyx funnel-shaped, 5–7 mm long, tomentose or woolly, teeth broadly triangular, acute, 0.5–1 mm long, corolla funnel-shaped, about 10–12 mm long, distal part tomentose or woolly, red or yellowish-red, lobes triangular-ovate, about 2 mm long, stamens 20–35 mm long, white at the base, purple toward the top, tube shorter than corolla tube. Pod oblongoid, straight



Samanea saman (Jacq.) Merrill – 1, habit; 2, leaf; 3, inflorescence; 4, marginal flower; 5, pod.

or slightly curved, 15–20 cm × 1.5–2.3 cm, turgid with thickened margins, indehiscent, woody, black, about 15-seeded; crustaceous exocarp loosens from the pulpy, sweet mesocarp; endocarp woody, forming one-seeded chambers. Seed ellipsoid, strongly biconvex, 9 mm × 5 mm × 4 mm, brown with a distinct U-shaped pleurogram, shiny, not arillate, areole elliptical, 7 mm × 3 mm. Seedling with epigeal germination.

Growth and development *S. saman* grows slowly in the first year of planting, but is generally considered to be fast growing. The first two leaves are opposite or sub-opposite, subsequent leaves are arranged spirally. In Thailand, trees reached a height of 1.3 m, 11 months after planting, whereas in Indonesia the height increment was 0.7 m and the diameter increment 1.5 cm in the first 6 months after planting. On average planted stumps reached a height of 2 m, 7.5 months after planting. In a trial plantation in Papua New Guinea, *S. saman* planted at 2 m × 3 m distance attained an average height of 2.3 m and a diameter of 4.5 cm, 8 months after planting. Young trees often shed their leaves during the dry season.

In Thailand, mature trees flower twice a year, in February–May and in September–November. In Java, flowering is observed from August to April. Fruits mature 5.5–8 months after flowering.

S. saman forms N-fixing nodules with strains of *Bradyrhizobium*. In the Philippines, *S. saman* proved highly responsive to inoculation with vesicular-arbuscular mycorrhizae and the increase in biomass was 40% compared with uninoculated plants.

The abundance of epiphytic ferns and orchids on avenue rain trees, as observed in Peninsular Malaysia, is a striking phenomenon. The trees tend to have a large crown with wide-spreading branches and their branches can stretch right across roads. This habit, however, makes the tree unsuitable for smallholder woodlots.

Other botanical information The genus *Samanea* Merrill is closely related to *Albizia* Durazz. and distinction between the two genera is difficult. Some differences are: *Samanea*: central flower with 7–8 perianth segments (*Albizia* 5), fruits fleshy and internally segmented (*Albizia* fruits are not fleshy and usually not segmented inside). A thorough revision of the 2 genera might reveal that they should be united.

At night and during cloudy days the leaves of *S. saman* droop. The extrafloral nectaries excrete sugar-rich juice which sometimes drops from the tree like rain (hence rain tree). At flowering time abundant stamens drop like a shower from the tree canopy from time to time.

Ecology *S. saman* thrives in a wide range of climatic and soil conditions, from sea level up to 1000 m altitude. It is found in both monsoon and equatorial climates with an annual rainfall of 1000–2500 mm. It is not well adapted to climates with a pronounced dry season and withstands only 2–4 dry months. A lower rainfall (700 mm) is tolerated if evenly distributed throughout the year, as in Curaçao. It grows best in climates with a mean minimum temperature of the coldest month of 18–22°C and a mean maximum temperature of the hottest month of 24–30°C. *S. saman* is rarely found in forest stands and requires high light intensities.

Soil requirements range from moderately acidic to alkaline, pH 5.5–8.5. It grows well on clayey or sandy soils and withstands seasonal waterlogging.

Propagation and planting *S. saman* is commonly propagated by seed, but can also be propagated through stem and root cuttings. Pods can be collected from the ground. If left in a dark place, the valves are eaten by termites, while the clean seeds are left intact. Mature seed has a hard seed-coat and must be treated for even germination. To break dormancy the seed is immersed in hot water for 3 minutes and then soaked overnight in cool water. Passage through the intestines of herbivores also enhances germination. Germination of untreated seed increases in the course of the first year of storage. Seed sown in containers placed in full light generally have a germination rate of over 90%. Seedlings can be planted in the field after 6–8 weeks when they are 15–25 cm tall. They may be stumped with a root length of 40 cm, a shoot length of 20 cm, and a diameter of 0.5–3 cm. When grown for fodder, seedlings are spaced at 3 m × 1 m. Spacings of 4 m × 4–8 m are recommended for wood production. In the Philippines, *S. saman* is planted at 10 m × 10 m spacing in coffee plantations grown at 3 m × 3 m.

Husbandry *S. saman* planted on paddy bunds in north-eastern Thailand increased the organic matter content of the topsoil from 0.36% to 0.58% and the total soil nitrogen from 0.06% to 0.08%, while the pH increased from 4.8 to 5.8 under the trees. However, shading also caused a reduction in the yield of rice. In Malaysia, an increase in growth, yield and nutritive quality of the pasture grass *Axonopus compressus* (Swartz) P. Beauv. was observed when grown under *S. saman*. This is attributed to the higher N content of the soil and a beneficial micro-climate under the trees. Folding of the leaves and drooping branches allow rainfall to reach the grass directly during the night and on cloudy days (another reason for the name rain tree). On sunny days, the unfolded leaves provide shade and help to conserve moisture.

When planted in hedges trees should be maintained by heavy lopping. In north-eastern Thailand, *S. saman* is pollarded at 1 m height every six months for the production of fodder. Pollarding is also used for firewood production.

For lac production in north-eastern Thailand, lac insects are usually cultured on the trees during December and February. The lac can be harvested 12 months later. After harvesting, the trees are left uncut for at least 3 years before restarting the lac cultivation.

Diseases and pests A wound parasite, *Ganoderma lucidum* is reported from the Philippines. It may cause white soft rot in the lower part of the stem. A powdery mildew (*Erysiphe communis*) is very common in nurseries and may cause complete defoliation of seedlings. Two psyllid species attack *S. saman*, but rarely cause serious damage. The leucaena psyllid (*Heteropsylla cubana*) feeds on young shoots and in severe cases may cause defoliation, stunted shoot growth and eventually the death of the tree. *Psylla acacia-baileyanae* feeds on the shoots, often causing leaves and shoots to curl.

Yield Annual increment of wood is 10–15 m^3/ha when harvested 10–15-years after planting. Yields of lac depend on tree size, but annual amounts of 50–100 kg per tree have been obtained.

Genetic resources and breeding Neither substantial germplasm collections nor breeding programmes of *S. saman* are known to exist.

Prospects *S. saman* is a valuable multipurpose tree. It is easily raised and can grow under a wide range of environmental conditions. The slow initial growth is a disadvantage for wood or fodder production. The integration of lac production with firewood and timber production warrants further studies.

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R. Akkasaeng

Schleichera oleosa (Lour.) Oken

Allg. Naturgesch. Bot. 2: 1341 (1841).
SAPINDACEAE
$2n = 32$

Synonyms *Pistacia oleosa* Lour. (1790), *Schleichera trijuga* Willd. (1806), *Cussambium oleosum* O. Kuntze (1891).

Vernacular names Macassar oil tree, gum-lac tree, Ceylon oak (En). Qennettier-rose, pongro (Fr). Indonesia: kosambi (Javanese), kasambi (Sundanese). Malaysia: kusambi. Cambodia: pongro. Laos: (do:k) phen (Spire). Thailand: machok (northern), takhro (north-eastern). Vietnam: c[oj] ph[ef]n, c[aa]y van rao, pongro.

Origin and geographic distribution *S. oleosa* occurs naturally from the foothills of the Himalayas and the western Deccan to Sri Lanka and Indo-China. It was probably introduced to Malesia and has naturalized in Indonesia (Java, the Lesser Sunda Islands (Bali and Nusa Tenggara), Sulawesi, the Moluccas, Ceram and the Kai Islands). It is occasionally cultivated throughout the tropics, especially in India.

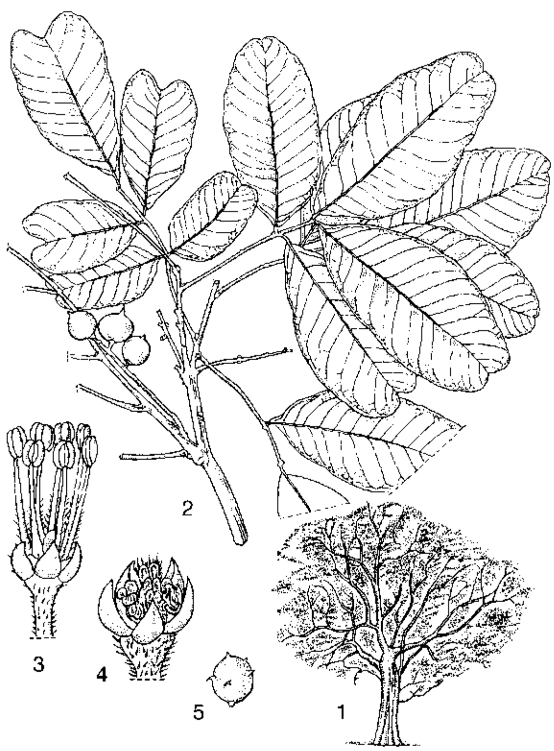
Uses *S. oleosa* has many important uses. The wood is suitable as firewood and makes excellent charcoal; the pinkish-brown heartwood is very hard and durable, excellent to make pestles, cartwheels, axles, ploughs, tool handles, and rollers of sugar mills and oil presses. Oil extracted from the seed, called 'kusum oil', is a valuable component of true Macassar oil used in hairdressing; it is also used for culinary and lighting purposes and in traditional medicine it is applied to cure itching, acne and other skin afflictions. Unguents are made of the harder fraction of the oil. In Madura and Java the oil is used in the batik industry, and in southern India as a cooling bath oil. The pleasantly acid arillodes of the ripe seeds are eaten, whereas immature fruit is pickled. Cooked young leaves make a side dish. Powdered seeds are applied to wounds and ulcers of cattle to remove maggots. A dye is obtained from the bark. The bark contains tannin and is astringent and used against skin inflammations and ulcers, while an infusion is taken against malaria. It used to be utilised occasionally for tanning leather. Leaves, twigs and seed-cake are used to feed cattle. In India *S. oleosa* is used as host for the lac insect (*Laccifer lacca*). The product is called kusum lac and is the best in quality and in yield. In Central India, *S. oleosa* is much planted as a wayside tree.

Properties The energy value of the wood is about 20 800 kJ/kg. The oil content of the kernel varies from 59–72%. The oil is yellowish-brown and semi-solid and consists of oleic acid (52%), arachidic acid (20%), stearic acid (10%), gadoleic acid (9%). It also contains cyanogenic compounds, which may cause giddiness and should be removed if the oil is used for human consumption. The press cake contains per 100 g approximately: water 5.5 g, protein 22 g, fat 49 g, carbohydrates 14 g, fibre 5 g, ash 3.5 g.

The leaves contain per 100 g dry matter approximately: crude protein 10.5 g, ether extract 2 g, N-free extract 49 g, crude fibre 32.5 g. The bark contains about 10% tannin and the analgesic compound lupeol and the antitumour agents betulin and betulic acid have been isolated from it.

The heartwood of *S. oleosa* is pinkish-brown, very hard and durable, but cracks very easily during seasoning. To avoid cracking, logs should be sawn when green and the sawn timber closely stacked; the piles should be protected from the sun and from drying wind. The wood can be kiln-dried satisfactorily. The wood is very durable under cover, but not durable when exposed. It takes preservatives well. Dry wood is very hard to saw, it can be planed to a very smooth surface which takes a high, lasting polish. The weight of 1000 seeds is 500–700 g.

Description Dioecious, deciduous tree, up to 40 m tall. Bole occasionally up to 2 m in diameter, but generally much less, usually crooked and slightly buttressed. Bark smooth, grey. Branches terete, striate, with sparse, short fulvous sericeous hairs when young and with sessile glands, black, later yellowish-brown to ashy. Leaves paripinnate, (2–)3(–4)-jugate, the topmost leaflet sometimes situated like a terminal leaflet; axial parts usually early glabrescent; petiole terete to somewhat flattened or slightly grooved above, 2–6(–8) cm long, pulvinate; rachis terete to triangular; petiolule swollen, slightly grooved above, 1–3 mm long; leaflets elliptical to obovate, 4.5–18.5(–25) cm × 2.5–9 cm, chartaceous to coriaceous, dark brown or greyish-green above, lighter brown to greenish beneath, deep purple when young, base subacute to cuneate, often oblique, margin entire to repandous, apex obtuse or emarginate, sometimes shortly acuminate, veins in 12–15 pairs, looped and joined near the margin.



Schleichera oleosa (Lour.) Oken – 1, habit; 2, fruiting branch; 3, male flower; 4, female flower; 5, spiny fruit.

Inflorescence 6–15 cm long, situated in the defoliated part of branchlets above leaf scars, sometimes axillary, consisting of a few simple (female) or sparsely branched (male) thyrses, the basal part with scattered, many-flowered fascicles, the upper part spicate, sparsely hairy; flowers functionally unisexual, pale yellow or pale green; pedicel up to 5 mm long; sepals 4–5, connate at base, lobes ovate to deltoid, about 1.5 mm long, obtuse to acute, with thin hairs on both sides, margin ciliate and sometimes glandular, deciduous in fruit; disk uninterrupted, patelliform, sinuate; petals absent; stamens 5–9, filaments about 2 mm long, sparsely hairy, much reduced in female flowers; ovary ovoid, slightly 3-angular and indistinctly 3-sulcate, about 1.3 mm long, style rather thick, up to 1.5 mm long, pistil much reduced in male flowers. Fruit a broadly ovoid, ellipsoid to subglobular berry, 1–2-seeded, 1.5–2.5 cm × 1–2 cm, base narrowed, apex pointed, yellow, hard-crustaceous, smooth or slightly spiny. Seed subglobular, about 12 mm × 10 mm × 8 mm, hilum orbicular, testa brown, smooth, glabrous; arillode completely covering the seed, thin papery, yellow.

Growth and development *S. oleosa* is deciduous, but completely leafless for a few days only. In India, leaves drop in December. It flowers at the beginning of the dry season and fruits about 6 months later. *S. oleosa* produces root suckers freely and pollards well. In cultivation, it does not stand heavy pruning, since growth is rather slow. In Bihar (India), trees grow to a height of about 7 m and a stem diameter of 10 cm in 16 years; in Uttar Pradesh (India) coppice shoots reach a height of 2 m in 1 year, in South Kanara (India) 5 m in 3 years.

Ecology *S. oleosa* requires 750–2500 mm annual rainfall and a dry season, which explains its absence from western Malesia. It tolerates absolute maximum temperatures of 35–47.5°C and absolute minimum temperatures of –2.5°C. In Java, it occurs usually at low altitudes, but can be found up to 900(–1200) m. It occurs spontaneously in dry, mixed deciduous forest and savanna with only scattered trees, sometimes gregariously. In Java, it is found in areas with natural teak forest. It grows on rather dry to occasionally swampy locations on various, often rocky, gravelly or loamy, well drained, preferably slightly acid soils. *S. oleosa* is fire-resistant. Seedlings are frost sensitive and light-demanding.

Propagation and planting Natural regeneration is by seed and root suckers. Seed can be stored in gunny bags for 1 year, in sealed containers for up to 2 years. Propagation is by direct sowing in thoroughly prepared soil or by stump planting. In nurseries in West Bengal (India), seed is sown 7.5 cm apart immediately after collection. Stumps are prepared after one year, when the seedling stem is about 1 cm in diameter. The stem is cut back to about 4 cm, the roots to 25 cm. Plant holes should be about 30 cm deep and wide. Regular weeding and protection from grazing is required.

Husbandry When *S. oleosa* is employed as a host for lac insects in northern India, trees are inoculated early in the rainy season (June–July) or in January–February. Shoots of 4–10 months old are most suitable for larval settlement. Lac is harvested after about 6 months. Only trees with a fully developed crown produce a good yield of lac. Trees can be improved by heavy pollarding. Trees should be rested for 12–18 months before being reinoculated.

Diseases and pests Stem blight (*Rosellinia bunodes*), yellow cork rot (*Polyporus weberianus*), white spongy rot (*Daedalea flavida* and *Hexago-*

nia apiaria) and white fibrous rot (*Irpex flavus*) are important diseases in India. Several defoliators, borers and sap suckers cause damage. The seed is attacked by a bug (*Serinetha augur*).

Yield In India, a mature tree yields 21–28 kg depulped seed per year.

Handling after harvest For depulping, fruits are kept in heaps for 2–4 days and are then rubbed clean. After crushing the depulped seed, the oil is extracted by boiling or pressing. The oil yield obtained by boiling is 32–35% of the kernel weight, by pressing 25–27%.
Raw lac is harvested with the branches as sticklac. It is washed, dried and winnowed to yield a granular substance called seed-lac.

Prospects Where wild *S. oleosa* occurs abundantly, it remains important as a fuelwood, but its growth is too slow to be planted for fuel. Where seed is available in large amounts, pressing and refining of oil combined with the manufacturing of seed cake as cattle feed may be viable, although the quantity currently processed is well below its potential. As a host of the lac insect, *S. oleosa* is preferable to other hosts. Depending on demand for natural lac, it may be useful in village industry.

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S. Iwasa

Senna didymobotrya (Fresenius) Irwin & Barneby

Mem. New York Bot. Garden 35: 467 (1982).
LEGUMINOSAE – CAESALPINIOIDEAE
$2n = 28$

Synonyms *Cassia didymobotrya* Fresenius (1839), *C. verdickii* de Wildeman (1900), *C. nairob(i)ensis* L.H. Bailey (1941).

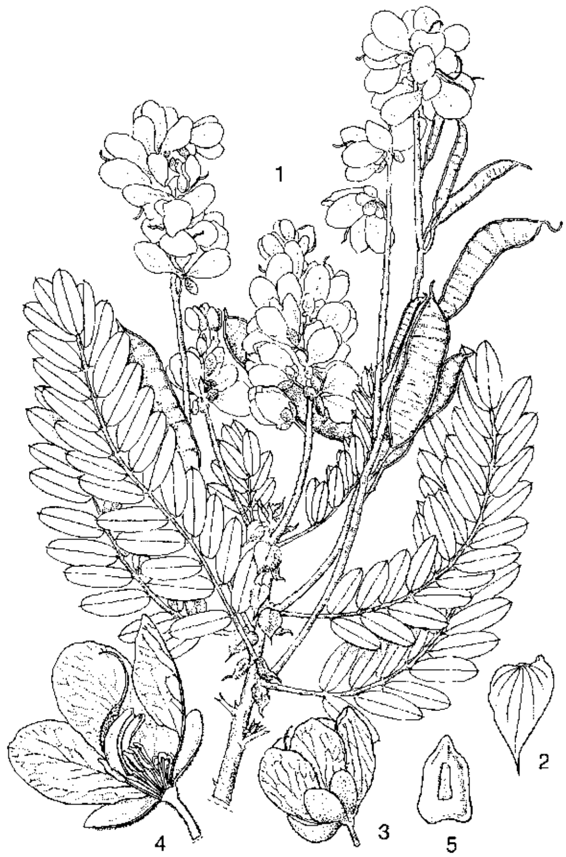
Vernacular names Candelabra tree, wild senna (En). African wild sensitive plant (Am).

Origin and geographic distribution *S. didymobotrya* is a native of tropical East and Central Africa, from Ethiopia and Sudan to Angola and Mozambique. It was introduced into tropical Asia and America as a green manure and cover crop, and later as an ornamental. It sporadically naturalized in frostless regions, including Malesia. It is now grown throughout the world as an ornamental.

Uses *S. didymobotrya* was introduced as a cover crop and green manure in India, Sri Lanka, Peninsular Malaysia and Java and has been used as a shade tree in tea plantations. In sites where *Erythrina* spp. do not grow well, *S. didymobotrya* may be a valuable substitute. It is now also popular as an ornamental plant owing to its bright yellow flowers and black-green bracts.
In Africa, *S. didymobotrya* is commonly used as a stupefacient poison for fishing and as ornamental plant. Medicinally, it is widely used as a purgative and an anti-malaria medicine. A decoction of the leaves is used against stomach complaints.

Properties The aboveground biomass of *S. didymobotrya* grown as ground cover in Sri Lanka was found to contain 0.7 g N per 100 g fresh material. Leaves and roots contain a number of anthraquinones, choline, and the trisaccharide raffinose. In vitro cultures of *S. didymobotrya* produced chemical compounds that can be converted into low-energy sweeteners and insecticides. When in flower or bruised, the plant emits an unpleasant smell said to be very reminiscent of mice.

Botany Usually a several-stemmed shrub or small tree, 0.5–5(–9) m tall. Branches terete, striate, pubescent to villous, rarely subglabrous. Leaves simply paripinnate, narrowly oblong-elliptical in outline, 10–50 cm long; stipules broadly ovate-cordate, 6–17 mm × 8–10 mm, acuminate, palmately veined, reflexed, tardily caducous; petiole terete, 1–8 cm long, rachis up to 40 cm long, both pubescent and eglandular; petiolules up to 3 mm long; leaflets in 8–18 pairs, chartaceous, elliptical-oblong, 2–6.5 cm × 0.5–2.5 cm, 2–3 times



Senna didymobotrya (Fresenius) Irwin & Barneby – 1, flowering and fruiting branch; 2, stipule; 3, side view of flower; 4, longitudinal section through flower; 5, seed.

longer than wide, base oblique, apex rounded but mucronate, pubescent to glabrescent, marginal veins distinct. Inflorescence an erect, axillary, 20–30-flowered, spike-like raceme, 10–50 cm long; peduncle terete, 5–8 cm long, pubescent; bracts broadly ovate, 8–27 mm × 5–15 mm, black-green, at first imbricate and enclosing the flower buds; bracteoles absent; pedicel slender, 3–10 mm long, densely pubescent; sepals 5, subequal, oblong-obovate, 9–14 mm long, puberulous, green; petals 5, slightly unequal, at first incurved, later on more spreading, ovate to obovate, 17–27 mm × 10–16 mm, with a slender, about 1 mm long claw, glabrous, bright yellow, delicately veined; stamens 10, filaments shorter than anthers, anthers of 2 lower stamens 9–11 mm long, 3 upper stamens staminodial, anthers of 5 median stamens about 5 mm long; ovary and stipe velvety pubescent; style slender, glabrous, recurved, about 1 cm long; stigma punctiform. Fruit a flat, 9–16-seeded pod, linear-oblong, 7–12 cm × 1.5–2.5 cm, glabrescent, short beaked, dehiscent or indehiscent when dry, depressed between the seeds, sutures raised, blackish-brown. Seed flattened, oblongoid, apiculate, 8–9 mm × 4–5 mm × 2.5 mm, smooth, pale brown; areole elliptical, 3–4 mm × 0.7–1.5 mm.

Juvenile stems tend to be somewhat tender and should be staked. When growth is very rapid, plants are apt to become straggly. *S. didymobotrya* withstands lopping well. It flowers profusely twice a year; in temperate regions it flowers throughout the summer. The bracts, stipules and indumentum of *S. didymobotrya* are quite variable. In the axil of the leaves an abortive inflorescence is often present.

In the older literature, this species is best known as *Cassia didymobotrya*. Until the beginning of the 1980s, *Cassia* L. was considered to be a genus with over 500 species. The large genus *Cassia* L. emend. Gaertner has now been subdivided into 3 genera: *Cassia* (trees, some filaments curved, bracteoles present, no areoles on seed), *Senna* Miller (herbs, shrubs or trees, all filaments straight, bracteoles absent, areoles on seed) and *Chamaecrista* Moench (herbs or shrubs, all filaments straight, bracteoles present, no areoles on seed). *Cassia* now has about 30 species, *Senna* and *Chamaecrista* comprise about equal numbers of species.

Ecology In its natural habitat *S. didymobotrya* is often ruderal in riparian montane wooded grassland or evergreen bushland, at 900–2400 m altitude. It tolerates light frost.

Agronomy *S. didymobotrya* is easily propagated by seed; cuttings are said not to be successful. The seed may be sown in the nursery or directly in the field. When planted as a small shade tree in tea it is spaced at about 5 m × 5 m.

The plants can be lopped several times per year to provide green manure. Lopping is preferably done when the plants are in flower, when the nutrient content in the leaves is high. The plant yields a fairly large amount of loppings. About 5 t of green material provides 35.5 kg nitrogen. In temperate areas, potted ornamental plants are overwintered in greenhouses.

S. didymobotrya is hardy and quite free from diseases and pests.

Prospects *S. didymobotrya* used to be a ground cover and green manure crop, appreciated mainly as an alternative plant in locations where *Erythrina* spp. did not flourish. It has now been largely replaced as a green manure crop by species such as *Tephrosia candida* (Roxb.) DC., *T. purpurea* (L.) Pers. and *T. vogelii* Hooker f. Its potential as an ornamental pot plant is being developed.

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B. Sunarno

Senna hirsuta (L.) Irwin & Barneby

Phytologia 44 (7): 499 (1979).

LEGUMINOSAE – CAESALPINIOIDEAE

$2n = 28, 56$; $2n = 16 + 1B$ is reported from Nigeria

Synonyms *Cassia hirsuta* L. (1753), *C. leptocarpa* Benth. (1849).

Vernacular names Woolly wild sensitive plant (En). Indonesia: kasingsat bulu (general), kasingsat (Sundanese). Malaysia: sinteng, kacang kayu. Philippines: balbala tuñgan, katanda, tighiman (Tagalog). Thailand: phong pheng (northern), dapphit (peninsular). Vietnam: mu[oof]ng r[uwf]ng.

Origin and geographic distribution *S. hirsuta* is a native of tropical America and is now distributed throughout Malesia, Indo-China, Thailand and most other countries in the Asian and African tropics. In Java, where it has long been known and has naturalized, it is more common in West Java than towards the east.

Uses *S. hirsuta* is used as a green manure and forage plant. In Africa it is planted as a shade plant in young coffee plantations. The leaves and young pods are eaten, usually steamed or cooked in vegetable dishes or in salads. The unpleasant smell can be reduced by relatively long cooking. In Java the leaves are used medicinally for treating herpes. A decoction of the leaves is used against irritations of the skin in Thailand. In Laos the seeds are used as a substitute for coffee.

Production and international trade *S. hirsuta* is very occasionally sold in village markets, but there are no production data.

Properties The seed contains a water-soluble gum, though not in commercial quantities; it also contains a bi-anthraquinone and a tri-terpenoid, which may prove medicinally important. The weight of 1000 seeds is 4 g.

Botany Erect or diffuse, simple or several-stemmed herb, up to 2.5 m tall, becoming soft-woody with age, with a fetid smell, hairy but highly diverse in pubescence; twigs grooved and ribbed, densely hairy. Leaves simply paripinnate, 10–20 cm long; stipules linear-acute, 3–15 mm long, usually not persisting; petiole stout, up to 6.5 cm long, villose, above the insertion with a sessile, oblong gland; rachis 3–16 cm long, glandless;

Senna hirsuta (L.) Irwin & Barneby – 1, flowering and fruiting branch; 2, leaflet; 3, part of branch; 4, flower with sepals and petals removed; 5, pod.

petiolules up to 3.5 mm long, slender, villose, often not quite opposite; leaflets 2–8 pairs, strongly accrescent distally, chartaceous, lanceolate-acuminate, 2–12.5 cm × 1–5 cm, 2–6 times as long as wide, slightly unequal-sided, base acute or rounded, dark green, roughly villose on both surfaces. Inflorescence an axillary or rarely terminal, 2–8-flowered raceme (up to 45 in South America), 1(–8) cm long, aggregate in leafy panicles; peduncle up to 3 cm long; bracts linear to lanceolate, 1.5–5 mm long, early caducous; bracteoles absent; pedicel 1–2.5 cm long, pubescent; sepals 5, unequal, 2 outer ones small, orbicular, 4–7 mm long, hairy, 3 inner ones larger, 7–10 mm long, partly glabrous; petals 5, unequal, obovate, 8–28 m long, yellow, glabrous, short-clawed; stamens 10, 2 large with flat filaments 4–7 mm long and curved anthers 7–8 mm long opening by apical pores, 4 smaller and 4 staminodial; ovary woolly, recurved; style short, glabrous with hairy subapical stigma. Fruit a falcate to straight angular pod, 6–28 cm × 3–7 mm, septate, 50–90-seeded, strigose. Seed slightly compressed, orbicular, about 3 mm in diameter, dark olive coloured; areole narrowly elliptical, 0.5–2.5 mm long.

S. hirsuta is very variable and 7 varieties have been distinguished for South America. In South-East Asia, 2 varieties occur: var. *hirsuta* (widespread as a weed in South-East Asia and the rest of the Old World tropics; fruit straight, 11–15 cm × 4–6.5 mm, bristly-hirsute) and var. *puberula* Irwin & Barneby (widespread in South America, but in South-East Asia only present in the Philippines as a weed, fruit simply arched outward, 15–25 cm × 3–6 mm). In South-East Asia *S. hirsuta* flowers throughout the year. The usually numerous fruits are curved when young and straight when mature; they are characterized by somewhat raised, glabrescent sutures and woolly strigose sides.

The synonymous name *Cassia hirsuta* is still commonly used in the literature. Until the beginning of the 1980s, *Cassia* L. was considered to be a genus with over 500 species. The large genus *Cassia* L. emend. Gaertner has now been subdivided into 3 genera: *Cassia* (trees, some filaments curved, bracteoles present, no areoles on seed), *Senna* Miller (herbs, shrubs or trees, all filaments straight, bracteoles absent, areoles on seed) and *Chamaecrista* Moench (herbs or shrubs, all filaments straight, bracteoles present, no areoles on seed). *Cassia* now has about 30 species, *Senna* and *Chamaecrista* comprise about equal numbers of species.

Ecology In South-East Asia *S. hirsuta* is found in plains and hilly areas up to about 700 m altitude. It grows spontaneously in waste locations, along roadsides, railway embankments, dry ditches and in secondary forest. It is found in gardens and fields as a weed and prefers open locations.

Agronomy *S. hirsuta* is propagated by seed. As a green manure *S. hirsuta* is fast growing, easy to cut, coppices well and can produce considerable amounts of foliage material in a growth cycle of 8 months. Observations in Central Africa indicate that it competes poorly with weeds. It is very susceptible to *Corticium salmonicolor* and is also affected by a root disease (*Rosellina* sp.), and by *Sclerotium rolfsii*.

Prospects *S. hirsuta* is one of the *Senna* species which has been proposed as a green manure crop. However, research has so far not confirmed its potential for green manure, pasture, or forage.

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H. Sangat-Roemantyo

Senna siamea (Lamk) Irwin & Barneby

Mem. New York Bot. Garden 35: 98 (1982).

LEGUMINOSAE – CAESALPINIOIDEAE

$2n = 28$

Synonyms *Cassia siamea* Lamk (1785), *C. florida* Vahl (1794), *Senna sumatrana* (Roxb. ex Hornem.) Roxb. (1832).

Vernacular names Siamese senna, kassod tree, Thailand shower (En). Indonesia: johar (general), bujuk, dulang (Sumatra). Malaysia: johor, sebusok, guah hitam. Philippines: robles. Cambodia: 'ângkanh'. Laos: 'khi:z hlek. Thailand: khilek (general), khilek-luang (northern), khilek-yai (central). Vietnam: c[aa]y mu[oof]ng den, mu[oof]ng xi[ee]m, humbo (Thuân Hai).

Origin and geographic distribution *S. siamea* is native to South and South-East Asia, from Thailand and Burma (Myanmar) to southern India and Sri Lanka. However, it has been cultivated for so long, that its exact origin is unknown. It is widely planted throughout the tropics and is locally naturalized.

Uses *S. siamea* is grown as a shade tree along roads and in coffee and tea plantations and is often planted as an ornamental. There is increasing interest in its use as a source of mulch, especially in alley-cropping systems. In drier regions such as northern India it is planted as a wind-break and shelter-belt, while in other tropical regions it is used extensively for rehabilitation of degraded lands. It is also used to revegetate aluminium mine tailings (red mud).

In Thailand and Indo-China, young fruits and leaves are eaten as a vegetable. During preparation, the cooking liquid is replaced three times to remove toxins. The flowers and young leaves are used in curries in Sri Lanka.

S. siamea is not widely grown for fodder, but the trees are browsed and plantations should be protected from livestock and wildlife. In Bangladesh, browsing by deer caused a 70% reduction in growth in the first year in unfenced plots. The alkaloids and other secondary plant compounds in the leaves, flowers and pods of *S. siamea* are highly toxic to non-ruminants, like pigs and poultry, and these animals should be excluded from plantations. Caution should be exercised when feeding the leaves to ruminants, since little is known about the long-term effects. *S. siamea* is used as a host plant for the lac insect in China, while in India it is used as a host for sandalwood (*Santalum* sp.), a parasitic tree producing the well-known aromatic wood.

The oil from the seeds is a minor source of vernolic and cyclopropenoid fatty acids. The dark heartwood is used for joinery, inlaying, handles, sticks and other decorative uses. The wood has also been used for posts, poles, bridges, mine poles, beams and produces excellent firewood and charcoal. Large plantations of *S. siamea* were established in Ghana, Nigeria and Sierra Leone in the 1920s mainly for this purpose.

All parts of the plant can be used for tanning. In traditional medicine, the root is used to charm away intestinal worms and to prevent convulsions in children. The heartwood is said to be laxative and in Cambodia a decoction is used against scabies.

Properties Leaves of *S. siamea* contain per 100 g dry matter approximately: N 1.7–3.0 g, P 0.1–0.2 g, K 0.5–1.2(–1.9) g, Ca 1.6–2.8 g, Mg 0.2–0.25 g, Na 0.02 g, S 0.2 g, polyphenols 1.5 g, cellulose 18 g, lignin 6.6 g, and hemicellulose 22 g. Annual leaf fall of *S. siamea* as high as 6.1 t/ha has been reported, providing per ha: 113 kg N, 40 kg K, 91 kg Ca, and 13 kg Mg. Per 100 g dry matter, neutral detergent fibre and acid detergent fibre contents were 42 g and 40 g, respectively, the ash content was 5.2 g, lignin 23 g. In vitro dry matter digestibility has been measured at 62–65%, which is consistent with the relatively low fibre content. The leaves and other plant parts produce many chemicals: anthraquinones, anthrones, flavones, triterpenoids and alkaloids, including cassiadimine, a chromone alkaloid. Tannin is present in the bark (9%), leaves (17%) and fruits (7%). The dense, dark coloured wood of *S. siamea* makes good fuel, although it does produce some smoke when burning. The energy value of the wood is 22 400 kJ/kg, the density is 600–800 kg/m^3. The wood sometimes produces a yellow powder that may cause irritation to the skin.

The weight of 1000 seeds is 25–28 g.

Description Tree, 6–12(–30) m tall, with spreading branches forming a dense rounded crown. Bark almost smooth, grey, young shoots ribbed. Leaves simply paripinnate, oblong-elliptical in outline, 10–35 cm long; stipules subulate, 1 mm long, very early caducous; petiole terete but with a shallow ventral groove, 1.5–3.5 cm long, glandless; rachis 4.5–25 cm long, glandless; petiolule 2–4 mm long; leaflets in 4–16 pairs, subcoriaceous, oblong to ovate-oblong, 3–8 cm × 1–2.5 cm, 2–4 times as long as wide, base unequal-sided rounded to cuneate, apex rounded to retuse or blunt, often mucronate, glossy and glabrous above, dull and rough to delicately puberulous below. Inflorescence an erect, terminal, 10–60-flowered, leafy panicle, 15–60 cm long, composed of numerous dense corymbs up to 10 cm × 5–6 cm; peduncle robust, 5–7 cm long; bracts obovate in lower half, suddenly narrowing into a linear acute top 3–6 mm long, puberulous, early caducous; bracteoles absent; pedicel 2–3.5 cm long; sepals 5, unequal, rounded-ovate, 4–9 mm long, thick, pu-

Senna siamea (Lamk) Irwin & Barneby – 1, habit tree; 2, flowering and fruiting branch; 3, flower; 4, pods.

berulous, repanding-reflexed, long persistent; petals 5, orbicular-obovate, 1–2 cm long, yellow, glabrous, standard with 1–2 mm long claw; stamens 10, 3 lower ones with 6 mm long filaments and 5 mm long anthers, 3 upper ones staminodial, 4 meridian ones with 3–4 mm long filaments and 5 mm long anthers; ovary shortly tomentellous, style 4–5 mm long, stigma punctiform. Pod flattened, 20–30-seeded, 15–30 cm × 12–16 mm, alternately bulging and depressed in the centre, rim thick, glabrescent, dull, finally dehiscent. Seed very flat ovoid, 6.5–8 mm × 6 mm, light brown, glossy; areole oblong-elliptical, 3–4.5 mm × 1 mm.

Growth and development Mature seed germinates readily after scarification. The first leaves are 1-jugate. Early seedling growth can be quite slow in comparison to *Gliricidia sepium* (Jacq.) Kunth ex Walp. and *Leucaena leucocephala* (Lamk) de Wit, growing to only 29 cm in 8 weeks after planting. After this early phase, growth may be quite rapid. Trees show Scarrone's architectural model, with an indeterminate trunk bearing tiers of orthotropic branches, which branch sympodially as a result of terminal flowering. Once established, flowering is precocious and abundant throughout the year. It starts flowering and fruiting at the age of 2–3 years. Fruits remain long on the tree. Unless carefully pruned, it ages ungracefully, the crown becoming straggling and misshapen with upright and drooping branches. In many species comparison trials, *S. siamea* has ranked in the top 2 or 3 with respect to biomass production in the first 2–3 years. In a test of 17 multipurpose tree species in southern Sumatra, *S. siamea* gave the highest leaf yield of up to 1200 g per plant per year. It also performed better than 16 other species tested in experiments in the highlands of Uganda, reaching a height of 8 m and a root collar diameter of 20 cm in 40 months.

The root system consists of a few thick roots, growing to considerable depth and a dense mat of rootlets in the top 10–20 cm of the soil, which may reach a distance of 7 m from the stem in 1 year and eventually a distance of up to 15 m.

As with many species of the subfamily *Caesalpinioideae*, *S. siamea* does not nodulate and does not fix nitrogen through *Rhizobium* symbiosis, although there is some evidence that nitrogen-fixing activity may occur in the warty, lenticellate bark. *S. siamea* forms ecto-mycorrhizae.

Other botanical information In older literature, this species is best known as *Cassia siamea*. Until the beginning of the 1980s, *Cassia* L. was considered to be a genus with over 500 species. The large genus *Cassia* L. emend. Gaertner has now been subdivided into 3 genera: *Cassia* (trees, some filaments curved, bracteoles present, no areoles on seed), *Senna* Miller (herbs, shrubs or trees, all filaments straight, bracteoles absent, areoles on seed) and *Chamaecrista* Moench (herbs or shrubs, all filaments straight, bracteoles present, no areoles on seed). *Cassia* now has about 30 species, *Senna* and *Chamaecrista* comprise about equal numbers of species. A chemotaxonomic study of 28 Indian species of *Senna* and *Cassia* revealed that the terpenoid lupeol (considered a primitive character), was present only in *S. siamea*, suggesting that it may be the ancestor of the modern sennas and cassias.

Ecology *S. siamea* will grow in a range of climatic conditions, but is particularly suited to the lowland tropics with a monsoon climate with a mean annual rainfall of 500–2800 mm with an optimum of about 1000 mm. Under semi-arid conditions (500–700 mm), *S. siamea* will grow only when its roots have access to groundwater. It requires a mean minimum temperature of 20°C, ranging from 14–28°C, and a mean maximum temperature of 31°C, ranging from 24–36°C. The maximum length of the dry period should not exceed 4–8 months. It is susceptible to cold and frost and does not do well at altitudes above 1300 m. Light requirements are high.

S. siamea performs best on deep, well-drained, fertile soils with pH 5.5–7.5, but will grow on degraded, lateritic soils provided drainage is not impeded. It grows poorly on infertile, poorly drained podzolic soils. It is not tolerant of salinity, but is reasonably tolerant of acid soil conditions.

Propagation and planting *S. siamea* is normally propagated by seed, and plantations are often established by direct seeding. Mature seed has a hard seed-coat and scarification is required. Immersion in concentrated sulphuric acid for 10–30 minutes has been shown to be very effective, although treatment with boiling water is normally sufficient. Using the first method seed germinates for about 90% within 60 days. Germination of untreated seed is about 75% in 4–29 days. Seedlings can be raised in polythene bags in nurseries using standard techniques. Seed should be sown in full light as the slightest shade reduces germination quite considerably. The seedlings are usually transplanted when 25–40 cm tall, about 8–12 weeks after germination. Plants taller than 40 cm should be trimmed before transplanting, to prevent excessive transpiration. Planting density varies according to use. In fuelwood plantations, spacings range from 1 m × 1(–3) m. In hedges used for alley cropping or as shelterbelt, spacing between plants in the row should be 25–50 cm. *S. siamea* can be propagated using tissue culture techniques, but this is not a common practice.

Husbandry The relatively slow-growing seedlings are susceptible to competition from weeds during early growth. *S. siamea* needs weeding for the first 1 or 2 years. Cultivation before sowing and the use of selective herbicides (such as fuazifop) helps to reduce weed competition. Alternatively, a broad spectrum herbicide such as glyphosate can be applied in a strip before planting *S. siamea* to kill grasses and weeds, which then tend to act as a mulch for the young seedlings planted in the centre of the strip.

Although not N-fixing, *S. siamea* has been increasingly used in alley-cropping systems, largely because of its coppicing ability and high biomass production. However, a number of studies have shown possible competition between *S. siamea* and associated crops. In Togo, maize yields in rows adjacent to *S. siamea* hedges were significantly reduced in the area where *S. siamea* roots dominated the top 0–30 cm of soil. The very extensive root system of *S. siamea* may prove a disadvantage in alley-cropping systems, unless it can be controlled by careful pruning.

The decomposition rate of the leaves is neither fast nor slow. In experiments in Nigeria and in Hawaii, mulching with *S. siamea* leaves caused initial N-immobilization during 4 weeks. Thereafter, a slight increase in soil mineral nitrogen was found, reaching levels comparable to *Leucaena leucocephala* and *Sesbania sesban* (L.) Merrill. Where a mulch is used to control erosion, *S. siamea* performs better than *Grevillea robusta* A. Cunn. ex R. Br. because its finer leaves retain water better and also better than *Gliricidia sepium*, which decomposes more quickly.

Diseases and pests No serious diseases or pests have been recorded for *S. siamea*, but minor damage has occurred in a number of locations. The fungus *Phaeolus manihotis* occasionally causes damage to the root system. In Indonesia, *Ganoderma lucidum* is locally a serious disease, causing wood rot on young plants. In Vietnam, the butterfly *Catopsylia crocale* is a serious pest, its larvae feeding on the foliage. The castor slug caterpillar *Parasa lepida* has been observed feeding on the leaves of *S. siamea* in India, while the caterpillar *Enerma blanda* has caused damage to the terminal buds in plantations in Sri Lanka.

Harvesting *S. siamea* is very tolerant of coppicing, lopping, or pollarding. Plantations can be harvested for fuelwood every 5–7 years, although shorter rotations are often practised in favourable environments. Where mulch or leaf production is the primary aim of a plantation, the first cut may be 12–18 months after sowing, followed by 3–4 cuts per year thereafter.

Yield Very high biomass yields can be achieved under favourable conditions. Under irrigation in Karnataka (India) *S. siamea* was the highest-yielding of 13 species with 55.6 t/ha per year. Unirrigated, its yield was 18.7 t/ha per year, second to *Acacia auriculiformis* A. Cunn. ex Benth. In lowland Nepal it was the most productive species tested, giving a mean annual increment for oven-dry fuelwood of 10 t/ha at 2.5 years of age. Total yields of wood for timber, poles and fuelwood may reach 10–15 m^3/ha per year.

Prospects *S. siamea* has long been cultivated for fuelwood in many tropical countries. It was the most widely used plantation species in Africa in the 1920s and is still highly regarded as a fuelwood because it grows rapidly, coppices well and produces small-size wood, easily handled by smallholder producers. It is worth trying *S. siamea* as a timber plantation tree. Recently, it has been utilized in sustainable production systems such as alley cropping, and this use will expand. Further studies are required to evaluate its potential as a fodder crop for ruminants. Its relatively high in vitro digestibility, high nutrient content and low fibre content suggest potential in this regard, if the problem of anti-nutritive secondary plant compounds can be overcome.

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R.C. Gutteridge

Sesbania Adanson

Fam. pl. 2: 326 (1763) (*Sesban*), corr. Scopoli, Intr.: 308 (1777), nom. cons.

LEGUMINOSAE – PAPILIONOIDEAE

$x = 6$; *S. bispinosa*: $2n = 12, 14, 24$; *S. cannabina*: $2n = 12$; *S. sericea*: $2n = 12, 24$

Major species and synonyms

- *Sesbania bispinosa* (Jacq.) W.F. Wight, U.S. Dept. Agr. Bur. Pl. Ind. Bull. 137: 15 (1909), synonyms: *Aeschynomene aculeata* Schreb. (1770), *A. bispinosa* Jacq. (1792), *Sesbania aculeata* (Willd.) Pers. (1807).
- *Sesbania cannabina* (Retz.) Poiret, Encycl. 7: 130 (1806), synonyms: *Aeschynomene cannabina* Retz. (1789), *Sesbania australis* F. Mueller (1855).
- *Sesbania rostrata* Bremek. & Oberm. - see separate article.
- *Sesbania sericea* (Willd.) Link, Enum. Hort. Berol. 2: 244 (1822), synonyms: *Coronilla sericea* Willd. (1809), *Sesbania pubescens* DC. (1825), *S. polyphylla* Miq. (1855).

Vernacular names General: Sesbania (En). Sesbane (Fr.)

- *S. bispinosa*: Prickly sesban, sesbania pea (Australia)(En). Laos: sanô: (general), sanô s'a:ngz (Louang Prabang), kho:ng kh'wa:y (Houa Phan). Thailand: sano-khangkhok (central). Vietnam: r[us]t (Hanoi, Thanh Hoa), (c[aa]y) di[eef]n di[eex]n, di[eef]n s[ooj]i.
- *S. cannabina* Yellow pea bush (Australia), dhaincha (India) (En). Sesbane chanvré (Fr). Malaysia: turi. Philippines: balakbak (Tagalog), ganai (Bisaya), rubau (Ilokano).
- *S. sericea*: Malaysia: turi. Vietnam: (c[aa]y) di[eef]n di[eef]n.

Origin and geographic distribution *Sesbania* comprises about 50 species and occurs throughout the tropics and subtropics; it is richest in Africa. *S. bispinosa* is widespread from Africa and Madagascar, through India and Pakistan to China and South-East Asia; although its origin is unknown it is thought to have been introduced in much of its range. *S. cannabina* occurs naturally in Australia, Papua New Guinea and eastern Indonesia. It is probably introduced in other areas of South-East Asia and in South Asia (from India up to Iraq) and is also cultivated in other tropical areas. *S. sericea* occurs in tropical Africa and southern Arabia, China, Indo-China, Thailand, Java and New Guinea. It was introduced into the West Indies and northern South America.

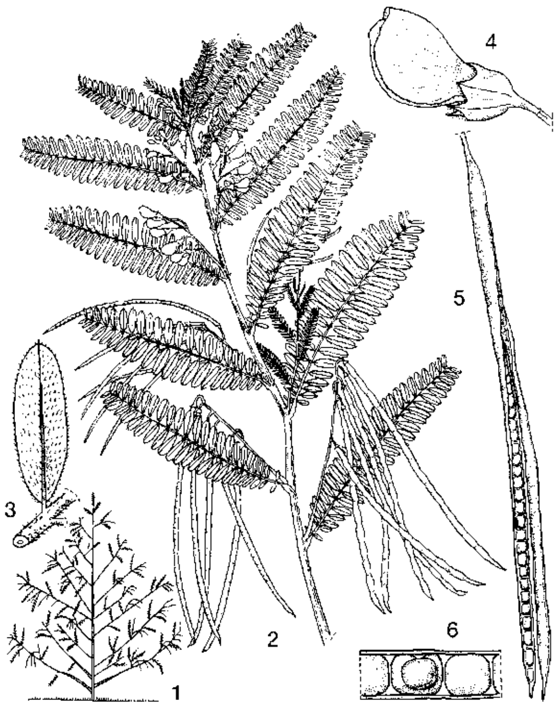
Uses Sesbania yields light, small sized firewood, while green branches and leaves are used as green manure in the production of food crops, especially rice. In north-eastern India, it is also widely grown as green manure in tea estates. Sesbania is planted as temporary shade and grown as hedges, it is also used as a wind-break. Shade plants and wind-breaks also provide seed for green manure crops. The stems of *S. bispinosa* and *S. cannabina* yield a phloem fibre used mainly in northern India as a substitute for sunn hemp (*Crotalaria juncea* L.) or jute (*Corchorus* spp.) in making ropes, cordage for fish nets, and sails; the fibre is also used in paper manufacture. The leaves are used as fodder. A galactomannan gum obtained from the seed is used as a substitute for gum from *Cyamopsis tetragonoloba* (L.) Taubert. In traditional medicine, seed mixed with flour is used for treatment of ringworm and other skin diseases and wounds.

Properties The green parts of *S. sericea* contain per 100 g approximately: water 82 g, crude protein 4.5 g, ether extract 0.7 g, N-free extract 6.8 g, crude fibre 4.3 g, ash 1.6 g, P 0.05 g, Ca 0.2 g. The composition of the seed approximates per 100 g: crude protein 35 g, ether extract 5 g, N-free extract 45 g, crude fibre 11 g, ash 5 g, P 0.6 g, Ca 0.4 g. The fibre is suitable for making paper. The endosperm of the seed contains per 100 g 25–30 g gum made up of galactose and mannose in the approximate proportion 1:1.5. It is water-soluble and produces a smooth, light coloured, coherent and elastic film used for sizing textiles and paper products and for thickening and stabilizing solutions.

Description Erect annual, or short-lived perennial, herbs or slightly woody shrubs or small trees, often producing a dark gummy juice when the bark is cut. Hairs simple, white or golden. Leaves paripinnate; leaflets often more than 10 pairs. Inflorescence an axillary or terminal raceme; bracts and bracteoles often early caducous; calyx campanulate with 5 subequal teeth; corolla glabrous, blue, mauve, white, red or orange, or more commonly yellow; standard usually streaked and spotted or continuously veined with purple, the claw with two vertical parallel or divergent variously shaped appendages; wings with transverse lamellate sculpturing, usually toothed or hooked at the base, the claw much shorter than the blade and than that of the keel; keel rounded below, rounded or broadly pointed at the tip, usually toothed at the base, shorter or slightly longer than the claw; stamens 10, diadelphous, vexillary stamen free, bent sharply near the base; pistil subglabrous; stigma small, globose or ovoid. Fruit a usually long pod, dehiscent, rostrate, usually stipitate, sometimes winged, transversely septate, up to 50-seeded. Seed usually ellipsoid or cylindrical, hilum often surrounded by a narrow rim-aril. Seedling with epigeal germination; first leaf entire.

– *S. bispinosa*. Herb, (0.6–)1–3 m tall. Stem terete, glabrous or sparsely pilose when young, usually aculeate. Leaves (5.5–)9.5–29.5(–35) cm long; stipules 5–11 mm long, pilose on margins and above, late caducous; petiole 2–20 mm long; leaflets in (10–)20–50(–55) pairs, oblong to oblong-linear, 0.75–2(–2.6) cm × 1.5–3(–5) mm, base obtuse, apex obtuse, emarginate, usually apiculate, glabrescent. Raceme (1–)2.5–15(–16.5) cm long, 1–12(–14)-flowered; peduncle (0.5–)1.5–4(–6) cm long, glabrous; calyx 3–4 mm × 3–4 mm, tube glabrous except for woolly margins, teeth triangular, 0.5–1 mm long; corolla yellow; standard rounded to obovate, 1–1.5 cm × 8–14 mm, pale yellowish, spotted brownish or purplish; wings oblong, 1–1.25 cm × 2.5–3 mm, yellow; keel straight, 1–1.3 cm × 3.5–5 mm; staminal tube up to 12 mm long, free filament parts 2–4 mm long; pistil glabrous, style 2–3 mm long, stigma capitate. Pod 28–45-seeded, curved, 12.5–25 cm × 2–3 mm, glabrous, constricted between the seeds. Seed ellipsoid, 3 mm × 1.5 mm × 1.2 mm, pale brown, olive-green or greenish-black.

– *S. cannabina*. Annual slender subshrub, up to 3.5 m tall. Stem terete, slightly striate, glabrescent. Leaves with 10–45 pairs of leaflets; stipules linear-lanceolate, up to 6 mm long, ciliate; petiole 3–15 mm long; rachis sparsely hairy; stipels subulate with gland-like tips; leaflets oblong-obtuse or truncate-apiculate or mucronate, 8–25 mm × 3–4 mm, glabrous or sparsely sericeous especially on prominent midrib on lower surface. Raceme about 6 cm long, 4–12-flowered; peduncle about 1 cm long; pedicel slender, shorter or a little longer than the calyx; calyx 3–5 mm long; corolla yellow or orange-yellow; standard transversely oblong-orbicular, 13 mm × 15 mm, conspicuously streaked on back, pale within, claw flat and short, not thickened; wings about as long as the standard; keel slightly shorter than the wings; pistil glabrous. Pod very slender, 12–20 cm × 2.5–4 mm, curved or almost straight, more or less torulose when young, hardly so when mature, olive-green to brown, with darker, transverse markings corresponding to the septa. Seed cylindrical, about 3 mm × 1.7 mm, dark brown, shiny.



Sesbania sericea (Willd.) Link – 1, habit; 2, flowering and fruiting branch; 3, leaflet; 4, flower; 5, pod; 6, seed in fruit.

– *S. sericea.* Herb or subshrub, 1–3 m tall, striate and pubescent throughout except for the flower and fruit, silky when young. Stem often with minute prickles hidden amongst the hairs but not obviously aculeate, exuding bluish, slightly milky juice after cutting. Leaves with 20–25 pairs of leaflets; stipules linear-lanceolate, up to 6 mm long, very early caducous; petiole 0.5–3 cm long; rachis 10–15 cm long; leaflets linear-oblong, up to 2 cm × 4 mm, rounded at apex, apiculate, entire. Raceme lax, axillary, 1–9 cm long, 2–7-flowered; peduncle up to 2 cm long, softly silky or pilose; pedicel 3–8 mm long, sparsely silky pilose; calyx 3–4 mm × 3 mm, tube glabrous, teeth triangular, up to 0,7 mm long; corolla yellow; standard elliptical, 6–9 mm × 8–10 mm, broader than long, pale cream, slightly flecked violet or purple; wings obovate, 5–9 mm × 3–4.5 mm; keel 7–8 mm × 4–6 mm. Pod 15–30-seeded, straight or slightly curved, up to 16 cm × 2.5–3.5 mm, not torulose, brown, glabrous. Seed 3 mm × 2 mm × 1.5 mm, brown to reddish-brown, with tiny blackish spots.

Growth and development Sesbanias are normally spreading shrubs, but in dense stands they are less branched. They grow very rapidly and may reach a height of over 3.5 m in 6 months, making them very competitive with weeds. Root nodules that effectively fix atmospheric nitrogen are formed with *Rhizobium*. Under waterlogged conditions, the submerged part of the stem forms a spongy mass of aerenchyma. Sesbania can produce a green manure crop in 2–3 months and a fuelwood crop in 5–6 months. Leaves of sesbania follow the direction of sunlight and fold at night. The flowers are mainly pollinated by bees. Ripe pods normally do not shatter and harvesting of seed can be delayed for several months, although pods will shatter eventually and may be damaged by insects.

Other botanical information The taxonomy of the 3 species treated here is very confused and in the agronomic literature it is often impossible to attribute information unequivocally to a single species. The differences between *S. bispinosa* and *S. cannabina* in particular are small and can mainly be found in the morphology of the keel. *S. cannabina* has sometimes been included in *S. bispinosa* and also in *S. sericea*. The variability of the 3 species is great, many varieties have been described, but often a clear distinction cannot be made. Only a thorough, worldwide revision of the genus might bring clarity.

In South-East Asia other *Sesbania* species occur with similar uses, e.g. *S. grandiflora* (L.) Poiret, *S. sesban* (L.) Merrill and *S. javanica* Miquel.

Ecology Most *Sesbania* species are found in seasonally wet habitats in the tropics and subtropics. *S. bispinosa* grows along waterways, in marshes, often on disturbed sandy soils, from sea level to 1100 m altitude, in areas with an annual rainfall of up to 1200 mm. *S. cannabina* grows in wet areas like river beds and irrigated rice fields, up to 50 m altitude. *S. sericea* is tolerant of high temperatures, at least up to 40°C, but does not tolerate even light frost. It is found up to 1250 m altitude, in Indo-China to 850 m. *S. sericea* grows best in locations with an annual rainfall of 500–2000 mm, is tolerant of waterlogging and also very tolerant of drought. It is adapted to clayey, moderately acid and alkaline soils. In trials in India, growth was retarded in soils with pH 5.6 and 9.3. Under irrigated conditions, sesbania, like rice, can tolerate fairly high concentrations of sodium (ESP ≥ 50).

Propagation and planting Sesbania is propagated by seed. No seed treatment is required for *S. bispinosa*, *S. cannabina* and *S. sericea*. When grown as sole crop for green manure, seed requirements per ha are about 90–100 kg when broadcast, or 20–60 kg when drilled in rows. Dense stands are used to obtain tender plants for green manure. When grown as a green manure for rice, several cropping systems are used, mainly depending on the availability of time and labour. When the growing season is long enough, sesbania is grown as a sole crop in rotation with rice. This method is the least labour intensive. When time interval between rice crops is short and sufficient labour is available, sesbania is either relay sown into the standing rice crop, or even sown in a nursery and transplanted. Relay sowing is reported from northern Vietnam and southern China, transplanting from southern China. When the time interval between rice crops is even shorter, sesbania may be grown as a cut and carry green manure on field bunds or outside the paddy fields. When the water level in the rice paddy is too high for relay sowing, mounds are made at a spacing of about 100 cm × 50 cm in between the rice rows with the tops of the mounds just emerging above the water. About 3–5 seeds are sown in these mounds 6 weeks before harvesting the rice crop.

Husbandry Because of its very fast growth, sesbania competes very well with weeds and may even suppress *Imperata cylindrica* (L.) Raeuschel on sites where moisture is adequate. In some areas, it is considered a weed. When grown for green manure, *S. sericea* is either grown in situ or in nearby fields, field bunds or waste areas to be transported and dug in the field. Decomposition of sesbania after ploughing in is rapid. As green manure it can be ploughed in just before transplanting rice. Delaying transplanting may result in a lower response to the green manure. Rice yields after a sesbania green manure crop ploughed in 60–70 days after planting are about equal to those obtained with application of about 80 kg N/ha of chemical fertilizer (on average 4.3 t/ha, compared with 3.3 t/ha without fertilizer or green manure). This is lower than has been obtained with *S. rostrata*. Sesbania is considered easier to grow than *Azolla pinnata* R. Br., but cultivated as an intercrop it competes more with the rice crop. In Vietnam, sesbania planted as a green manure crop is sometimes left to mature and produce firewood when the rains are inadequate to produce a rice crop. In Taiwan, *S. sericea* is grown in the interrows in banana plantations, and sown at the time of planting banana. The legume is later cut and spread out as a mulch to control weeds and used as green manure. In the foothills of the Himalayas in northern India, *S. sericea* is sown as a green manure in ginger (*Zingiber officinale* Roscoe) fields. They are progressively thinned from around the ginger plants to provide green manure or mulch, but a few plants, spaced 2–3 m apart are left to provide a light shade. Intercropping *S. sericea* with maize to provide green manure for a subsequent wheat crop has been tried in India. When sown simultaneously with the maize, *S. sericea* smothered the maize; delaying sowing *S. sericea* by 6 weeks did not depress the maize yield and boosted the following wheat yield by about 20–40%. In India, growing *S. sericea* is often combined with applications of gypsum to improve saline-sodic soils.

Diseases and pests Damage caused by diseases is generally of limited and local importance only. A number of insect pests affect the leaves and stems, but damage is mostly minor. References to seed pests are very few, although large amounts of seed are produced and stored in India.

Yield *S. sericea* can produce large amounts of organic matter in a short period. In Hawaii, several selections produced over 15 t dry matter per ha in 14 weeks, about half of it in stems. In India, sesbania grown as a sole crop produced 20–30 t/ha fresh above-ground biomass (4–6 t dry matter, containing 60–100 kg N) in 60 days. In the Philippines, the reported yields of sesbania in 60 days were even higher (7.8–9.9 t/ha of dry matter containing 170–225 kg N).

Handling after harvest To extract the fibre of *S. cannabina*, stems are submerged in water for about 25 days. When fully retted, the bast is removed manually and the fibre is cleaned and dried.

Genetic resources and breeding The Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia maintains the largest collection of *Sesbania* germplasm, including many accessions from Australia. Other collections are maintained at the International Rice Research Institute, Los Baños, the Philippines, and the Institut français de Recherche Scientifique pour le Développement en Coopération, Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Dakar, Senegal. A small collection is maintained in the United States at the Department of Agronomy and Soil Science, University of Hawaii and at the Southern Regional Plant Introduction Station, Griffin, Georgia. No breeding programme is known.

Prospects Sesbania deserves wider attention as a green manure and firewood crop. It grows very rapidly, is tolerant to adverse soil conditions, waterlogging and moisture stress. Plant biomass decomposes rapidly after being ploughed in. Although the wood is light, large quantities are produced in a very short time. A worldwide taxonomic revision is urgently needed.

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I.B. Ipor & L.P.A. Oyen

Sesbania rostrata Bremek. & Oberm.

Ann. Transvaal Mus. 16: 419 (1935).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 12$

Synonyms *Sesbania pachycarpa* DC. (1825) pro parte, *S. hirticalyx* Cronquist (1952).

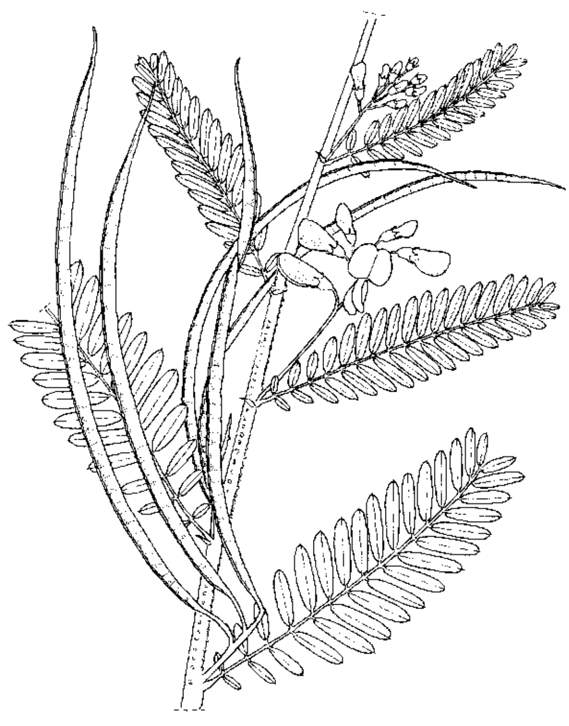
Vernacular names Sesbania (En).

Origin and geographic distribution *S. rostrata* occurs naturally throughout tropical Africa. It is cultivated, mainly on experimental scale, in West Africa and East and South-East Asia.

Uses *S. rostrata* is used as green manure in wetrice cultivation. It has also shown potential for incorporation in alley-cropping systems. It is suitable as a fodder for both ruminants and non-ruminants. The leaves are processed into leaf meal. Dry stems are used as fuel e.g. in Madagascar.

Properties The above-ground parts of 50 days old *S. rostrata* grown in northern India contained per 100 g dry matter: N 2.9 g, P 0.3 g, K 1.6 g, S 0.4 g.

Description Erect, robust, softly woody, non-aculeate annual or short-lived perennial, 1–3 m tall. Stem pithy, sparsely pilose, glabrescent, with vertical rows of pustules usually evident above the leaf axils and producing warty outgrowths on older stems, submerged portions clothed with matted fibrous roots. Leaves paripinnate, (4.5–)7–25 cm long; stipules linear-lanceolate, 5–10 mm long, reflexed, pilose, very persistent; petiole 3–8 mm long, pilose; rachis up to 19 cm long, sparsely pilose; stipels present at most petiolules; leaflets opposite, in (6–)12–24(–27) pairs, oblong, 0.9–3.5 cm × 2–10 mm, the basal pair usually smaller than the others, apex rounded to obtuse to slightly emarginate, margins entire, glabrous above, usually sparsely pilose on margins and midrib beneath. Inflorescence an axillary raceme, shorter than subtending leaf, 1–6 cm long, (1–)3–12(–15)-flowered; rachis pilose; peduncle 4–15 mm long, pilose; pedicel 4–15(–19) mm long, sparsely pilose; bracts and bracteoles linear-lanceolate, 5–8 mm long, sparsely pilose, caducous; calyx campanu-



Sesbania rostrata Bremek. & Oberm. – flowering and fruiting branch.

late, 5–7.5 mm × 4–5 mm, sparsely pilose, teeth 1–2 mm long, subulate, sparsely pilose; standard suborbicular, 12–16(–18) mm × 11–14(–15) mm, yellow or orange, speckled dark purple or reddish, apex emarginate, appendages with short, triangular, upward-pointing or slightly incurved, free tips, less than 1 mm long; wings 13–17 mm × 3.5–5 mm, yellow, a small triangular tooth and the upper margin of the basal half of the blade together characteristically inrolled; keel 12–17 mm × 6.5–9 mm, yellow to greenish, basal tooth short, triangular, slightly upward-pointing with small pocket below it on inside of the blade; stamens 10, vexillary stamen free, bent sharply near the base, staminal sheath longer than free parts of filaments, auricled; ovary sparsely pilose on upper margin or glabrous, style glabrous, stigma small. Pod in outline falcate, 15–22 cm × 3.5–5 mm, beak slender, up to 3.5 cm long, thicker at the centre than at the sutures, up to 50-seeded. Seed subcylindrical, 3–3.5 mm × 2.5–3 mm × 2–2.5 mm, brown, greenish or dark reddish-brown; hilum in a small, central, circular pit.

Growth and development Under favourable conditions, *S. rostrata* grows very fast, reaching a height of 2 m in 60 days, accumulating 8–11 t above-ground dry matter per ha.

S. rostrata nodulates with three groups of rhizobia. Stem nodules are formed following infection with strains of *Azorhizobium caulinodans* such as TCSR-1 and ORS-571. This symbiosis is highly specific. *A. caulinodans* differs from *Rhizobium* and *Bradyrhizobium* strains in its ability to fix atmospheric nitrogen as a free-living organism and is closely related to *Xanthobacter*. *A. caulinodans* may infect many *Sesbania* species, but forms an effective symbiosis almost exclusively with *S. rostrata*. A second group of rhizobia belongs to *Rhizobium* and forms root nodules only; it infects and fixes atmospheric nitrogen in symbiosis with many *Sesbania* species. The third group comprises a few strains of *Rhizobium* and forms effective stem and root nodules in *S. rostrata* and only root nodules in several *Sesbania* species. Information on the ability of *S. rostrata* to fix atmospheric nitrogen in the presence of soil nitrogen is conflicting. Some studies indicate that nodule numbers and N-fixation rate are only slightly reduced by soil nitrogen and N-fertilizer applications of up to 100 kg/ha. Other studies have found a reduction in the number of stem nodules proportional to the N-fertilizer gift, and no formation of root nodules. Acetylene reduction assays have indicated that the rate of nitrogen fixation of stem nodules was reduced to only 10% of the unfertilized control by an N-fertilizer application of 30 kg/ha, and to even lower levels with higher applications up to 60 kg/ha. Plant height and fresh weight, however, were highest with 30 kg N-fertilizer per ha.

S. rostrata is a quantitative short-day plant, with a critical photoperiod of 12–12.5 hours.

Other botanical information *S. rostrata* is one of the 3 taxa of *Sesbania* Adanson that form stem nodules, the others being *S. speciosa* Taubert from East Africa, cultivated and naturalized in Indonesia and New Guinea and *S. sesban* (L.) Merrill var. *punctata* (DC.) J.B. Gillett (synonym: *S. punctata* DC.) from tropical Africa.

Ecology *S. rostrata* occurs naturally in marshes, floodplains, on muddy river banks and the edges of pools, but has also been recorded in open savanna. It occurs up to 1600 m altitude and tolerates waterlogged soils and flooding to over 1 m deep. In cultivation, *S. rostrata* is almost always associated with wet rice.

Propagation and planting *S. rostrata* is mainly propagated by seed. Treatment of seed with concentrated sulphuric acid for 30 minutes improved the germination rate to more than 90%. Subsequently, treated seed should be washed with ample water to avoid overheating. Scrubbing seed with sand, or a hot water treatment are much less effective. Seed is broadcast, requiring 40–60 kg/ha. *S. rostrata* is either planted in rice paddies or on the bunds of rice fields and waste land near rice fields. Vegetative propagation by stem cuttings is possible, as the nodulation sites on the stems consist of adventive root primordia. Using of cuttings instead of seed results in a quick establishment of the crop and may double the N accumulation in a 6-week growth period, or reduce the growth period by 2 weeks.

It is only necessary to apply a solution of an appropriate *Rhizobium* strain in locations where *S. rostrata* has not been grown before. Spontaneous inoculation in the field is generally adequate for a high rate of nitrogen fixation. Although *Rhizobium* strains for stem inoculation are highly specific, they are easily established in the soil, as they can be transferred via the seed-coat. They show a high rate of survival under flooded and dry conditions. Natural infection of stems probably occurs through wind, rain splash and insects.

Husbandry Grown as a green manure crop, *S. rostrata* is allowed to grow for 45–65 days depending on its growth rate. When it is left to grow longer than about 55 days, the lignin content increases which decreases the decomposition rate of plant biomass. During the short-day season, it may be left to grow longer as it starts flowering early, resulting in a lower growth rate. The green manure crop is ploughed in just before the rice crop is sown or transplanted. Initial decomposition is rapid, with 30–45% of the leaf material decomposing in 10 days after incorporation. Decomposition then slows down considerably, reaching 50% after 35 days, while the half-life of stems and root-stubble is about 110 days.

When *S. rostrata* is grown for green manure, applying P and K fertilizers at the rate normally given to rice may increase nitrogen fixation by 30% and improve the availability of N, P and K to the subsequent rice crop.

At the International Rice Research Institute, Los Baños, the Philippines, the average rice grain yield was about 6 t/ha after incorporation of a *S. rostrata* crop grown for 45–60 days, which is the same as the yield obtained with urea applied at a rate of 50–60 kg N/ha. Under favourable conditions the amount of N accumulated in the green manure crop is about 100 kg/ha in 50 days and 160 kg/ha in 60 days. The residual effect of *Sesbania* green manure application on soil organic matter and N levels seems limited.

It has been proposed to plant *S. rostrata* on field bunds. Prunings of these plants would provide cuttings for vegetative propagation, or be a source of readily available green manure. These plants could also be a source of seed.

Diseases and pests The most common diseases affecting *S. rostrata* are damping-off caused by *Pythium* spp. and *Rhizoctonia* spp., leaf spot caused by *Cercospora* spp. and viral leaf mosaic. The root-knot nematode *Meloidogyne* attacks the root system. In dry conditions of the West African Sahel, nematode attack may be so serious that it is impossible to grow *S. rostrata*.

Genetic resources and breeding Germplasm collections of *Sesbania* are maintained at the International Rice Research Institute, Los Baños, the Philippines, by the Institut de Recherche Scientifique pour le Développement en Coopération, Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Dakar, Senegal, and by the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. A small number of accessions is maintained at the Southern Regional Plant Introduction Station, Griffin, Georgia, the United States. No breeding programme is known to exist.

Prospects Stem-nodulating legumes such as *S. rostrata* have a high potential as green manure in wet-rice production systems, because of their very fast growth and high rate of atmospheric nitrogen fixation, especially under wet conditions. Its tolerance of flooding gives *S. rostrata* a competitive advantage over most other legumes. Selection of cultivars resistant to diseases is urgently needed.

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I.B. Ipor

Sonneratia ovata Backer

Bull. jard. bot. Buitenzorg, Série 3, Vol. 2: 329 (1920).

SONNERATIACEAE

$2n = 22$

Synonyms *Sonneratia alba* auct., non J. Smith (1819).

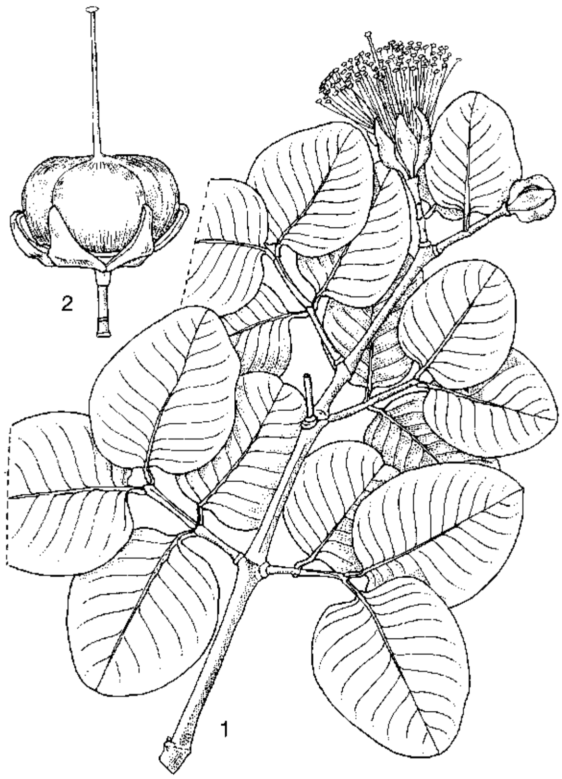
Vernacular names Sonneratia (En). Brunei: perapat. Indonesia: bogem (Palembang), kedabu (East Sumatra). Malaysia: gedabu (Peninsular Malaysia), (pedada) rogam (Sarawak). Cambodia: ampea, lapea. Thailand: lamphaen. Vietnam: b[aaf]n [oor]i, b[aaf]n h[oo]i.

Origin and geographic distribution *S. ovata* is found scattered in widely separate localities from China and Thailand through Peninsular Malaysia, the Riau Archipelago, Java, and Borneo, to Sulawesi, the Moluccas, and Daru Island and Milne Bay in New Guinea. References to its occurrence in Queensland and the Northern Territory in Australia have been disclaimed. It is locally numerous, but on the whole rather rare.

Uses The wood of *S. ovata* serves as firewood. As a timber it is of very limited value. *S. ovata* can be used to control erosion of tidal river banks. Like other *Sonneratia* spp., the bark contains tannin, but in amounts too small for commercial exploitation. The fruits are edible, though they taste very sour. Because of their acidity they are sometimes used as substitutes for vinegar. The fruit is also applied in poultices to relieve sprain. The fermented juice is believed to check haemorrhages.

Properties The wood of *S. ovata* has been described as moderately hard to very hard and moderately heavy to heavy. Its pulping qualities have yet to be tested; the wood of the related species *S. caseolaris* (L.) Engler can be pulped by a sulphate process to give a pulp with strength properties similar to commercial eucalypt pulp.
The wood of *Sonneratia* L.f. has retained many protomyrtalean characters. One primitive feature is the rudimentary presence of scalariform and reticulate perforation plates in the wood structure. Growth rings are distinct, mainly delimited by radially flattened fibres. Parenchyma is absent, fibres are septate, with 2–3 septa per fibre.

Botany Columnar tree, up to 2–5(–20) m tall, with stem up to 20 cm in diameter. Stem short and usually twisted, base not buttressed, surrounded by thin, pointed, pneumatophores about 20 cm long. Bark grey, smooth to slightly fissured, lenticellate, inner bark pale brown to reddish, faintly laminated, rather watery. Sapwood pale yellow, soft. Twigs distinctly jointed above the nodes, quadrangular when young, terete with age, greyish brown. Leaves simple, opposite, exstipulate; petiole 2–15 mm long; blade usually ovate to orbicular or broadly ovate, 4–10 cm × 3–9 cm, base rounded or subcordate, apex broadly rounded, upper surface glossy, slightly corrugated with 9–16, fine but conspicuous lateral veins. Flowers bisexual, usually in terminal groups of 2–3(–4), occasionally solitary; pedicel 1–2 cm long, sometimes absent; buds broadly ovoid, apex rounded or obtuse, finely verruculose, 1.5–3 cm × 1–1.5 cm; calyx persistent, calyx tube cup-shaped, tapering abruptly into a stalk-like base, ribbed segments usually 6,



Sonneratia ovata Backer – 1, flowering branch; 2, fruit.

ovate-triangular, 13–15 mm long, inner surface markedly reddish cream at base; petals absent or vestigial; stamens many, filaments about 2 cm long, white, anthers yellow; ovary 10–15-celled, style about 2.5 cm long. Fruit an indehiscent, flattened globose berry, resting on the calyx-tube, 3–5 cm in diameter, 2–3 cm thick, dark green when young turning yellowish-green when ripe. Seeds numerous, rounded, irregular, about 5 mm long, embedded in foul-smelling pulp; embryo straight.
Hybrids between *S. ovata*, *S. alba* J. Smith and *S. caseolaris* (L.) A. Engler have been found in the estuary of Brunei, where they grow together. Normally they are ecologically separated, *S. ovata* growing closest to the land-side. Diagnostic field characteristics for *S. ovata* are the broadly ovate leaves without mucro, the verruculose calyx surface, the appressed calyx lobes in fruit, the absence of petals, the white filaments and the rounded irregular seeds. Its flowers are ephemeral and open at sunset, lasting for only one night; stamens fall off in the early morning. Bats and nectar-feeding birds are the pollinators. In Papua

New Guinea, *S. ovata* flowers from March to October, and fruits are ripe in April–December. In Vietnam it flowers in March–April and bears mature fruits in June–July.

Ecology *S. ovata* is occasionally found on the banks of tidal creeks and rivers, on muddy soils inundated only by spring tides. Fruits float, so water is the normal means of dispersal. It is found as individual trees, scattered among other mangrove species, such as *Excoecaria agallocha* L. *S. ovata* has never been found forming pure stands similar to *S. alba* and has also never been recorded from coral reefs.

Agronomy Although *S. ovata* mostly grows wild, it is cultivated for its fruits and as an ornamental in some villages in coastal Sarawak. Propagation is by seed.

Prospects Although the wood of *S. ovata* is used as firewood, it is not sought after. *S. ovata* may be used to control erosion along tidal river banks. *S. ovata* will probably remain of very limited economic importance.

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B. Othman

Tephrosia candida (Roxb.) DC.

Prod. 2: 249 (1825).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22$

Synonyms *Kiesera sericea* Reinw. (1828), *Robinia candida* Roxb. (1832), *Xiphocarpus candidus* (Roxb.) Endl. ex Hassk. (1843).

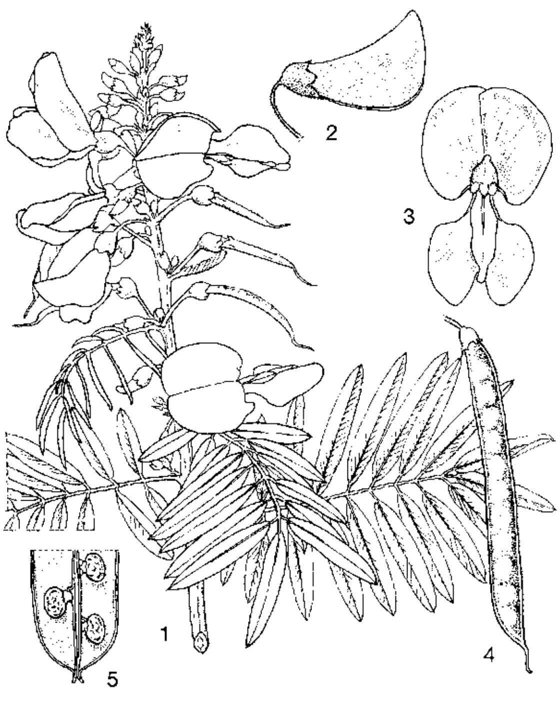
Vernacular names White tephrosia (En). White hoary pea (Am). Indigo sauvage (Fr). Indonesia: enceng-enceng (Javanese), kapeping badah (Sundanese), poko tom (Sumatra). Papua New Guinea: pis pea (Pidgin).

Origin and geographic distribution *T. candida* is native to the tropical foothills of the Himalayas in India, and is cultivated and naturalized throughout South-East Asia, from India and Sri Lanka through Burma (Myanmar), Indo-China, Malaysia, Indonesia, the Philippines and Papua New Guinea to the Solomon Islands, New Zealand and Hawaii. It has also been introduced in the West Indies and South America and has been tested in Africa.

Uses *T. candida* is grown for many auxiliary purposes. It rehabilitates degraded land and controls erosion. During the first few years after planting it is used as a green manure crop; when it becomes woody with age it provides fuelwood. In newly planted perennial crops such as citrus, coconut, coffee, rubber and tea, it is grown as a temporary shade crop and later for filling in gaps for erosion control. It is said to improve the quality and yield of tobacco. In Vietnam, it is planted as a green manure in rotation or intercropped with annual crops. It is suitable for making hedges along contours, around fields and home gardens, as it is not eaten by domestic animals such as buffaloes and goats. There are unconfirmed reports of the bark and roots being used as fish poison. Powdered leaves are used as insecticide. *T. candida* is occasionally grown as an ornamental.

Properties The approximate composition of dry leaves of *T. candida* per 100 g is: N 2.4–3.8 g, P 0.12 g, K 1.15 g, Ca 0.3 g; of the roots: N 1.18 g, P 0.07 g, K 0.47 g, Ca 0.14 g. The seeds and leaves contain small amounts of rotenoids, tephrosin and flavonoids.

Description Herb, shrub or small tree, erect with straggling branches from base, up to 3.5 m tall. Leaves spirally arranged, imparipinnate; stipules 5–11 mm × 0.8–1.5 mm, often caducous; rachis (including the petiole) up to 22.5 cm long, with brown indumentum, pulvinate at base; petiolule 1.5–4 mm long, pulvinate; leaflets 6–13 pairs, opposite, narrowly ovate, elliptical to narrowly obovate, 1.3–7.5 cm × 0.5–1.7 cm, glaucous green, soft, with silvery indumentum, base acute, apex acute, long-mucronate, venation distinct below. Inflorescence a terminal, axillary or leaf-opposed pseudoraceme, 2.5–40 cm long; basal bracts few, leaf-like, upper bracts narrowly triangular, 2.2–6 mm × 0.5–1.5 mm, often caducous; flowers in fascicles of 5–13; bracteoles triangular, smaller than bracts, sometimes caducous; pedicel 9–16 mm long; flower 13–26 mm long, white, silky, with dark brown hairs on the outside; calyx campanulate, unequally 4-toothed, cup fleshy, 3–4 mm × 4.5–7 mm, green, sericeous, teeth deltoid, sericeous outside, glabrescent, pubescent to sericeous inside; standard broadly ovate to obovate, 13–25 mm × 11–25 mm, apex rounded to emarginate, acuminate, claw 1–5 mm long; wings 12–20 mm × 5.5–13 mm, glabrous, claw 1–4.4 mm long; keel 11–20 mm × 3–10 mm, glabrous, lateral pockets sometimes bulging, claw 1.5–5 mm long; stamens 10, auricled, staminal tube 8–20 mm long, glabrous, vexillary filament free at base, connate halfway, other filaments alternately longer and shorter, free part 3 mm long; pistil with bearded style of up to 11 mm long, stigma penicillate at base. Pod linear, 7–12 cm × 0.5–1 cm, green or brown with silky hairs, slightly convex around the 10–15 seeds. Seed broadly ovoid, 4–5.5 mm × 3–4 mm, brown or greyish-brown with dark patches.



Tephrosia candida (Roxb.) DC. – 1, flowering and fruiting branch; 2, flowerbud just before opening; 3, flower, back view; 4, pod; 5, opened top part of fruit showing seeds.

Growth and development *T. candida* is deep-rooting. It is slow to establish, but grows steadily thereafter. It forms root nodules with *Bradyrhizobium* and fixes large amounts of atmospheric nitrogen. In Malesia, flowering occurs year-round; in Vietnam, flowering takes place from August to early September and pods can be harvested from October until February. Over-mature pods will shatter their seed. Maximum growth normally takes place in the second year after planting, but with regular pruning a dense cover can be maintained for many years.

Ecology *T. candida* grows in the seasonally dry tropics with an annual rainfall of 700 mm to over 2500 mm and a dry season of up to 4 months. It is cultivated in northern Vietnam, growing well under a rainy season of only 4 months and some showers during the rest of the year. It occurs from 0–1600 m altitude with an annual mean temperature of 18–27.5°C, and does not tolerate frost. *T. candida* is grown on sandy soils in coastal areas and on very poor, eroded upland soils and mine spoils where few other crops can grow. It tolerates a pH range of 3.5–7; the more acidic soils seem to be more suitable. Waterlogging is not tolerated. The habitat of *T. candida* is primary and secondary forest, higher locations in sago palm swamps and disturbed places such as roadsides, river banks, steep slopes and fields.

Propagation and planting Prior to sowing, seed is soaked in water for 4–5 hours. It is sown just before or during the rainy season. The germination rate of fresh seed is 95–100%, but decreases rapidly unless stored in a cool dry place. The optimum time for sowing in Vietnam is March–May. When broadcasting, a plant density of 50 000–60 000 per ha is aimed at, requiring 15–20 kg seed. Spacings of 40–90 cm × 10 cm are reported for intercropping, depending on the associated crop. Young plantings should be kept free from weeds.

Husbandry In Papua New Guinea, it takes about 4 months for *T. candida* to cover the soil, but once established it forms a dense cover keeping the soil weed-free. It responds well to regular pruning. In Vietnam, three cuts for green manure can be made in the first year after planting and 2–3 cuts in subsequent years. In India, 3–4 cuts are made annually during 4–5 years. Cutting should be done 20 cm above the ground. When grown for ground cover, *T. candida* should be pruned lightly and frequently. *T. candida* has been tried as an alley crop with cassava planted in 7 m wide interrows. Preliminary results indicate a greatly increased yield of cassava and a considerable reduction of erosion. On poor soils *T. candida* responds well to fertilizers, especially phosphate. Fertilizer recommendations in Vietnam are: P_2O_5 120 kg/ha, K_2O 12 kg/ha, CaO 400–600 kg/ha. As no suckers are formed, it is easy to remove when land is to be cleared, but older plants with thick woody stems may be more difficult and costly to uproot.

Diseases and pests *T. candida* is susceptible to the root fungi *Ganoderma* spp. and *Rosellinia* spp. and to the nematode *Heterodera radicola*. Therefore, care should be taken when growing it in rotation or association with susceptible crops. When weakened by shade and woody with age, *T. candida* becomes liable to attack by *Fomes* spp. It should therefore be replanted at regular intervals. In Indonesia, the *Tephrosia* beetle (*Araeocerus fasciculatus*) attacks young pods. It used to be a serious pest making seed of *T. candida* difficult to obtain, but it can now be controlled easily with insecticides.

Yield Seed yields vary between 350–500 kg/ha. *T. candida* can yield well on acid soils where *Leucaena leucocephala* (Lamk) de Wit does not grow at all. On such soils in Vietnam it realizes an annual green matter production of 10–18 t/ha, increasing the organic matter content of the soil from 1.7% to 4% in 2 years. On fertile soils, 25–30 t/ha of green matter can be harvested annually in 3 cuttings.

Genetic resources and breeding A small collection of *Tephrosia* germplasm is maintained at the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia and at the Southern Regional Plant Introduction Station of the United States Department of Agriculture, Griffin, Georgia. There is no known breeding programme with *T. candida*.

Prospects The ability of *T. candida* to grow well on poor, acid soils makes it an excellent temporary shade and green manure crop and a valuable alternative for *Leucaena leucocephala* on such soils. It has been little studied in research programmes and deserves further attention.

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L.P.A. Oyen

Tephrosia purpurea (L.) Pers.

Syn. pl. 2: 329 (1807).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 24$

Synonyms *Cracca purpurea* L. (1753), *Tephrosia diffusa* (Roxb.) Wight & Arnott (1834), *T. wallichii* Grah. ex Fawc. & Rendle (1917).

Vernacular names Purple tephrosia, wild indigo (En). Fish poison (Am). Indigo sauvage (Fr). Indonesia: pohon nila hutan (Java). Philippines: balatong-pula, balba-latong, tina-tinaan (Tagalog). Cambodia: trôm' khmaôch. Laos: s'a:z kh'a:m moyz (Louang Prabang). Thailand: khram-pa (northern). Vietnam: c[aa]y c[oos]t kh[is] t[is]a, ve c[as]i, do[ax]n ki[ees]m d[or].

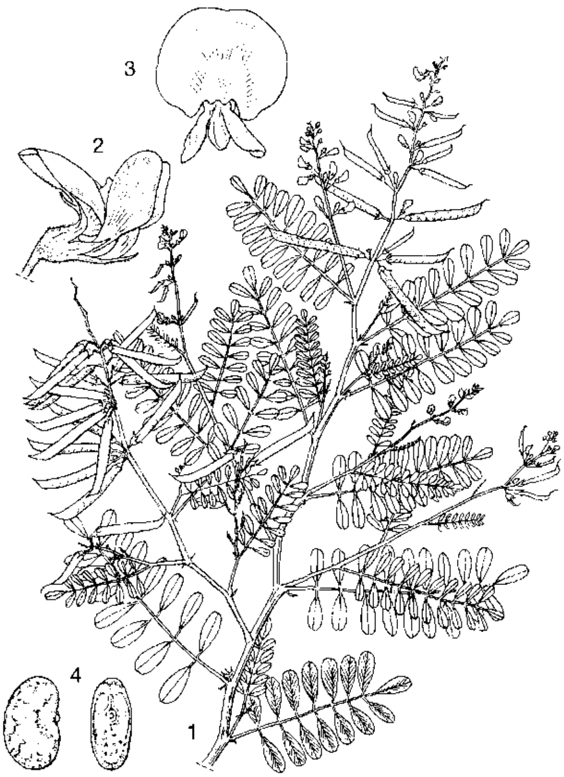
Origin and geographic distribution *T. purpurea* is native to tropical Asia, and is found from India and Sri Lanka to southern China, and through South-East Asia to tropical Australia and the Polynesian Islands. It is now naturalized and cultivated pantropically.

Uses *T. purpurea* is used as green manure for vegetables, rice, coconut and banana, especially in India and Sri Lanka, and on a more limited scale in Indonesia, Malaysia and southern China. It is also applied as temporary shade. When grown as a green manure on saline-sodic soils in Rajastan (India), it is most successful in reducing soil salinity and lowering the pH. In northern India, dry plants are collected for fuel. In Indo-China the seeds are used as a substitute for coffee. The leaves are occasionally used to dye orange-brown, or, in a mixture with *Mucuna cyanosperma* Schumann, black.

Medicinally, all parts of the plant have tonic and laxative properties. The dried plant is deobstruent, diuretic and useful in treating bronchitis, bilious febrile attacks and obstructions of the liver, spleen and kidneys. It is also recommended as a blood purifier, in the treatment of boils and pimples and is considered a cordial treatment. In southern India, a decoction of the fruit is given against intestinal worms and a fruit extract is used to relieve bodily pains and inflammatory problems. The roots are bitter and a decoction is used as a nematicide for treatment against *Toxocora canis* larvae which cause a lung disease in Sri Lanka; it is also used against dyspepsia, colic, and chronic diarrhoea and as anthelminthic. Pounded leaves are used to stupefy and catch fish. Information on the fodder value of *T. purpurea* is conflicting. In India and in South Africa, it is used as a fodder before flowering, but in Australia it is reported to cause livestock poisoning.

Properties Green manure of *T. purpurea* grown in Rajastan (India) contains per 100 g dry matter: C 36 g, N 1.9 g, P 0.3 g, K 1.8 g, Ca 1.8 g, Mg 0.8 g, S 0.4 g. The energy value of the wood of *T. purpurea* is 14 500 kJ/kg. The toxic properties of *T. purpurea* are due to the presence of flavonoids; those recorded include rotenone and several of its isomers named deguelins. One of the deguelins, tephrosin, is poisonous to fish, but not to mammals. The leaves contain up to 2.5% rutin (a flavonol glucoside). The poisonous compounds occur in too low concentrations in the plant to be extracted commercially.

Botany An erect or spreading annual or short-lived perennial herb, sometimes bushy, 40–80 cm tall, rarely up to 1.5 m; indumentum sericeous, strigose or velutinous; stem slender, erect or decumbent at base. Leaves imparipinnate; stipules narrowly triangular, 1.5–9 mm × 0.1–1.5 mm; rachis up to 14.5 cm long, including the petiole of up to 1 cm; petiolule 1–3 mm long; leaflets 5–25, obovate to narrowly elliptical, terminal leaflet 7–28 mm × 2–11 mm, lateral leaflets 5–30 mm × 2–11 mm, acute at base, apex rounded to emarginate, venation usually distinct on both surfaces. Inflorescence an axillary or leaf-opposed pseudoraceme, (1.5–)10–15(–25) cm long, sometimes with basal leaf-like bracts; flowers in fascicles of 4–6; bracts to fascicles and to flowers small, bracteoles usually absent; pedicel 2–6 mm long; flower 4–8.5 mm long, purplish to white; calyx campanulate, persistent, cup 1.4–2.3 mm × 1.5–3.2 mm, unequally 4-toothed, teeth pubescent inside; standard broadly ovate, 3.5–7.3 mm × 5–10 mm, clawed; wings 2.5–6 mm × 1.5–3.8 mm, auricled on vexillary side, clawed; keel 2.2–4.5 mm × 2–3 mm, auricled on vexillary side, clawed; stamens 10, staminal tube 4–6 mm long, filaments alternately longer and shorter, free part up to 3.5 mm long, vexillary filament free at base, connate halfway, 5–8 mm long; style up to 4.5 mm long, upper half glabrous, stigma penicillate at base. Pod flat, linear, 2–4.5 cm × 3–5 mm, somewhat up-curved to-



Tephrosia purpurea (L.) Pers. – 1, flowering and fruiting branch; 2, flower, side view; 3, flower, front view; 4, seeds.

wards the end, convex around the seeds, flattened between, margins thickened, dehiscent with twisted valves, 2–8(–10)-seeded. Seed rectangular to transversely ellipsoid, 2.5–5 mm × 1.8–3 mm, light to dark brown to black, sometimes mottled.

T. purpurea is associated with the vesicular-arbuscular mycorrhizal fungi *Glomus heterosporum* and *Sclerocystis microcarpus* in waste sites of coal mines and calcite mine spoils, and is nodulated by *Rhizobium*. It flowers throughout the year in Java.

T. purpurea is a very variable species and many subclassifications exist. Most characteristic is the shape of its pod: convex around the seeds with a distinctive flat area in between. The name *T. purpurea* is often erroneously applied to the cultivated *T. noctiflora* Bojer ex Baker which has longer inflorescences, a very long carinal calyx tooth and reticulately ridged seeds.

For South-East Asia *T. purpurea* is subclassified as follows;

– subsp. *barbigera* Bosman & de Haas: vexillary

filament and staminal tube velutinous; occurring in the Philippines, New Guinea and Australia. Based on flower and inflorescence lengths, further subdivided into 2 varieties: var. *barbigera* (flower 7–8 mm long, longest inflorescence 11–19.5 cm long) and var. *rufescens* Benth. (flower 5–6 mm long, longest inflorescence 4.5–11 cm long).
- subsp. *purpurea*: characteristics and distribution as described for the species; vexillary filament and staminal tube glabrous.

Ecology *T. purpurea* occurs naturally in grassy fields, waste places and thickets, on ridges, and along roadsides, in Java up to 400 m altitude. It generally grows at low altitudes, but may be found to 1300 m altitude. In Hawaii, it grows near the seashore. It prefers dry, gravelly or rocky and sandy soils, but in Madras (India) it grows well on loamy soils. It is tolerant of saline-sodic soil conditions.

Agronomy *T. purpurea* can easily be propagated by seed. Its growth is often not very luxuriant, limiting its value as a temporary shade crop or green manure. When added to the soil as green manure it increases humus content and induces the formation of large, stable soil aggregates. It produces ample seed and builds up a large seedbank in the soil.

Genetic resources and breeding A small germplasm collection is maintained at the Southern Regional Plant Introduction Station, Griffin, Georgia, the United States. There is no breeding programme.

Prospects *T. purpurea* is not generally recommended as a green manure and temporary shade crop, but may nevertheless be useful on saline-sodic soils. It deserves further testing for medicinal uses.

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N.O. Aguilar

Tephrosia vogelii J.D. Hooker

Niger fl.: 296 (1849).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22$

Synonyms *Cracca vogelii* (J.D. Hooker) O. Kuntze (1891).

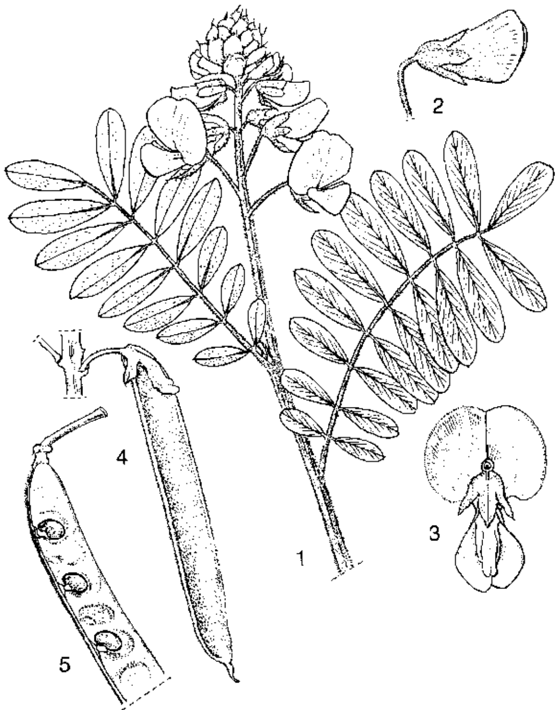
Vernacular names Vogel's tephrosia, fish-poison bean (En). Papua New Guinea: pilawa. Laos: hu: kata:yx (Vientiane).

Origin and geographic distribution *T. vogelii* is native to tropical Africa. It was introduced to tropical America and South and South-East Asia as a cover crop. It was introduced into Java in 1908 and is now found throughout Malesia.

Uses In Indonesia *T. vogelii* is cultivated as a green manure, wind-break, and temporary shade crop in cocoa, coffee, tea, rubber and cinchona plantations. In Central Africa, the Philippines and Peninsular Malaysia it is used as green manure e.g. in coconut plantations. *T. vogelii* grows taller than *T. candida* (Roxb.) DC. and is thus a good wind-break and shade plant. Because of its dense growth, it is a suitable hedge plant, while its variously coloured flowers make it also suitable as ornamental. In Africa and elsewhere it is cultivated for fish and arrow poison. The poison stupefies the fish, which is then easily caught. Dry crushed leaves are used as an insecticide against lice, fleas, and ticks, and as molluscicide. Medicinally, *T. vogelii* is used as an abortifacient, as a cure for skin diseases, schistomiasis, as a bactericide, emetic, and purgative, while a weak infusion of the leaves is taken as an anthelmintic. It is not used as a fodder because of its toxicity.

Properties Grown as a green manure in Indonesia, the nitrogen content per 100 g dry matter is 3.7 g for 2–3 months old plants, falling to 1.2 g for 10 months old material, while the phosphorus content drops from 0.8 g to 0.2 g. The leaves of *T. vogelii* contain the toxins rotenon and several of its isomers: deguelin, tephrosin, iso-tephrosin and hydroxydeguelin-C. Per 100 g dry matter the leaves contain 0.7–4.3 g rotenoids; the stems, roots and seed also contain rotenoids, but in smaller quantities. As deguelin is closely related to rotenon, *T. vogelii* can be used like *Derris* spp. as fish poison. The weight of 1000 seeds is 31–37 g.

Description A softly woody, branching herb or small tree with dense foliage, 0.5-4 m tall, with velutinous to sericeous indumentum. Stem and branches tomentose with long and short white or rusty-brown hairs. Leaves arranged spirally, imparipinnate; stipules 10–22 mm × 3–3.5 mm, early caducous; rachis 5–25 cm long, including petiole of up to 3 cm, pulvinate; petiolule 1.5–5 mm long; leaflets in 5–14 pairs, narrowly elliptical to elliptical-oblanceolate, up to 7 cm × 2 cm, base acute to obtuse, apex rounded to emarginate, venation most distinct on lower surface, silky tomentose.



Tephrosia vogelii J.D. Hooker – 1, flowering branch; 2, flowerbud just before opening; 3, flower, back view; 4, pod; 5, part of opened fruit showing seeds.

Inflorescence a terminal or axillary pseudoraceme, 8–26 cm long, rusty tomentose; basal bracts leaf-like; peduncle stout, as long as pseudoraceme; flowers in fascicles of 2; bracts to fascicles orbicular to obovate, cuspidate, about 1.5 cm long, bracts to flowers narrowly elliptical to spatulate, about 1 cm long; flower 18–26 mm long, fragrant when fresh, white, violet, purple or blue; pedicel up to 23 mm long; bracteoles sometimes present on calyx; calyx campanulate, tube 4–6 mm × 6.5–10 mm, pale greenish brown, outside sometimes sericeous, usually 4-toothed, teeth puberulous to sericeous within, vexillary tooth broadly ovate, 5–12 mm × 8–12 mm, lateral teeth oblong, 4.5–10 mm long, apex rounded, the carinal one narrow, boat-shaped, 6–15 mm long, acute; standard suborbicular, 20–28 mm × 24–32 mm, auricled at base, apex emarginate, the apical half and the margins puberulous to sericeous within, claw 3–5.5 mm long; wings 17–22 mm × 11–13 mm, auricled, inside sericeous, clawed; keel 15–20 mm × 10–12 mm, slightly auricled, clawed, hairy only on carinal side; stamens 10, staminal tube 19–20 mm long, glabrous, vexillary filament free at base and connate halfway, 22–26 mm long, glabrous, free parts of the other stamens alternately longer (6–11 mm) and shorter (4–7 mm); style bent through 70°, 11–15 mm long, bearded on both sides, stigma glabrous. Pod linear, slightly turgid, 5.5–14 cm × 0.8–1.8 cm, brown or green, woolly to sericeous, 6–18-seeded. Seed ellipsoid to reniform, 5–7 mm × 3–5 mm, dark brown to black. Seedling with epigeal germination; cotyledons rather thin, leaf-like, green, long persistent; first leaf simple, second leaf usually 3-foliolate.

Growth and development Under favourable conditions, *T. vogelii* grows rather fast, usually exceeding the growth rate of other green manure legumes, such as *Crotalaria micans* Link, *C. trichotoma* Bojer and *Mimosa diplotricha* C. Wright ex Sauvalle. In Java, initial growth is slow, plants attaining only 8 cm at 6 weeks after planting. Subsequent growth, however, is rapid and plants may reach 36 cm at 3.5 months and 2 m or more at 1 year after planting. In Java, flowering and fruiting starts 10–12 months after planting and *T. vogelii* does not live much longer than one year. In Sri Lanka, however, it may grow for at least two years, and under favourable conditions even longer. *T. vogelii* is tolerant to repeated pruning only under favourable conditions; drought often stops resprouting.

Other botanical information *T. vogelii* is closely related to *T. nana* Kotschy ex Schweinf.

The latter is a native of Africa but is cultivated and naturalized in Java and can be distinguished by its 3–4 flowers per fascicle, smaller flowers and large number of seeds in relatively short pods. *T. vogelii* also greatly resembles *T. candida*, but is easily distinguished by its generally more luxuriant foliage and larger, more hairy pods. It yields a larger amount of green material when young than *T. candida*, but its life cycle is shorter. African specimens of *T. vogelii* usually have smaller calyx teeth. In East Africa, a white-flowered form predominates, in West Africa a purple-flowered form.

Ecology *T. vogelii* is found in widely varying habitats, including savanna-like vegetation, grassland, forest margins and shrubland, waste land and fallow fields. It is tolerant to drought, strong wind and grazing. Burning has little effect on *T. vogelii*, as it resprouts readily due to its deep root system. It occurs in climates with an annual rainfall of 850–2650 mm and an annual mean temperature of 12.5–26.2°C and is found up to 2100 m altitude. It grows well on andosols not subject to flooding and on well drained loams with pH 5.0–6.5 and is also tolerant to poor soils with low pH. In acid soil, it grows much better than *Leucaena leucocephala* (Lamk) de Wit and forms root nodules and fixes atmospheric nitrogen where the latter does not. On poor soils, however, growth of *T. vogelii* is slow and more prone to diseases.

Propagation and planting *T. vogelii* is commonly propagated by seed. Air-dried seed can be stored in sealed containers for at least 1.5 year. Fresh seed should preferably be stored for 2 months before planting. Without treatment, the germination percentage is 65% and the seedling survival rate about 60%. Soaking in warm water (45°C) for 5 minutes stimulates germination. For a green manure crop, the recommended spacing is 40 cm × 40 cm, with 2–3 seeds per hole, when planted in hedges the spacing should be 1.5 m between the rows. For large plantings, sufficient seedlings should be available for replanting in case of a low survival rate. When sown in rows, the recommended sowing rate is 5 kg/ha and when broadcast 8–13 kg/ha. Planting should be done at the beginning or in the middle of the rainy season.

Husbandry Maximum biomass yield of green manure is obtained before flowering starts. To obtain tangible results, the plant material should be dug in towards the end of rainy season immediately after it has been cut. If the plants are weakly branched, they should be lopped to promote branching. Results of experiments in Indonesia have indicated that soils into which a 3-month-old *T. vogelii* crop had been incorporated showed an increase in organic matter (from 8% to 10%), nitrogen (from 0.4% to nearly 0.5%), phosphorus and potassium. The increase is larger when 2-month-old material is incorporated. In Indonesia and Sri Lanka, a 5-month-old crop was found to yield about 27 t/ha of green material. About 40% of the material was provided by the leaves and twigs alone, and the remainder by the stalks and roots. In Central Java *T. vogelii* may yield 4.4–4.8 t/ha green material about 110 days after planting. The use of *T. vogelii* green manure was found to increase yields of subsequent maize or rice crops by about 0.5 t/ha per planting season.

Diseases and pests In Java, stems of *T. vogelii* are liable to serious attacks by *Corticium salmonicolor*, especially after lopping. When tested in the United States as a pesticide-producing crop, root-knot nematodes caused very serious damage. In Central Java, *Helopeltis* spp., a serious pest of cocoa, can also heavily attack *T. vogelii*. Because of this, *T. vogelii* is no longer recommended for planting in Java.

Handling after harvest To make fish poison, leaves and small branches are gathered as needed; the leaves are macerated in water or beaten to a pulp and then thrown into the water. After about 10 minutes, stupefied fish float to the surface and can be easily collected. Pounded roots are used similarly.

Genetic resources and breeding No germplasm collections of *T. vogelii* and its relatives are known to be maintained and no breeding programme is known to exist.

Prospects The prospects of *T. vogelii* as a green manure, temporary shade or wind-break are not promising compared to *T. candida*, *Crotalaria* spp., or *Leucaena leucocephala*. However, *T. vogelii* may be useful if suitable alternatives are absent. Efforts should be made to select strains that are promising for use as green manure or to restore soils.

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B. Sunarno

Thespesia populnea (L.) Soland. ex Correa

Ann. Mus. Hist. Nat. Paris 9: 290 (1807).

MALVACEAE

$2n = 24, 26, 28$

Synonyms *Hibiscus populneus* L. (1753), *Thespesia macrophylla* Blume (1825), *Hibiscus populneoides* Roxb. (1832).

Vernacular names Pacific rosewood, portia tree (En). Cork tree, seaside mahoe, milo (Hawaii) (Am). Indonesia: baru laut (Indonesian), waru laut (Javanese), salimuli (Moluccas). Malaysia: baru-baru (general), baru laut, bebaru (Sarawak). Philippines: banalo (Tagalog), tuba-tuba (Bikol), balu (Sulu). Cambodia: baëhs sâmut(r), chréi sâmut(r). Thailand: pho-thale (central).

Origin and geographic distribution *T. populnea* probably originates from the Asiatic tropics but now it occurs throughout the tropics. It is fairly common all along the shores of South-East Asia, and is also cultivated further inland.

Uses In mangrove areas, *T. populnea* is often planted to consolidate ridges and bunds in an aqua-silvicultural system for prawn production. In Karnataka (India), it is planted along the coast as protection against erosion. The fine-grained, strong, hard and durable wood is highly priced furniture wood, and is also used for light construction, flooring, moulds, musical instruments, utensils and vehicle bodies. As it is very durable under water, it is popular for boat building. The bark is much used for caulking and making ropes. Chippings have been tried as a green manure. The young leaves are eaten as a vegetable. The wood and the yellow gum from the fruits and flowers yield a dye. The corewood is used in medicines against colic and fever. The leaves and fruit are applied to cure skin diseases, while the ripe fruit, pounded with coconut oil, provides a cure against lice.

In many parts of the Pacific, *T. populnea* is a sacred tree, often planted near temples. Elsewhere, it is also grown as an ornamental and roadside tree.

Properties The fruits yield 0.4% of a flavonoid colouring matter; while thespesin, ceryl alcohol and beta-sitosterol have been isolated from the unsaponifiable fraction of the seed oil. Gossypol is present in the flowers and bark. Plant extracts have significant anti-malarial activity. The wood of *Thespesia* spp. is light to medium-weight with a density of 400–770 kg/m^3 at 15% moisture content. The heartwood is dark red and smooth. Its texture is medium to fine. Shrinkage upon seasoning is very low to low. The wood seasons well. It is easy to saw and work despite its wavy grain.

Botany Shrub to medium-sized, evergreen tree, up to 20 m tall with dense crown. Bark greyish. Twigs densely covered with brown to silvery scales, glabrescent. Leaves alternate, simple; petiole 5–8(–16) cm long; stipules lanceolate to subulate, 3–10 mm long, scaly; blade orbicular, deltoid, ovate or oblong, 7–23 cm × 5–16 cm, apex acuminate, base generally cordate, sinus deep and narrow, rather fleshy and shiny, palmately 7-veined, in the axils of the basal veins beneath mostly with

Thespesia populnea (L.) Soland. ex Correa – 1, flowering branch; 2, fruit.

saccate nectaries, main veins yellow. Inflorescence a large, solitary, axillary flower; pedicel 2.5–8 cm long, erect or ascending, sometimes articulate with 2 scale-like bracts near the base, at apex with a discoid hypanthium 6–8 mm in diameter; epicalyx segments 3, oblong to lanceolate, 4–17 mm × 2 mm, caducous, subcoriaceous, acute, densely scaly; calyx campanulate, subtruncate, 12–14 mm long, 18 mm in diameter, densely appressed hirsute within, scaly, glabrescent outside; corolla broadly campanulate, up to 6 cm long and wide, pale yellow with dark purple centre; petals 5, obliquely obovate, 6–7 cm × 4.5–6 cm, apex rounded; stamens many, monadelphous, staminal column glabrous, filaments about 4 mm long, anthers about 1.5 mm long; ovary globose to ovoid, 8–10 mm in diameter, scaly, 10-celled, style about 4 cm long; stigmas connate to clavate, pale yellow. Fruit a globose capsule, 2–4.5 cm in diameter, faintly 5-angular, 5-celled, apex obtuse or slightly depressed, with disk-like calyx at the base of the young fruit, usually indehiscent, exuding a bright yellow gum when cut. Seeds 4 per cell, obovoid, 8–15 mm × 6–9 mm, slightly angular, covered by closely matted silky hairs.

The yellow flowers open at about 10 a.m. in the morning, turning reddish-orange in the afternoon, then fading to pink on the tree and not falling off for several days.

Some authors recognize the specimens occurring along the coasts of the Indian Ocean as a distinct species: *T. populneoides* (Roxb.) Kosteletsky, having somewhat bronzed or coppery, shallowly cordate to subtruncate leaves, pedicel 5–12 cm long, drooping, a dehiscent outer layer of the fruit and seeds with short clavate or bulbous hairs. However, many intermediate specimens exist, called 'hybrids' by some, occurring where both forms can be found. In Sri Lanka some of these 'hybrids' have been widely propagated vegetatively as ornamentals and living fences.

Ecology *T. populnea* is found on coasts throughout the tropics, often in locations where sandy beaches covered by *Casuarina equisetifolia* L. give way to coral outcrops and in *Barringtonia* vegetations. In Malaysia, it is also found on rocky coasts. It does not occur in mangroves. The seed floats in sea water, making natural distribution by sea currents possible. *T. populnea* is only sparingly found on the inland edge of mangrove or persisting from cultivation. It is a suitable tree for very dry locations.

Agronomy Propagation is by seed or stump cuttings. *T. populnea* is prone to fungal root and butt rot caused by *Phellinus noxius*. This is characterized by slowly enlarging diseased patches and a thick, dark brown mycelial sheath around the base of infected trees. *T. populnea* is one of the alternative hosts of a number of serious cotton pests, such as cotton stainer (*Dysdercus* spp.) and cotton boll weevil (*Anthonomus grandis*).

Genetic resources and breeding No germplasm collections and breeding programmes are known to exist.

Prospects Because of its tolerance to saline conditions *T. populnea* is suitable for planting to control beach erosion. Its similarity to *Hibiscus tiliaceus* L. suggests that it deserves testing as a wind-break.

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A. Latiff & I. Faridah Hanum

Trema orientalis (L.) Blume

Mus. bot. Lugd.-Bat. 2: 62 (1856).

ULMACEAE

$2n = 20, 36, 40$

Synonyms *Celtis orientalis* L. (1753), *Sponia orientalis* (L.) Decne (1834), *Trema guineensis*

(Schumach. & Thonn.) Ficalho (1884).

Vernacular names Charcoal tree, Indian charcoal tree (En). Indonesia: anggerung (Javanese), kuray (Sundanese), lenggung (Bali). Malaysia: menarong, mengkirai (Peninsular Malaysia), randagong (Sabah). Philippines: anabiong (Tagalog), pitidan (Igorot), anadgong (Bisaya). Cambodia: srô:l. Laos: po: hu:. Thailand: po-haek (northern), takhai (central), pa-dang (Karen). Vietnam: hu dai, hu l[as] nh[or].

Origin and geographic distribution *T. orientalis* most probably originated in tropical Asia. It is widely distributed in tropical Africa and from the western Himalayas to the Pacific extending into China and southern Japan, and into Queensland. It is found throughout South-East Asia, though it is rare in the Lesser Sunda Islands (Bali and Nusa Tenggara), the Moluccas, and New Guinea.

Uses The wood is widely used as firewood and provides excellent charcoal which is even suitable for making gunpowder and fireworks. *T. orientalis* is often planted as a shade tree in coffee and cocoa plantations and also in other crops in Asia and Africa. Being a pioneer species, it is suitable for planting on poor soils to reforest denuded or disturbed areas. It is common as a fallow species in shifting cultivation. In South Africa it is planted to reforest riverine areas, thereby functioning as the first species in a succession of trees. In the Philippines, *T. orientalis* silage is fed to cattle, buffaloes and goats while the bark is used for making ropes and as a source of tannin. The use of leaf meal in feeds is usually limited by the high fibre content and toxins. However, these limitations can be overcome by extracting protein from the leaves. In Malaysia, Indonesia and India, the wood is used in manufacturing panel products such as medium density fibre board (MDF) and particle boards, and also for making paper.

Properties The wood of *T. orientalis* has a fairly low density (415–465 kg/m^3) and a relatively low energy value (18 900 kJ/kg). However, it is an attractive fuel because of its high heating value and negligible ash content. Silage made from its foliage has a high crude protein content (18.9 g/100 g dry matter) which is comparable to the amount found in common concentrates.

The wood is soft and light, its texture is even, but moderately coarse, with straight or interlocked grain. The sapwood is not distinct from the buff heartwood. Sawing and planing are moderately easy although the surface produced is rough. The wood seasons fairly rapidly, shrinkage is average, but it suffers severe cupping, twist, staining and bowing. It is not durable under exposed conditions. The average length of wood fibres from 7-year-old trees is over 1.6 mm, which compares favourably with that of poplars (*Populus* spp.) commonly used in the United States for paper manufacture. Fibres are longer in taller trees than in smaller ones and length increases from the pith towards the bark and from the butt to the top of the tree. Paper made of *T. orientalis* has good tensile strength and folding endurance.

Description Deciduous, usually monoecious shrub to large tree, up to 36 m tall, with open crown and spreading branches. Bole up to 90 cm in diameter, sometimes with buttresses up to 1.2 m high; bark smooth to finely fissured, lenticellate, greyish. Branchlets, stipules, petioles, and inflorescences densely set with appressed and matted or erect 1-celled, silvery to glaucous hairs and short, multicellular glandular hairs completely covering the epidermis. Leaves alternate; stipules linear-lanceolate to ovate-acute, 3–4 mm ×

Trema orientalis (L.) Blume – 1, flowering branch (female); 2, female flower; 3, male flower; 4, sepal and stamen; 5, fruit.

1–2 mm; petiole 1–1.5 cm long, often pinkish-purplish; blade ovate to lanceolate, (6–)10–15(–20) cm × (1.5–)2.5–6(–10) cm, often slightly asymmetrical, thinly or thickly leathery, often rigid and brittle, dark green above and glaucous beneath, base cordate, rounded, or sometimes truncate, often contracted, margin serrate to denticulate, apex acute to acuminate-caudate, upper surface scabrid and sparsely set with bulbous-based hairs, lower surface densely covered with matted star-shaped and simple erect hairs; primary and secondary veins sunken above and prominent beneath. Inflorescence a much branched panicle or thyrse, either male or female, borne on separate vegetative branches, at anthesis lax or condensed; axes 1–2 mm thick; bracts ovate-acute, 2–3 mm × 1 mm; flowers 5-merous, tiny, greenish-cream; male inflorescence 2.5(–5) cm long, 20–100-flowered, male flower 1.5–2 mm in diameter, perianth lobes ciliate, 1.5–2 mm × 1 mm, filaments 1–1.5 mm long, anthers about 1 mm × 0.5 mm, pistillode obovoid-conical, compressed; female inflorescence 5–15 flowered, 1.5–2.5 cm long, female flower 2–3 mm × 1–2 mm, perianth lobes ovate, acute, 1.5 mm × 0.5 mm, ciliate and densely short-pubescent, glabrescent, staminodes absent, ovary ovoid-conical, about 2 mm × 1 mm, with 2 slender spreading stigmatic arms. Fruit an ovoid drupe, 5–8 mm × 4–5 mm, glabrous, green turning red, then black, tipped by 2 short styles, seated on the persistent but not enlarged calyx, generally in clusters. Seedling with epigeal germination.

Growth and development Seed requires a high light intensity for germination. *T. orientalis* is very fast growing, attaining harvestable size for pulpwood when 3–4 years old. It coppices well and its extensive root system enables it to withstand dry periods. Flowering and fruiting occurs year-round. *T. orientalis* regenerates quickly in forest clearings and may become dominant. After selective logging of *Araucaria* forest in Papua New Guinea it may thus delay the reestablishment of *Araucaria* forest by 30–100 years. The fleshy drupes are dispersed by birds.

Several species of the closely related genus *Parasponia* Miq. form root nodules after *Rhizobium* infection and can fix atmospheric nitrogen. Early reports of nitrogen fixing nodules being found in *T. orientalis* have not been confirmed.

Other botanical information *T. orientalis* is very variable in leaf thickness, leaf form, leaf hairiness and fruit size. It is closely related to the similarly distributed *T. tomentosa* (Roxb.) Hara, the latter sometimes being included in *T. orientalis* as subsp. *tomentosa* (Roxb.) Murata. *T. tomentosa* can be distinguished by its much less densely hairy leaf undersides and concolorous leaves, a larger male inflorescence (up to 5 cm long) and compressed ovoid fruits. It is sometimes assumed that *T. tomentosa* is a juvenile form of *T. orientalis*.

Ecology *T. orientalis* is found in the lowland humid tropics (especially in eastern Malesia), extending up to about 2000 m altitude (in western Malesia), even reaching 2500 m (in the Himalayas). It requires 1000–2000 mm annual rainfall and an average annual temperature of 20–27°C. It grows on a wide range of soils from heavy clay to light sand; it tolerates moderate alkalinity and salinity, but does not withstand waterlogging. It is intolerant of fire. *T. orientalis* is amongst the first trees to establish in clearings, flood-damaged river-banks and also colonizes denuded, poor soils. In the Philippines, the early tree vegetation in forest clearings left fallow is often composed largely if not entirely of *T. orientalis*.

Propagation and planting *T. orientalis* is propagated by seed or by stump cuttings. To break dormancy, seed has to be steeped in gibberellic acid dissolved in agar at 500 ppm, or stored at 2°C for 3–4 months. In the Philippines, stumps of 2–3-year-old trees, 10–14 cm in diameter at a height of 1.3 m and cut at a height of 30 cm, yield an optimum number of cuttings. Older trees produce fewer sprouts.

Husbandry Little information is available on the management of *T. orientalis*, as wood and fodder are mostly collected from natural stands.

Diseases and pests No serious diseases and pests are known. Larvae of *Sahyadrassus malabaricus*, a sapling borer of *T. orientalis*, causes some damage in India, but can be controlled completely with insecticides. Caution is advised if *T. orientalis* is to be introduced outside its natural habitat as it may spread insect pests to other plants of economic importance. Ants and rodents favour the fruits.

Harvesting When harvested for firewood and charcoal, sustained periodic harvests are possible from the same area. Cutting is done every 3–4 years at 20–30 cm above the ground. The cut should be slanting, to prevent the stumps from rotting.

Yield Bark for tanning purposes is often harvested from trees of 40–50 cm stem diameter. The bark yield of such trees is on average 7.8 kg/m^2 (green weight) and 2.8 kg/m^2 (air-dried weight).

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

Prospects Because of its easy establishment, fast growth, high heating value, and good palatability and feeding value, *T. orientalis* is a potential multipurpose tree. As trees 3–4 years old attain a size suitable for fuelwood and pulpwood, the feasibility of establishing *T. orientalis* plantations warrants further research. The leaves have potential as a protein source for non-ruminants in the form of leaf meals, but the nutrient availability and toxicity should be studied further. *T. orientalis* is a promising raw material for paper and wall board industries.

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I. Faridah Hanum

Vigna hosei (Craib) Backer

Geïll. Handb. Jav. Theeonkr.: 153 (1924).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 20$

Synonyms *Dolichos hosei* Craib (1914), *Vigna oligosperma* Backer (1924, nom. nud.).

Vernacular names Sarawak bean (En). Indonesia: tolo lembut.

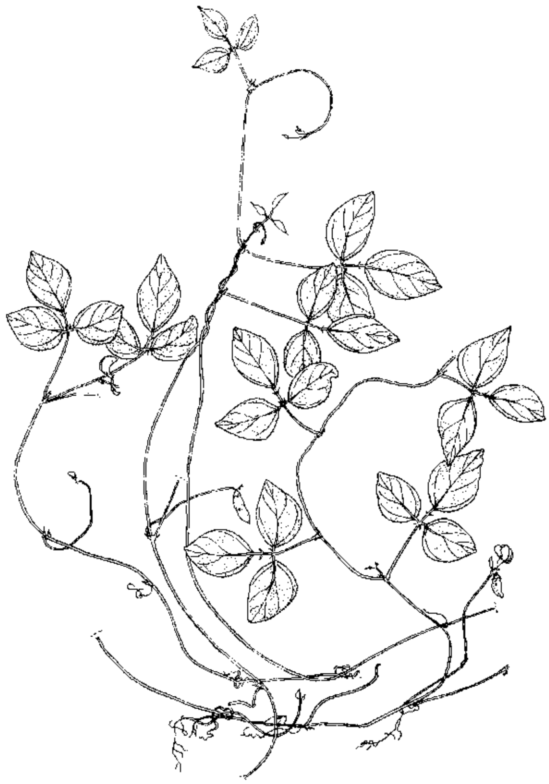
Origin and geographic distribution *V. hosei* most probably originated in south-eastern Africa, but is now also found in the humid tropics of South-East Asia from Sri Lanka to Japan, and in Australia. It is also recorded from the United States. In South-East Asia it was first found in cultivation in Sarawak and taken from there to Peninsular Malaysia and later to Java. It is now cultivated in Malesia, Sri Lanka, East Africa and Surinam.

Uses *V. hosei* is grown as a green manure and cover crop in young tree plantations; in Indonesia in rubber, tea and coconut, in Malaysia in rubber and oil palm, in Sri Lanka in coconut plantations. In Rwanda it is being tested as a green manure in association with annual crops. It is also used as a pasture legume.

Properties The weight of 1000 seeds is about 27 g.

Description A twining or creeping vine often forming a thick ground cover. Root system shallow. Stem 1–2 m long, with scattered hairs, easily rooting at the nodes. Leaves alternate, trifoliolate; petiole 2–5 cm long; stipules linear, base cordate, long persistent; rachis 2.5–6 cm long; petiolule 1.5–3 mm long, hairy; leaflets ovate-elliptical to obovate-oblong, terminal leaflet 2–7.5(–9) cm × 1.5–5(–6) cm, laterals oblique, apex acute, rarely obtuse, base more or less rounded, both surfaces with sparse, long hairs. Inflorescence an axillary raceme, 2–8 cm long, bearing small, yellow, paired flowers; peduncle 1.5–7 cm long; pedicel about 2 mm long, appressed pubescent; bracteoles very small, early caducous; calyx tubular, tube about 2 mm long, ending in 5 teeth, the 2 upper teeth connate, triangular, about 1 mm long; standard orbicular, 6–12 mm in diameter, yellow; ovary 2–4(–5)-locular, with densely appressed, long hairs. Pod, 1–2 cm × 4–4.5 mm, finely pubescent, black, usually containing 1–3(–4) seeds. Seed brown, blotched with dark brown. 'Subterranean pod' 1–1.5 cm long, pale yellow, densely covered with fine hairs, 1–2-seeded, on up to 7 cm long peduncle.

Growth and development Seedling growth is vigorous and young plants quickly suppress weed



Vigna hosei (Craib) Backer – habit of flowering and fruiting branches.

growth. Flowering occurs about 6 months after planting, self-pollination is the rule. Seed set is poor. Although non-specific in its *Rhizobium* requirement, inoculation is preferably carried out with a selected cowpea strain such as CB 756. *V. hosei* fixes significant amounts of atmospheric nitrogen and forms a dense leaf litter. Besides producing normal aerial flowers and pods, *V. hosei* also produces flowers and pods which are hidden under the litter of leaves covering the soil.

Other botanical information Sometimes 2 varieties are distinguished mainly based on hairiness of stems and leaves: var. *hosei* is glabrescent, mainly found in South-East Asia; var. *pubescens* Maréchal, Mascherpa & Stainier is pubescent and occurs mainly in Africa.

V. hosei is very similar and probably closely related to *V. parkeri* Baker from Central and East Africa. The latter species has blue to violet flowers, never forms subterranean pods and has 22 chromosomes.

Ecology *V. hosei* requires an annual rainfall of 2500 mm. Since it has a shallow root system, it has a low tolerance of drought but it can withstand flooding. It can be found up to 1100 m altitude in grassland and secondary forest, in both open and shaded locations. An outstanding characteristic is its persistence under shade, but full sunlight is required for good seed production. It is adapted to a wide range of soils, but prefers acid soils of pH 4.9 or less.

Propagation and planting *V. hosei* can be propagated by seed and by cuttings. When sown as a cover crop it may be mixed with other leguminous covers such as *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth. For satisfactory germination the seeds are scarified by immersing them in concentrated sulphuric acid for 10 minutes followed by repeated rinsing, or by soaking in hot water (75°C) for 2 hours or in cold water for 3 days. Mechanical scarification is also possible. Prior to sowing, the seeds may be inoculated with compost containing an appropriate *Rhizobium* strain, and mixed with rock phosphate fertilizer equivalent to the weight of the seeds used. Seeds are sown in shallow furrows about 5 cm deep. About 2–3 drills are established in between rows of young plantation trees. A pre-emergence herbicide is sprayed along the drills after the seeds are covered. When establishing a pasture, a good seed-bed is prepared and 1 kg seeds per ha are drilled at a depth of 1.25 cm, followed by harrowing or rolling. *V. hosei* combines well with guinea grass (*Panicum maximum* Jacq.), pangola grass (*Digitaria eriantha* Steudel) and *Brachiaria* grasses. For vegetative propagation it is recommended to plant during the rainy season and to use 20 cm long, 3-noded cuttings planted 1–1.5 m apart.

Husbandry Application of compound fertilizer (15% N, 15% P_2O_5, 6% K_2O and 4% MgO) at a rate of 30 g per 6 m drill is recommended 1 and 3 weeks after germination. Fertilizer should be applied during dry weather, to avoid scorching the foliage. At 3 and 6 months after sowing, rock phosphate is broadcast over the cover at a rate of 60 kg/ha. If a magnesium deficiency is expected, kieserite should be applied at 125 kg/ha. Hand weeding is carried out at 2-week intervals during the early establishment stage of the legume. It is common to have a relatively pure legume cover during the early growth of plantation trees, maintaining the cover until the tree canopy starts to shade it out. In rubber and oil-palm plantations the planting of leguminous cover crops has been shown to have beneficial effects on tree growth. As

a pasture legume, *V. hosei* can be subjected to light grazing during the early stages of establishment. Once established it can tolerate heavy stocking. Seed production is often poor and only about 50 kg/ha can be harvested. Harvesting seed on a field scale is also difficult.
A cover of *V. hosei* can be removed easily by hoeing the soil, followed by a clean weeding.

Diseases and pests As a cover crop, *V. hosei* is susceptible to a fungus disease ascribed to *Rhizoctonia solani* which causes wilting or damping-off of the leaves, the effect being that large patches of leaves die off. It may or may not regenerate, depending on weather conditions. Wet weather favours the spread of the disease. If the attack is severe, the affected patches may be sprayed with 0.2% ferbam. When replanting cleared rubber plantations, that were severely affected by root diseases, the cover may also suffer attacks by *Fomes lignosus* and *Ganoderma pseudoferreum*. Control by fungicides is not economical in such instances.
Most of the pests that can destroy cover crops are leaf eaters: caterpillars, beetles, bugs, grasshoppers, snails and slugs. The roots may be attacked by cockchafer grubs and root-knot nematodes. Control measures against these pests, especially chemical sprays, are considered unnecessary because they upset the natural balance.

Prospects Due to its persistence under shade, *V. hosei* can enrich a mixture of leguminous covers for young plantation trees. Being a low-growing creeper, it hardly climbs trees, which is considered important for a good cover crop. Its persistence in sward-forming grasses also renders it a promising pasture legume.

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K.C. Wong

Vigna marina (Burm.) Merrill

Interpr. Rumph. Herb. Amboin.: 285 (1917).
LEGUMINOSAE – PAPILIONOIDEAE
$2n = 22$

Synonyms *Phaseolus marinus* Burm. (1769), *Dolichos luteus* Swartz (1788), *Vigna lutea* (Swartz) A. Gray (1854).

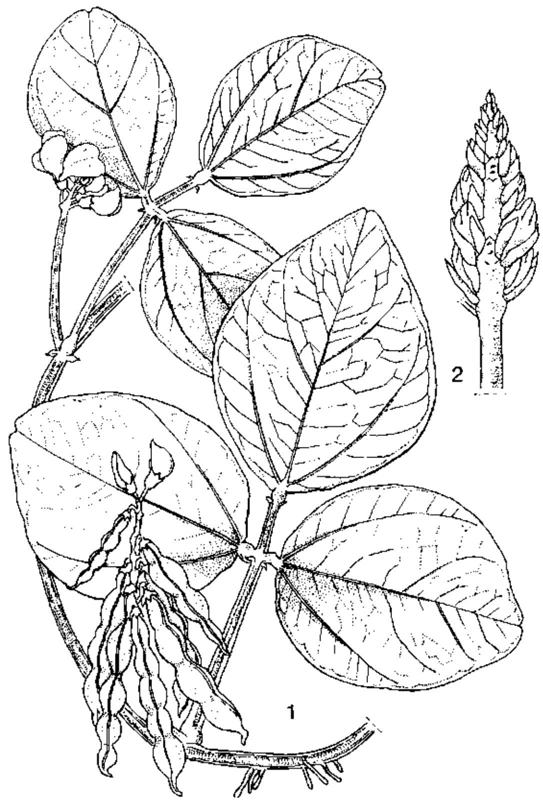
Vernacular names Dune bean, sea bean (En). Notched cowpea (Am). Indonesia: kacang laut (Java), rerenge makenti (Sulawesi), fofuo dowongi (Ternate). Malaysia: kacang laut. Philippines: pataning-dagat.

Origin and geographic distribution The origin of *V. marina* is unknown. It is widely distributed pantropically along sea shores.

Uses *V. marina* occurs as a natural sand binder on sea shores and coastal sand dunes. It is also cultivated as a cover crop. In the Maldives it is grown for its edible seeds, while in Australia its thicker roots are eaten after roasting. After thorough cooking, the leaves can be eaten as a vegetable. Livestock will eat the plant when cut as green forage.

Properties The approximate composition of *V. marina* per 100 g fresh material is: water 66 g, protein 3 g, carbohydrates 24 g, fat 1 g, fibre 4 g, and ash 2 g.

Botany Prostrate or trailing, biennial or short-lived perennial herb up to several metres long. Stem subsucculent, glabrous or with a few scattered hairs, ribbed, rooting at the nodes. Leaves trifoliolate, succulent to membranaceous; stipules cordate, about 5 mm × 3 mm, persistent; petiole 5–11.5 cm long; rachis 1.5–3 cm long; petiolule about 0.5 cm long; stipels 2 mm long; leaflets rounded-obovate to oblong-ovate, 5–8.5(–9) cm × 5–8(–10) cm, often emarginate-mucronate at the apex, venation reticulate and raised, glabrous or with a few hairs on either surface. Inflorescence an axillary, erect raceme, 1.5–3 cm long; peduncle 4–7(–13) cm long, bearing 6–12 flowers at the top



Vigna marina (Burm.) Merrill – 1, flowering and fruiting branch; 2, inflorescence with nectaries.

and between which extra-floral nectaries are present; pedicel 3–6 mm long; flower yellow, 1.5–2 cm long; calyx tubular, tube 5.5–6.5 mm long, nearly glabrous, ending in 4 unequal teeth; standard of corolla obovate, 18–19 mm × 20–22.5 mm; stamens 10, diadelphous, 15–17 mm long; style bearded on the upperside and bearing a short beak beyond the stigma. Pod subcylindrical, 4–6 cm × 1 cm, straight or slightly curved, glabrous when old, strongly constricted between the 2–9 seeds, indehiscent, black. Seed subglobose to kidney-shaped, 4.5–6 mm in diameter, greyish-brown, with prominent yellowish hilum.

Nodulation occurs easily and profusely, probably with a wide range of *Rhizobium* strains. The coastal distribution seems related to the inflated, non-shattering pods, which may float from coast to coast.

For Africa, *V. marina* is subdivided into 2 subspecies: subsp. *marina* (as described here, occurring along the coast of the Indian Ocean, being similar to the form found in South-East Asia) and subsp. *oblonga* (Benth.) Padulosi (synonym: *V. oblonga* Benth.) (pods less inflated, seeds smaller, stems thinner, mainly occurring along the Atlantic coast). *V. marina* is often confused with the also pantropically occurring *V. luteola* (Jacq.) Bentham, from which it differs mainly in habitat. *V. marina* grows along sea shores, whereas *V. luteola* is found along freshwater shores. When crossed, the two species produce fertile hybrids.

Ecology *V. marina* grows naturally in the vicinity of sandy or stony sea shores, often just above the high tide mark, in coastal lagoons and river mouths, and does not occur at much higher altitudes. It grows well on wet and poorly drained soils. At least 500 mm annual rainfall is required. It is very frost-sensitive and obviously salt-tolerant.

Agronomy *V. marina* can easily be propagated by seed or cuttings. Per ha, 1–2 kg seed are needed. In Australia it has been tested in a 1:1 mixture with the grass *Paspalum plicatulum* Michaux. Its dry matter production was 3 t/ha containing 100 kg nitrogen. The grass yield was less than with other legumes such as *Macroptilium atropurpureum* (DC.) Urban.

Genetic resources and breeding It is unlikely that any substantial germplasm collections of *V. marina* are being maintained. There are no known breeding programmes. Its adaptation to dry conditions and possible tolerance of salinity may be useful in breeding programmes of other *Vigna* species.

Prospects *V. marina* is promising as a cover and forage crop especially for saline conditions, but more research is needed to optimize its use.

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N.O. Aguilar

Vigna trilobata (L.) Verdc.

Taxon 17: 172 (1968).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22$

Synonyms *Dolichos trilobatus* L. (1767), *Phaseolus trilobatus* (L.) Schreber (1770), *P. trilobus* auct., non L. (1753).

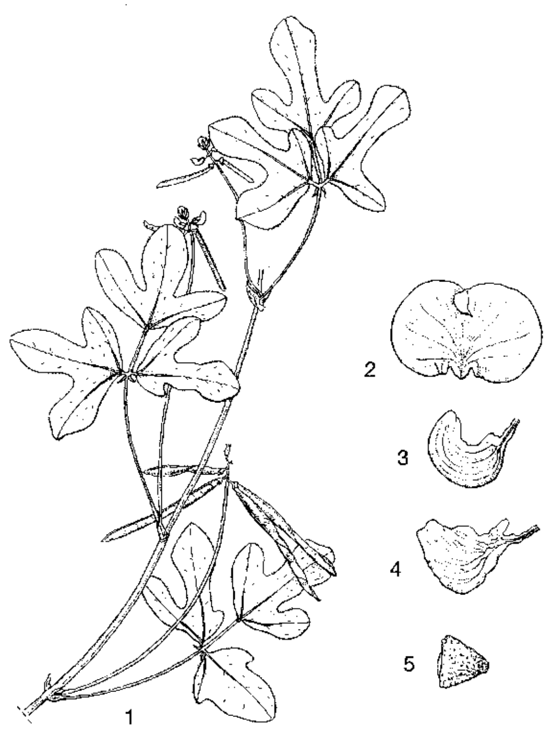
Vernacular names Phillipesara (En). Indonesia: kacang kate.

Origin and geographic distribution *V. trilobata* occurs from India and Sri Lanka to Malesia and Taiwan. In Malesia, it is reported from Indonesia, Malaysia and Papua New Guinea. Introductions have been made into Africa, Madagascar and Peru. It is cultivated in the Sudan.

Uses *V. trilobata* is grown as a green manure and fodder crop mainly in India, Pakistan and the Sudan. The seeds are eaten only by poor people in India.

Properties The approximate nitrogen yield per ha of the components of a crop of *V. trilobata* is: roots 5–16 kg, nodules 2–4 kg, leaves 84–97 kg, stems 53–94 kg, pods 14–35 kg. A trial in Queensland (Australia) comparing the nitrogen mineralization rates of 6 legume species found that the leaves and young stems of *V. trilobata* contained per 100 g dry matter: nitrogen 2.3 g, lignin 7.7 g and polyphenols 1.9 g. Stems and leaves incorporated in the soil decomposed fairly rapidly: two weeks after incorporation, 13% of the added N had been mineralized, rising to 27% after 6 weeks, and 42% after 12 weeks. The mineralization rate of *V. trilobata* was faster than that of leucaena (*Leucaena leucocephala* (Lamk) de Wit), but slower than lucerne (*Medicago sativa* L.)

Botany Annual or perennial, prostrate and trailing herb, up to 2 m long; branches striate, glabrous or pubescent. Leaves trifoliolate; stipules oblong, peltate, sometimes spurred, 4–15(–20) mm long; petiole 3.7–7.5(–11) cm long; petiolule up to 2.5 cm long; stipels small; leaflets deeply 3-lobed, 1–5 cm × 0.5–4 cm; lobes oblong-obtuse or subacute, central lobe largest, glabrous to subglabrous. Inflorescence a few-flowered, axillary raceme, 3–25 cm long; peduncle 8–22 cm long, bearing small, pale yellow flowers at the top; pedicel 2–3 mm long; bracts caducous; bracteoles linear-ovate, up to 4 mm long, attached below the calyx; calyx campanulate, 2.5 mm long, glabrous, bearing 5 teeth of which the 2 upper ones are united and the lowest one is longest; corolla yellow, 5.0–6.5(–8) mm long, standard subcircular, emarginate, auriculate, wings obovate, with linear auricle, keel asymmetrical, narrow, long, obtuse, twisted in a complex spiral; stamens 10, upper one free, others united; style spirally twisted, bearded below the oblique stigma. Pod curved, subcylindrical, 2.5–5 cm × 3–4 mm, glabrous to sparingly pubescent, 6–12-seeded. Seed ellipsoid, 3 mm × 2 mm, brown. In Pakistan, *V. trilobata* flowers in October. It nodulates and fixes atmospheric nitrogen. Nodule



Vigna trilobata (L.) Verdc. – 1, flowering and fruiting branch; 2, standard; 3, keel; 4, wing; 5, seed.

formation starts 10–14 days after germination, while nitrogen fixation can be detected from 17–23 days after germination. The number of nodules per plant at maximum plant weight ranges between 41–63. Nodule weight constitutes 1.3% of plant weight. Nodules are diffuse, lobed, of medium size (2–4 mm in diameter), and occur mainly on the main root, with smaller ones on lateral roots; they are easily shed.

V. lobata greatly resembles *V. radiata* (L.) R. Wilczek var. *sublobata* (Roxb.) Verdc. (small form of mung bean, occurring in the same region), but can be distinguished by its longer stipules and bracteoles, its longer peduncles, and its smaller flowers, fruits and seeds.

Ecology *V. trilobata* thrives in a wide range of conditions, especially near forest edges and on waste land. In India and Indo-China, it flourishes from the plains up to an altitude of 2100 m. Its drought tolerance is outstanding. From central Queensland (Australia), an accession has been reported to be particularly drought hardy, but it shatters its seed readily and is killed by frost. In northern Queensland, a selection from the Sudan showed good persistence, regeneration and spread in a 4-year experiment on heavy, cracking clay soils.

Agronomy Propagation is usually by seed, which needs scarification to improve germination. Inoculation with appropriate *Rhizobium* prior to sowing improves early growth in new locations. Planting density varies according to the use. Farmers in the Sudan broadcast 30 kg/ha when the crop is grown for fodder. The amount is increased to 60 kg/ha when it is grown as a green manure and is ploughed into lines to control weeds. A study on atmospheric nitrogen fixation of various forage legumes and their rotational effect on the yield of subsequent cotton crops in the Gezira Research Station, the Sudan, revealed that forage yield of *V. trilobata* was higher than the yield of butterfly pea (*Clitoria ternatea* L.), lablab (*Lablab purpureus* (L.) Sweet), groundnut (*Arachis hypogaea* L.), mung bean (*Vigna radiata* (L.) Wilczek), cowpea (*Vigna unguiculata* (L.) Walp. cv. group Unguiculata), and soya bean (*Glycine max* (L.) Merrill). The fresh and dry weight yields of *V. trilobata* were approximately 30–48 t/ha and 7–19 t/ha, respectively. The total nitrogen yield was 165–235 kg/ha. However, the *V. trilobata* forage–cotton rotation resulted only in a slight but non-significant increase in soil nitrogen and was not large enough to appreciably affect the nitrogen response of cotton yield. Thus *V. trilobata*, grown for fodder and cut and removed leaves, limited amounts of fixed atmospheric nitrogen to influence rotational effedts. If grown as a green manure the situation will be different, but research data are not available. Several strains of *Rhizobium* were greenhouse-tested on *V. trilobata* to determine their effectiveness in a soil of pH 6.3 that was N-deficient but otherwise fertile. Dry matter production and nitrogen yield of plants that received fertilizer N exceeded that from any of the unfertilized inoculated plants. In an acid soil, almost all *Rhizobium* strains tested nodulated *V. trilobata*. Liming the acid soil reduced nodulation and plant growth in all treatments.

In Gezira, the Sudan, *V. trilobata* was tested in an intercropping experiment with Sudan grass (*Sorghum ×drummondii* (Steud.) Millsp. & Chase) on heavy, alkaline clay soils. The highest forage and crude protein yield was obtained at a sowing rate of 15 kg/ha (75% of the seed rate for a sole crop) of *V. trilobata* and 15 kg/ha (25%) of Sudan grass. The dry forage yield per ha was 1.5 t of *V. trilobata* and 1.4 t of Sudan grass.

Genetic resources and breeding *V. trilobata* is included in several germplasm collections of *Vigna* spp., e.g. at the Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan and the Southern Regional Plant Introduction Center, Griffin, Georgia, United States. There are no known breeding programmes on *V. trilobata*.

Prospects With its ability to thrive under drought and with a rapid rate of N mineralization, *V. trilobata* can be an excellent pioneer green manure crop for semi-arid regions. Being high-yielding and able to compete vigorously with associated weeds under rainfed conditions, it is also a promising pasture legume.

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K.C. Wong

Vigna vexillata (L.) A. Richard

Hist. fis. polit. nat. de Cuba (Spanish ed.) 11: 191 (1845).

LEGUMINOSAE – PAPILIONOIDEAE

$2n = 22, (20)$

Synonyms *Phaseolus vexillatus* L. (1753), *Plectrotropis angustifolia* Schumach. & Thonn. (1827), *Vigna tuberosa* A. Richard (1847).

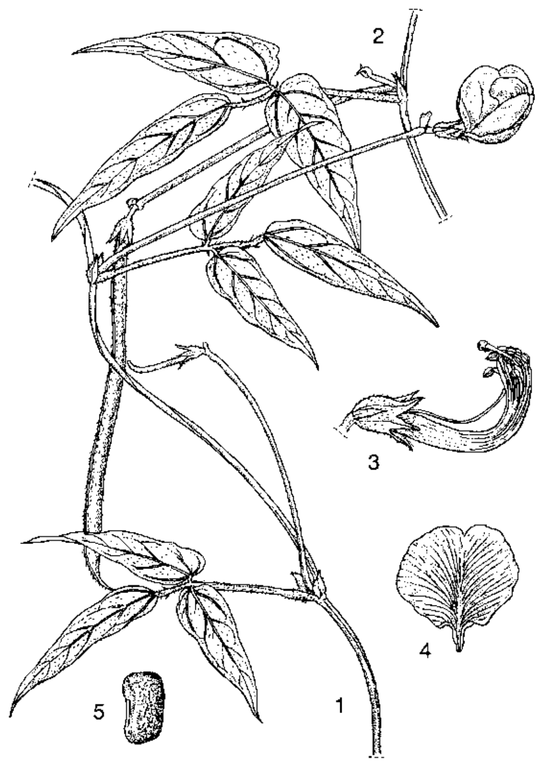
Vernacular names Wild mung bean, zombi pea (En). Pois zombi, pois poison (Fr). Indo-China: qua. Laos: thwàx phi:. Vietnam: qua (southern).

Origin and geographic distribution *V. vexillata* most probably originated in the Old World tropics. There are two centres of genetic diversity, one in Africa (from Tanzania to South Africa) and one in South-East Asia (from Yunnan (China) to Indonesia). It is now pantropical and occasionally it is also cultivated.

Uses *V. vexillata* is grown as a green manure, cover crop, erosion-controlling plant, and as a forage. The tuberous roots are eaten like sweet potatoes in north-eastern and southern India, Australia, Ethiopia, South Africa and the Sudan. In South Africa, the young leaves and young pods are also eaten as a vegetable. Seeds are eaten as a pulse e.g. in India.

Properties Per 100 g dry matter, an actively growing, flowering plant contains: crude protein 20.3 g, ether extract 6.1 g, nitrogen-free extract 37.2 g, crude fibre 26.4 g and ash 10.1 g. The corresponding digestibility values are approximately: dry matter 69%, crude protein 81%, crude fibre 62%, ether extract 74% and nitrogen-free extract 73%. A study conducted at this growth stage in south-eastern Queensland found it had one of the highest recorded dry matter intakes by sheep for tropical legumes, while N retention was second only to *Lotononis bainesii* Baker. Tubers contain per 100 g dry matter: protein 14.5 g, fat 0.9 g, carbohydrates 58.2 g, ash 3.8 g, Ca 58.5 mg, P 88.7 mg and Fe 1.0 mg. The seed contains large amounts of the dipeptide para-aminophenylalanine, a compound giving resistance against bruchids.

Description A polymorphic, perennial, climbing or trailing herb, up to 6 m long, with sparse to dense, brownish hairs, usually with a fusiform tuberous rhizome. Leaves trifoliolate, very variable, with silky hairs on both surfaces; petiole 1.5–11.5 cm long; stipules lanceolate-cordate, 0.5–1.3 cm long; rachis up to 3 cm long, petiolule 2–4 mm; leaflets very variable, ovate-lanceolate, elliptical or linear-oblong, 2–17 cm × 0.5–8.5 cm, apex acute or acuminate, base rounded, cuneate or truncate, usually entire but rarely slightly lobed. Inflorescence a 2–6-flowered, axillary raceme; peduncle 4.5–36 cm long; rachis very short, usually bearing 3 extrafloral nectaries; pedicel 1–2 mm long; flowers about 2.5 cm long, purple or pink, sometimes yellow or white; calyx



Vigna vexillata (L.) A. Richard – 1, flowering branch; 2, fruiting branch; 3, flower without corolla; 4, standard; 5, seed.

tubular, tube 5–7 mm long, bristly with long brown and short white hairs, ending in 5 lanceolate lobes up to about 2 cm long; standard asymmetrical, subcircular, 2.5–3.5 cm × 2–4 cm, emarginate, pale violet inside, yellowish outside; wings 2.5 cm long, purplish; keel asymmetrical, white or pale lilac, prolonged into a 180° incurved beak, twisted to one side; stamens 10, 1 free, 9 connate at base for 6–8 mm; pistil with upper half of style bearded and lateral stigma. Pod linear-cylindrical, 4–15 cm × 2.5–9 mm, 10–18-seeded, with brown bristly hairs. Seed globose to oblong reniform, 2.5–5 mm × 2–5 mm, plain brownish-green to black, or dark red with black speckles; aril hardly developed. Seedling with epigeal or hypogeal germination, depending on source of seed and variety.

Growth and development Seed takes about 8–10 days to germinate. *V. vexillata* produces excellent leaf growth and covers the ground quickly. Roots develop abundant N-fixing nodules. Flowering occurs 3–4 months after planting, and pods ripen 1 month later. In Costa Rica and South Africa, *Xylocarpa* bees play a role in the pollination. When the fruits are ripe, the tubers are also ready for harvesting.

Other botanical information Due to its great variability and wide distribution, many varieties and forms of *V. vexillata* have been described. The variability has been studied best for Africa; a thorough study for South-East Asia remains to be done. Three varieties seem most important in South-East Asia:
- var. *angustifolia* (Schumach. & Thonning) Baker: plants glabrescent or with sparse bristly hairs; leaflets very narrow, 4–8 cm × 0.5–1.5 cm; calyx lobes 2–8 mm long; occurring from Africa and India throughout South-East Asia to Australia, especially in areas with a long dry season.
- var. *macrosperma* Maréchal, Mascherpa & Stainier: stems rather thick, robust, leaflets ovate-elliptical, hirsute; pods 12–15 cm × 7–9 mm; seeds subglobose, 3.5–5 mm in diameter, yellow-green; widespread pantropically.
- var. *vexillata*: plants very densely ferruginous pubescent or bristly; leaflets ovate to lanceolate; calyx lobes up to 2 cm long; widespread pantropically; it is the most common form whose tuberous roots are used as food.

Ecology *V. vexillata* thrives in a wide range of conditions, e.g. in grassland, in disturbed areas and as a weed of cultivation. In India it flourishes from 1200–1500 m altitude in the foothills of the Himalayas and in the hills of eastern and north-eastern India. In Australia it grows in the far northern monsoon region with heavy summer rainfall (1250–1500 mm) followed by a very long, pronounced dry season, on very poor, lateritic, acid soils rich in aluminium. *V. vexillata* thrives during the rainy season and can withstand at least 6 months of waterlogged conditions. Although it is susceptible to frost and fire, it is one of the first plants to sprout after drought or fire, making the location of the tubers immediately apparent.

Agronomy Propagation is usually by seed, but is also possible by stem cuttings. Seed must be scarified to improve germination. Inoculation with appropriate *Rhizobium* and mixing with phosphate fertilizer prior to sowing improves establishment and growth. Seedlings grow vigorously. Planting densities vary according to the use of the crop. When grown for its tubers, it can be planted and treated much like Irish potatoes. *V. vexillata* is very sensitive to herbicides. When grown together with angleton grass (*Dichanthium aristatum* (Poiret) C.E. Hubbard), pangola grass (*Digitaria eriantha* Steudel) or para grass (*Brachiaria mutica* (Forssk.) Stapf), *V. vexillata* increases the N-content of the forage mixture significantly. *V. vexillata* develops more slowly in mixture with grasses, but maintains a high N-content longer than *Desmodium intortum* (Miller) Urban or *Pueraria phaseoloides* (Roxb.) Benth. In northern Australia, forage dry matter yields ranging from 300–1100 kg/ha have been obtained, depending on fertilization and soil type. In Zambia, dry matter yields of 2780 kg/ha have been achieved. Seed yields of 500–1250 kg/ha have been reported. Fresh tuber yields of 1.44 t/ha have been obtained in Nigeria.

Genetic resources and breeding Germplasm collections are being maintained at the Cowpea Breeding Program of the International Institute of Tropical Agriculture, Ibadan, Nigeria and at the Southern Regional Plant Introduction Station, Griffin, Georgia, the United States. The primary distinguishing attribute among the various varieties is the leaflet shape which appears to be simply inherited. Single, completely dominant gene action appears to control anthocyanin stem pigmentation, silver leaflet midrib, leaflet hirsuteness, presence of long hairs on the calyx lobes, black pod colour, speckled seed testa and twining stem habit. Width of the floral standard, peduncle length, number of seeds per pod, seed weight, tuberous root dry weight, total plant dry weight, and harvest indices for seed and tuberous roots all appear to be quantitatively inherited. In spite of the great variability, no difficulties have been encountered in obtaining F[illegible] and back-cross progenies involving crosses between accessions from Australia and Africa. No fertile interspecific crosses have been obtained so far.

Prospects With its wide ecological adaptability, ability to thrive on poor soils, tolerance of waterlogging, and spreading vigour, *V. vexillata* is an excellent pioneer for poor land as a cover crop, green manure or erosion-controlling crop. It may also prove to be a valuable tropical forage. The high protein content in the tuber makes it a promising protein food crop.

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K.C. Wong

3 Minor auxiliary plants

Acacia confusa Merrill

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Acacia richii* auct., non A. Gray, *Racosperma confusum* (Merrill) Pedley.

Vernacular names Philippines: ayangili, ualisen (Sambali). Vietnam: c[aa]y d[af]i loan t[uw][ow]ng t[uw].

Distribution Native to Taiwan and northern Philippines (Luzon, not clear whether indigenous, cultivated or naturalized); also cultivated in Thailand, Indo-China, Malaysia, Java, Sumatra and occasionally elsewhere.

Uses Grown as a green manure, shade tree and fodder crop.

Observations Tree, up to 10 m tall, trunk up to 1 m in diameter. Phyllodes alternate, linear-lanceolate, 6.5–10 cm × 5–9 mm, straight to slightly curved, usually with a hooked apex, leathery, glabrous, with 5 or more prominent, parallel veins. Inflorescence a globose head, 6–9 mm in diameter, single or paired in leaf axil; flowers numerous, pentamerous, yellow. Pod flat, linear, 4–10 cm × 7–10 mm, with 7–8 seeds. *A. confusa* is found on slopes and in dry forest at low altitudes. In Malaysia it is cultivated at 1000–1200 m altitude.

Selected sources 16, 48, 51, 84, 151.

Acacia elata A. Cunn. ex Benth.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Acacia terminalis* auct., *Racosperma elatum* (Benth.) Pedley.

Vernacular names Mountain hickory, (mountain) cedar wattle (En).

Distribution Originates from Australia (New South Wales), occasionally cultivated in Africa, India, Sri Lanka and Java.

Uses Planted for green manure in e.g. *Cinchona* plantations in Sri Lanka and West Java, where it grows well and fast. Wood pulp has proved to be excellent for making paper. Bark contains 20–31% tannin, used in South Africa. Also grown as ornamental.

Observations Unarmed tree up to 25 m tall. Branchlets terete, finely puberulous. Leaves bipinnately compound; petiole 8 cm long, with an elliptical gland halfway; rachis 11–17 cm long; pinnae 2–4 pairs, 8–14 cm long; leaflets opposite, subsessile, 8–14 pairs per pinna, ovate-oblong to ovate-lanceolate, 3–5 cm × 4–9 mm, both surfaces slightly appressed-puberulous. Inflorescence a pedunculate glomerule, 0.5 cm in diameter, arranged in axillary racemes or terminal panicles, whitish to light yellow. Pod oblongoid, 10–15 cm × 1.2 cm, 6–12-seeded. *A. elata* grows along rivers and in ravines.

Selected sources 8, 13, 49, 51, 70, 92, 101.

Acacia flavescens A. Cunn. ex Benth.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Racosperma flavescens* (A. Cunn. ex Benth.) Pedley.

Vernacular names Red wattle, yellow wattle (En).

Distribution Occurring naturally in Australia (coastal Queensland), and is cultivated in Papua New Guinea.

Uses Provides good, dense fuelwood. Suitable plant for erosion control in fire-prone areas. Foliage palatable to cattle. Bark contains 10–26% tannin. Wood attractively marked, close-grained, hard, brown.

Observations Unarmed straggling tree up to 10 m tall with straight stem and dark bark furrowed longitudinally. Branchlets angular with rather dense, grey-white, stellate hairs. Phyllodes ovate-falcate, 9–24 cm × 1–6 cm, with 3 prominent longitudinal veins, the upper 2 terminating at the margin with an indentation, usually with a gland. Inflorescence a globose head, grouped in terminal panicles 30 cm in diameter, each head consisting of up to 50 pale yellow flowers. Pod flat, somewhat winged, 6–12 cm × 1–2 cm, shining. Seed transverse, 6 mm × 4 mm, black, aril small and pale. *A. flavescens* coppices well, with vigorous regrowth from root suckers. It is found in coastal lowlands from 0–150(–1000) m altitude with 1000–2150 mm annual rainfall, on a wide range of soils (from sandy, well-drained, acid to neutral, to laterite ridges).

Selected sources 51, 146, 157, 170.

Acacia longifolia (Andr.) Willd.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Mimosa longifolia* Andr.

Vernacular names Sydney golden wattle, sallow (En).

Distribution Native to extratropical eastern Australia and Tasmania. Widely cultivated in the Old World Tropics, e.g. in mountain regions of West Java and in Indo-China.

Uses Planted for soil improvement, as a fast-growing cover crop and green manure. Useful as a nurse tree for establishing eucalypts on poor soil and for fixing dunes. It produces gum and the bark is suitable for tanning. Also a potential ornamental plant.

Observations Erect, unarmed shrub or small tree, 3–10 m tall. Young branches sharply triangular, older ones with angular ribs. Phyllodes variable in shape and size, oblong-lanceolate to narrowly linear, 4–16 cm × 3–25 mm, with 1-5 main veins. Inflorescence a loose, interrupted, simple spike, 1–3 per leaf axil, 2–5 cm long; flowers 4-merous, yellow, fragrant. Pod linear, straight or somewhat curved, 2.5–15 cm × 5–6(–10) mm, constricted between the 3–11 seeds; funicle thickened, arilloid. In Australia *A. elata* occurs mainly near the coast. It is considered invasive and weedy in South Africa, where it was introduced to stabilize dunes. It can be successfully controlled biologically by pteromalid gall wasps and curculionid weevils.

Selected sources 8, 13, 51, 58, 70, 138.

Acacia muricata (L.) Willd.

LEGUMINOSAE – MIMOSOIDEAE

Vernacular names Spineless acacia, ironwood (En).

Distribution Originates from the West Indies, introduced into many tropical countries.

Uses An alternative to *Leucaena leucocephala* (Lamk) de Wit where the latter is affected by psyllids.

Observations Deciduous, small tree up to 10 m tall, stem diameter up to 15 cm, crown thin. Bark grey, smooth. Twigs light green, spineless. Leaves bipinnate, alternate; rachis 5–12.5 cm long, with cup-like glands at the bases of 4–6 pairs of secondary axes 7.5–12.5 cm long; leaflets about 12 pairs, obliquely broad-ovate, sides unequal, midrib near one edge, apex and base truncate to rounded. Flowers in spikes near the apex of twigs before leaves unfold, 6 mm long, fragrant; calyx and corolla light yellow, 5-lobed; stamens white, exserted. Pod linear, flat, elliptical-oblong, 12–16 mm long, 1–2 per spike, 6–12-seeded. Wood hard, heavy, strong and durable. *A. muricata* is found in moist forest up to 330 m altitude.

Selected sources 63, 83.

Acacia oraria F. Muell.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Racosperma orarium* (F. Muell.) Pedley.

Vernacular names Indonesia: suli, kayu besi (Timor).

Distribution Australia (east coast of Queensland), Indonesia (Lesser Sunda Islands (Bali and Nusa Tenggara): Alor, Flores, Timor).

Uses Suitable for soil protection and as firebreak in savanna areas and for the control of *Imperata cylindrica* (L.) Raeuschel. The heavy and hard wood is locally used for house posts.

Observations Spreading tree up to 10 m tall, stem up to 50 cm in diameter, bark fibrous and fissured. Phyllodes alternate, thick, obovate-falcate, 4.5–11 cm × 1–4.5 cm, apex obtuse, base attenuate, with 3 prominent, longitudinal main veins. Inflorescence a globose head, 3–5 mm in diameter, arranged in axillary or terminal 3–5-branched racemes; flowers yellow, 5-merous. Pod flat, twisted or coiled when fully mature, 12 cm × 1–1.5 cm, brown. Seed black with large red translucent funicle. *A. oraria* often occurs along rivers and in coastal regions, up to 700 m altitude. It has been less successful in trials for fuelwood on poor soils in Java, and for weed control in teak plantations; its use has been restricted by its susceptibility to *Corticium salmonicolor*.

Selected sources 8, 51, 65, 87, 157.

Acacia pruinosa A. Cunn. ex Benth.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Racosperma pruinosum* (A. Cunn. ex Benth.) Pedley.

Vernacular names Frosty wattle (En).

Distribution Australia (New South Wales, Queensland). Occasionally cultivated elsewhere, e.g. in West Java.

Uses Occasionally grown for firewood in the mountains of West Java. No significance as fodder.

Observations Unarmed shrub up to 2 m tall. Branchlets terete, glabrous. Leaves bipinnate; petiole 3–5(–7) cm long with a gland in the distal half; rachis 2–7 cm long, reddish, glabrous, with glands at the junction of all or only the proximal pair of pinnae; pinnae 2–3(–4) pairs, 4–8 cm long; leaflets opposite, sessile, 8–13 pairs, oblong, 9–17 mm × 2–4 mm, obtuse, glabrous. Inflorescence a pale yellow head with 20–30 flowers, aggregated in terminal panicles or arising from the upper leaf axils. Pod strap-shaped, short-stalked, 5–8 cm × 0.8 cm, slightly constricted between the seeds, glaucous. Seed 5 mm × 3 mm, funicle expanded into a cupular aril. In Australia *A. pruinosa* grows on sandy soils derived from granite.

Selected sources 8, 10, 51, 62.

Acacia tomentosa Willd.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Mimosa tomentosa* (Willd.) Rottler, *Acacia chrysocoma* Miquel.

Vernacular names Indonesia: kolampis (Sundanese), klampis (Javanese), ai kendara (Sumba). Thailand: krathin-phiman (central), khaya, nam khao (northern). Vietnam: böröbu (southern).

Distribution Occurring naturally from India (Maharashtra, Gujarat) through Burma (Myanmar), Thailand, Indo-China to Indonesia (Java, Madura, Sumba, Sumbawa, Sulawesi).

Uses Grown as a ground-cover shrub and green manure, also providing fuel and utility wood. Leaves are browsed by goats and cattle. The red-brown bark is used for ropes and as a medicine for horses.

Observations Deciduous, armed tree with umbrella-shaped crown, 5–10(–18) m tall, stem diameter up to 50 cm, young parts densely yellow-hairy. Bark dark brown, irregularly fissured. Leaves and inflorescences on short shoots. Leaves bipinnate, with 7–25 pairs of pinnae; stipules spinescent, up to 4.5 cm long, straight; petiole 0.5–1 cm long with a gland just below the proximal pair of pinnae; rachis 3–9 cm long with glands on the junctions of 1–2 distal pairs of pinnae; leaflets 12–50 pairs, linear, 1–4 mm × 0.4–1 mm, opposite, sessile. Inflorescence a pedunculate glomerule, 1.5 cm in diameter, 1–7 in the axils of upper leaves, white or yellowish-white, fragrant. Pod curved, thin, 9–18 cm × 1 cm, 2–10-seeded. *A. tomentosa* is found in teak forest and coastal savanna and brushwood vegetation, up to 1000 m altitude. It is planted on bunds of rice fields and along roadsides.

Selected sources 8, 37, 51, 53, 70, 84, 149.

Adenanthera microsperma Teijsm. & Binnend.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Adenanthera pavonina* L. var. *microsperma* (Teijsm. & Binnend.) Nielsen.

Vernacular names Indonesia: sigawe (Java), sagawe (Bali). Malaysia: sigawe. Cambodia: chraèh phnôm, muntrèi. Laos: lam ta: kh'wa:y. Thailand: maklam-takai (northern), phai (peninsular). Vietnam: lim v[af]ng, mang lai, r[af]ng r[af]ng.

Distribution Occurring naturally in Burma (Myanmar), southern China, Indo-China, Thailand, Peninsular Malaysia, and Indonesia (Java, Lesser Sunda Islands (Bali and Nusa Tenggara)). Also occasionally cultivated.

Uses Shade tree for coffee and other tree crops (e.g. in Java) and ornamental.

Observations Tree up to 30 m tall, trunk up to 90 cm in diameter. Leaves pinnate; rachis 12–21 cm long, adaxially sulcate; pinnae 3–6 pairs, 6–11 cm long, puberulous; petiolules 1–2 mm long; leaflets 4–9 pairs per pinna, asymmetrically ovate-oblong to subtrapezoid, 1–3 cm × 0.5–2 cm. Inflorescence a raceme, 6.5–11.5(–25) cm long; pedicel 1.5–3 mm long; flowers yellow, 5-merous, bisexual; calyx shallowly campanulate; petals oblong, 2.5–3.5 mm long; stamens 10, free, 3–4.5 mm long. Pod about 15 cm × 1 cm, brown, 6–10-seeded, spirally contorted before dehiscence. Seed suborbicular to ellipsoid or broadly obovoid, 5–8 mm × 4.5–7 mm × 4 mm, bright scarlet. *A. microsperma* grows in dry evergreen and deciduous forest, and in forest margins, up to 600 m altitude. It flowers and fruits throughout the year.

Selected sources 8, 51, 53, 149, 165, 170.

Aeschynomene indica L.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Aeschynomene aspera* auct., non L., *A. diffusa* Klein ex Willd., *A. pumila* L.

Vernacular names Buddha pea (En). Indonesia: peupeuteuyan (Sundanese), dinding, katisan (Javanese). Cambodia: snaô ach mon (Kandal), snaô ba:y (Battambang). Laos: sanô:. Thailand: sano-hin, sano-kangkhok. Vietnam: d[aa]u ma (Hanoi), di[ef]n di[ef]n b[us]ng (An Giang).

Distribution Old World tropics, including South-East Asia; probably introduced into the Americas.

Uses In India and Indonesia used as green manure mainly in rice fields but also in tea plantations. Its wood ('sola wood') has a specific gravity of 0.04 and is the lightest wood known; it is sometimes wrongly considered as pith; it is used for handicraft, but is inferior to that of *A. aspera* L. *A. indica* is moderately palatable as a forage, even after plants have died, but it has been suspected of being toxic. It occasionally causes weed problems e.g. in Australia and India.

Observations Erect, branched, shrubby, annual herb, 0.5–2.5 m tall, glabrous. Stem hollow, at the base warty with stem nodules and coated with white aerenchyma. Leaves pinnate; stipules 6–7 mm long, extending below the leaf; rachis 5–7 cm long; leaflets 17–71, very close together, 3–15 mm × 1–4 mm, asymmetrical at base. Inflorescence an axillary raceme, 1–6-flowered, 2–5 cm long; calyx with shortly bifid upper lip, shortly trifid lower lip; standard 7–9 mm × 4–7 mm, yellow with purple streaks or patches. Pod stalked, 2.5–5 cm × 0.4 cm, 5–13-jointed. Seed reniform, 2–3 mm long, brownish. *A. indica* occurs mostly in wet sites, seasonally flooded or waterlogged grasslands, swamp margins, also on alkaline or saline heavy clay soils, up to 1000(–1600) m altitude. It forms aerial nodules on the stem with specialized *Rhizobium* spp. If its habitat is not waterlogged, the plant symbioses with vesicular-arbuscular mycorrhizal fungi and nodulates with *Rhizobium* spp.

Selected sources 4, 8, 17, 48, 52, 53, 62, 92, 113.

Ageratina riparia (Regel) R.M. King & H. Robinson

COMPOSITAE

Synonyms *Eupatorium harrisii* Urban, *E. riparium* Regel.

Vernacular names Mist flower, creeping crofton (En), hamakua pamakini (Hawaii) (Am). Indonesia: teklan (Sundanese).

Distribution Native to Mexico and the West Indies, now widely distributed in South-East Asia, Indo-China, India, Sri Lanka, Australia and Hawaii.

Uses *A. riparia* was spread mainly as an ornamental but has become a troublesome weed in Java, Thailand, India, Sri Lanka, Australia and Hawaii. In Java it is used as green material for composting, and as a cover crop to check erosion on slopes and terrace walls and the spread of *Imperata cylindrica* (L.) Raeuschel. Having strong antifungal properties it is used medicinally in Java and Sri Lanka. In southern Queensland it is suspected of causing mortality in horses feeding on it, via lung lesions resulting in chronic eosinophilic bronchiolitis.

Observations Erect, perennial shrub or herb, 0.5–1.0 m tall, with creeping stems, rooting at the nodes, hairy, becoming glabrous near the base. Leaves opposite; petiole 0.5–2.0 cm long, blade elliptical-lanceolate, 2–10 cm × 0.5–2.5 cm, margins sharply serrate in the upper part, nearly glabrous above, sparsely hairy beneath. Inflorescence a 12–15-headed, paniculate corymb; heads 15–20-flowered; flowers white, corolla 3.0–3.5 mm long, 5-lobed. Fruit an achene, linear-oblong, 1.5–2.0 mm long, 5-ribbed, ribs pubescent, narrow at the top, black. *A. riparia* occurs in South-East Asia between (250–)1000–2500 m altitude in shaded, humid locations, along watercourses and field boundaries, on slopes, in tea plantations and forest clearings. It is damaged by frost. It may produce up to 100 000 seeds per plant per year and 75% of fresh seed may germinate within a week. Germination is promoted by light and inhibited by burial. In some wet highland areas it has spread into pastures and reduced their carrying capacity considerably. *A. riparia* has allelopathic effects on crops. It is difficult to kill using herbicides only, but it can be controlled by brushing, followed by spraying with a herbicide, burning the area and sowing a leguminous cover crop. Biological control using white smut (*Entyloma ageratinae*) has been effective at 500–2000 m altitude in Hawaii.

Selected sources 5, 31, 37, 86, 155, 183.

Ailanthus excelsa Roxb.

SIMAROUBACEAE

Synonyms *Pongelion excelsum* (Roxb.) Pierre, *P. wightii* van Tiegh.

Vernacular names Tree of heaven (En).

Distribution India and Sri Lanka.

Uses Planted as a fuelwood and as a lawn tree to provide shade and to prevent erosion. The branches of mature trees are lopped for fodder. The timber is suitable for boat building, veneer and plywood, packing cases, toys, drums, fishing floats, and matches. The wood is suitable for the manufacture of paper but only with the addition of long-fibred material. The bark is used medicinally against asthma, bronchitis and dysentery.

Observations Medium-sized dioecious tree up to 24 m tall; bole up to 80 cm in diameter; bark pale grey. Leaves pinnately compound, up to 90 cm long, with 8–14 pairs of leaflets. Flowers small, yellowish, in panicles. Fruit a 1-seeded samara. The air-dry density of the yellowish-white wood is 335–480 kg/m^3. Seedlings of *A. excelsa* are avoided by cattle. It is suitable for planting in unfavourable rocky sites, does not tolerate waterlogged soils or high rainfall conditions and demands strong light. It is raised both from seed and stumps and is often planted along land boundaries and watercourses.

Selected sources 51, 61, 116, 149, 174.

Albizia carbonaria Britton

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Albizia sumatrana* Steenis.

Distribution Native to tropical Central and South America, introduced into India, Sri Lanka and Indonesia.

Uses Grown as a shade tree in tea plantations in Asia, in coffee plantations in Puerto Rico and Colombia.

Observations Tree up to 25 m tall and 60 cm in diameter, with flattened, spreading, thin crown. Bark light grey, scaly. Leaves alternate, bipinnate, 10–25 cm long; pinnae 8–17 pairs, 7–10 cm long; leaflets 15–25 pairs, oblong, 0.5–1 cm × 1.5 mm, base oblique or unequal, apex blunt, upper surface dull green, puberulous, lower surface paler. Flowers in many-headed clusters; calyx narrow, bell-shaped, hairy, 5-toothed, greenish; corolla 5 mm long, with narrow tube, 5-lobed. Fruit a 15–25-seeded pod, abruptly pointed at apex, short cuneate at base. *A. carbonaria* grows rapidly, is short-lived and its branches are fragile. The wood is pale brown and soft. In tea plantations in Indonesia it is grown up to 1300 m altitude.

Selected sources 8, 51, 94, 119.

Albizia odoratissima (L.f.) Benth.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Mimosa odoratissima* L.f., *Acacia odoratissima* (L.f.) Willd.

Vernacular names Black siris, fragrant albizia (En). Laos: du:x, du:x salen, kh'a:ng h'ung (Vientiane), len (Louang Prabang). Thailand: kang khi mot, ma kham pa (northern), khang-daeng (central). Vietnam: s[os]ng r[aaj] th[ow]m, x[us]a (Vinh Phu).

Distribution From India to Vietnam, including southern China, excluding Peninsular Malaysia. Its presence in Malesia is doubtful. It has been introduced into East Africa and is occasionally cultivated.

Uses Planted for erosion control, for soil conservation and as shade tree in coffee and tea plantations. Branches are lopped for fodder. Timber is used for indoor construction, furniture and decoration work. The tree produces an insoluble gum.

Observations Tree with dark green, drooping foliage, spreading crown and short trunk, up to 40 m tall. Bark yellowish-grey. Leaves bipinnately compound; rachis 7–20 cm long, bearing one lower gland 1–2 cm above the base, and one upper gland between the 2 distal pairs of pinnae; pinnae 3–5 pairs, 7–14 cm long; per pinna 10–16 pairs of oblong to obovate leaflets, 1.1–3.5 cm × 0.6–1.2 cm. Inflorescence a head, clustered into hairy terminal panicles 8–20 cm long; flowers 10–15 per head, dimorphic. Pod 16–22 cm × 3.5 cm, flat, leathery, brown, dehiscent, up to 14-seeded. Seed ovoid, 9 mm × 6 mm × 1.5 mm. *A. odoratissima* occurs in dry deciduous forest and evergreen hill forest, up to 1000(–1600) m altitude. The mean minimum temperature of the coldest month in its natural range is about 22°C, the mean maximum temperature of the hottest month about 33°C; absolute maxima may reach 49°C. Seedlings and young trees are frost-sensitive. Trees coppice well.

Selected sources 53, 61, 119, 149, 172, 174.

Andira inermis (W. Wright) DC.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Andira jamaicensis* (W. Wright) Urban, *A. excelsa* Kunth.

Vernacular names Angelin, cabbage tree, brown heart (En). Cabbage angelin, cabbage bark (Am). Angelin (palmiste) (Fr).

Distribution *A. inermis* occurs naturally in Central America from southern Mexico to western

Costa Rica and the West Indies, and in tropical Africa from Senegal to Sudan and Uganda. It has been introduced into botanical gardens in Singapore and Malaysia.

Uses In Puerto Rico *A. inermis* is widely grown as a shade tree in coffee plantations. Because of its very low branching, it has been proposed as a wind-break in Malaysia. The wood produces good timber. Smaller stems are used for poles. In the West Indies the bark is used as a vermifuge and the seeds are said to have purgative and narcotic properties. In Africa a decoction of the leaves is used as a beverage and for washing, and the fruit is eaten. The tree is regarded as a good honey tree and has also been planted for ornamental purposes.

Observations Deciduous tree up to 15(–30) m tall; bole usually short, in Malaysia reported to bear branches almost at base, but straight and cylindrical up to 50(–100) cm in diameter; crown columnar or pyramidal to spreading; bark fissured and scaly, with an unpleasant cabbage-like smell. Leaves alternate, imparipinnate, 15–40 cm long, with 7–17 leaflets. Flowers in much-branched panicles of 15–60 cm long; calyx bell-shaped, 3–5 mm long, purplish, with 5 small teeth; corolla 12–15 mm long, deep pink to purplish-red. Fruit a 1-seeded pod, fleshy outside, hard within, 4–8 cm × 3–5 cm. *A. inermis* grows in a wide range of habitats, from evergreen tropical rain forest to dry savanna vegetation, on well-drained sandy soils as well as on poorly drained clay soils, in plains and on hill slopes. It fixes nitrogen, but grows slowly. It is quite variable and several subspecies are distinguished.

Selected sources 45, 52, 69, 115, 125, 175.

Austroeupatorium inulaefolium (Kunth) R.M. King & H. Robinson

COMPOSITAE

Synonyms *Eupatorium pallescens* DC. *Inulaefolium* is often misspelled *inulifolium*.

Vernacular names Indonesia: ki rinyuh, ki papatong, babanjaran (Sundanese).

Distribution Of South American origin (Brazil). It has been found in Java since about 1900; it is occasionally cultivated in South-East Asia.

Uses *A. inulaefolium* is used as a hedge plant and to check erosion on slopes. It suppresses *Imperata* grass and can be used as a ground cover in *Pinus merkusii* Junghuhn & de Vriese, cinchona and tea plantations.

Observations Strongly branched perennial shrub, 2–6 m tall with hairy stem. Leaves opposite, ovate-lanceolate, margin toothed-serrate. Inflorescence terminal, many-headed; head short-pedunculate, 7–9-flowered, involucre with oblong-ovate scales, 2–3-seriate. *A. inulaefolium* is found from 200–1800 m altitude. Flowering occurs throughout the year. It can be propagated by cuttings. It is reported to contain pyrrolizidine, a probably hepatotoxic alkaloid causing death in cattle in Sumatra.

Selected sources 9, 70, 111, 153.

Ayapana triplinervis (Vahl ex Blume) R.M. King & H. Robinson

COMPOSITAE

Synonyms *Eupatoria ayapana* Vent. ex Millin, *Eupatorium triplinerve* Vahl ex Blume.

Vernacular names Pool root, white snakeroot (En). Indonesia: daun prasman (general). Philippines: ayapana (Pilipino), apana (Tagalog), inpana (Iloko). Cambodia: pang' kacha:t. Vietnam: c[aa]y b[ar] d[ooj]t.

Distribution Native to Brazil; introduced into Indonesia and the Philippines, locally naturalized in Java. It is occasionally cultivated and naturalized elsewhere (e.g. in India).

Uses Suitable as a ground cover in tea and rubber plantations. It is occasionally planted, but more often spontaneous and maintained by selective weeding. The leaves are used medicinally as a sudorific and a febrifuge against cold and diarrhoea, and are said to be effective against lung diseases. It is laxative when taken in quantity. A pale green essential oil is obtained by distilling the leaves.

Observations Perennial, tufted herb up to 100 cm tall. Leaves entire or with a few small remote teeth, lanceolate to narrowly oblong, 3–12 cm long, glabrous or with a few hairs. Heads arranged in umbels, 20–50-flowered, 6–7 mm long; involucre campanulate; corolla scarcely exserted from the involucre, reddish-violet with a greenish-white base. Achenes not developing in Java. *A. triplinervis* is found in secondary forest, in moist locations, up to 1600 m altitude. It can be easily propagated by cuttings or suckers.

Selected sources 8, 27, 86, 101, 107, 132, 174.

Cajanus scarabaeoides (L.) du Petit-Thouars

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Atylosia scarabaeoides* (L.) Benth.

Vernacular names Indonesia: dele rambat, kacang gude, kedelen (Javanese). Philippines: kidalis logua (Maranao); mangkitbagin (Tagalog). Thailand: thua-pi. Vietnam: d[aa]u t[uw][ow]ng d[aj]i (Hanoi), b[as]y n[owx] (Hué).

Distribution Widespread in South and South-East Asia and northern Australia, and spreading in Africa and the Caribbean.

Uses Component of ground cover and undergrowth in teak plantations and drought-resistant pasture. It improves barren rangeland, but its actual role as green manure is unknown.

Observations Prostrate herb or creeper-climber, puberulous. Leaves trifoliolate, petiole 4–20 mm, rachis 2–5 mm long. Leaflets obovate, 15–45 mm × 7–27 mm, coriaceous, with punctate glands below, sparsely white pubescent. Inflorescence a short, axillary raceme with 1–6 yellow flowers. Calyx up to 9 mm long, teeth lanceolate; standard obovate, sometimes with red veins. Pod oblong, 15–20 cm × 6–10 mm, constricted between the seeds, 2–6-seeded. Seed 4–5 mm × 2 mm, beetle-like because of the strophiole, greyish with black and cream mottle. *C. scarabaeoides* occurs in open grassland, dry scrub vegetation and deciduous monsoon forest as a drought-resistant element in the dry season, up to 1000 m altitude. It acts against diarrhoea in cattle. A long-peduncled variety is found in northern Australia.

Selected sources 48, 52, 53, 62, 162, 170, 174.

Canavalia cathartica du Petit-Thouars

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Canavalia ensiformis* (L.) DC. var. *turgida* Baker, *C. turgida* Graham ex A. Gray, *C. microcarpa* (DC.) Piper.

Vernacular names Malaysia: kacang rang-rang, kacang hantu. Philippines: dalakórak, danglin (Tagalog). Thailand: thua-krapao, thua-phi. Vietnam: d[aaj]u bi[eer]n, d[aaj]u c[ooj], (d[aa]y) qua qua.

Distribution Throughout tropical Asia, including South-East Asia, extending to East Africa, the Pacific and tropical Australia.

Uses *C. cathartica* is a sand binder on beaches. In Hawaii it is cultivated for its showy flowers. In Papua New Guinea the broad, white fibres from the stem are used to make carrying nets.

Observations Perennial climber, 3–10 m long. Stem sparsely pubescent or glabrous. Leaves trifoliolate; leaflets ovate or broadly elliptical to rounded, 3–20 cm × 2.5–13.5 cm, glabrous or sparsely pubescent. Inflorescence racemose, pendant, 4–12 cm long beyond a 10–22 cm long peduncle; flowers scented; calyx tube 9–11 mm long, upper lip 3 mm long, pubescent, green speckled with crimson when fresh; standard 2.5–3.5 cm long, magenta to purple, paler outside, wings and keel paler with white base; stamens 10, monadelphous. Pod oblong, 8–12 cm × 3–4.5 cm, curved, sutures not parallel, slightly inflated, indehiscent or tardily dehiscent, with 2 ribs along sutures and additional rib just below suture, often quite hairy when young. Seed oblong-ellipsoid, 14–18 mm × 9–12 mm, slightly compressed. *C. cathartica* occurs mainly in coastal habitats, sometimes on beaches intermingled with *C. maritima* (Aublet) du Petit-Thouars, but more commonly behind the beach in coastal thickets and coconut groves. It is occasionally found inland, up to 250 m altitude. The seed is not buoyant, but remains impermeable to water for at least 1.5 years.

Selected sources 8, 52, 53, 101, 141, 143, 170.

Canavalia maritima (Aublet) du Petit-Thouars

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Dolichos maritimus* Aublet, *Canavalia obtusifolia* (Lamk) DC., *C. rosea* (Swartz) DC.

Vernacular names Bay-bean (En). Indonesia: kekara laut, joa-joa dowongi (Moluccas). Malaysia: kacang rang-rang, kacang laut. Philippines: lagaylai, magtambokau (Bisayas), pataning-dagat (Tagalog). Thailand: kaitia, thua khla (Bangkok). Vietnam: d[aaj]u dao bi[eer]n, d[aa]y d[aaj]u.

Distribution Widespread along the sea coasts throughout the tropics and warm subtropics, except the Mediterranean.

Uses *C. maritima* is a spontaneous sand binder on beaches; it is occasionally cultivated as a cover crop in plantations.

Observations Perennial herb with trailing or climbing stem, 2–10 m long, becoming somewhat woody with age, silky hairy when young, glabrescent. Leaves alternate, trifoliolate; leaflets elliptical to nearly round, up to 12 cm × 10 cm, coriaceous, glabrous to sparsely pubescent. Inflorescence racemose, pendulous or upright, 4–18 cm long beyond a 10–21 cm long peduncle; flowers 2–3 together along rachis, pink-purple or mauve, sometimes bluish, often with white or yellow area; calyx campanulate, 11–14 mm long; standard rounded, 2–3 cm in diameter; stamens 10, monadelphous. Pod compressed-cylindrical, 10–17 cm × 2.5 cm, spirally dehiscent, sometimes explosively so, pale tan, with 2 ribs along sutures and a rib about 3 mm from ventral rib. Seed ellipsoid, 15–20 mm × 9–14 mm × 10 mm, slightly compressed, brown with darker markings. *C. maritima* occurs commonly on beaches and edges of coastal bushland, often in association with *Ipomoea pes-caprae* (L.) R. Br., occasionally inland along roadsides or lake shores. It flowers throughout the year, even in the subtropics. The seed is buoyant and impermeable to water.

Selected sources 8, 52, 53, 70, 101, 115, 143, 170.

Casuarina cunninghamiana Miquel

CASUARINACEAE

Vernacular names River she-oak, river oak, creek oak (En).

Distribution Native to northern and eastern Australia from southern New South Wales to northern Queensland, and cultivated in South America, tropical Africa and Thailand.

Uses Planted in wind-breaks and shelter-belts, to stabilize river-banks, and as an ornamental. In Thailand grown for firewood in *Imperata cylindrica* (L.) Raeuschel grasslands. The fairly heavy wood is also used for fishing poles, tool handles, ornamental turnery, shingles and bullock yokes. The foliage yields an excellent mulch. Leaves suitable for fodder in times of drought, though not very nutritious. A very adaptable species with good prospects.

Observations Dioecious, medium-sized to tall tree up to 35 m tall and 150 cm in diameter. Twigs needle-like, branchlets articulate, drooping in vigorous specimens, erect in depauperate ones. Leaves reduced to 8–10, commonly 9 'teeth'. Male flowers in terminal spike, female flowers in small, reddish cone. Fruit a compound cone-like structure, subglobose, 6–10 mm in length and width. In its natural area of distribution, *C. cunninghamiana* occurs mainly along watercourses between normal and flood levels, from sea level up to 1000 m altitude.

Selected sources 108, 117, 157, 173.

Casuarina glauca Sieber ex Sprengel

CASUARINACEAE

Vernacular names Swamp she-oak, swamp oak (En). Malaysia: ru paya (Peninsular).

Distribution Native to Australia in a narrow belt along the east coast, introduced into other areas for dry-land afforestation (e.g. Israel), planted in Singapore.

Uses Suitable for thick hedges on swampy or sandy soils, as pruning will encourage root suckers. Used for firewood in its native habitat and considered worth testing as a firewood crop elsewhere.

Observations Dioecious, medium-sized tree up to 15(–20) m tall and 60 cm in diameter. Twigs needle-like, branchlets spreading to drooping, up to 38 cm long, articulate, articulations 8–20 mm long, leaves reduced to 12–17(–20) 'teeth'. Male spike 1.2–4 cm long; female cone 9–18 mm × 7–9 mm. Fruit a compound cone-like structure, 1–2 cm × 1–1.5 cm. *C. glauca* occurs characteristically in the swampy margins of tidal areas.

Selected sources 34, 108, 116, 117, 152, 180.

Casuarina oligodon L.A.S. Johnson

CASUARINACEAE

Vernacular names Papua New Guinea: yar, soft yar.

Distribution Occurring naturally in the highlands of New Guinea, also cultivated.

Uses Commonly grown for fuelwood, charcoal, posts and small size timber. *C. oligodon* is strongly self-regenerating and is used in reforesting grasslands in the highlands of Papua New Guinea as it competes well with grasses such as *Imperata cylindrica* (L.) Raeuschel, *Saccharum robustum* Brandes & Jeswiet ex Grassl. and *Themeda australis* (R. Br.) Stapf. It is also planted as a shade tree in coffee plantations.

Observations Medium to tall tree, up to 30 m tall, trunk up to 60 cm in diameter. Bark grey-brown. Twigs needle-like, drooping, grooved; leaves reduced to 6 minute scales arranged in whorls. Male flowers in spikes at end of branchlets, consisting of 1 stamen surrounded by 4 scales; female flowers in ovoid heads. Fruit a small samara held in a woody cone less than 1 cm in diameter. *C. oligodon* fixes atmospheric nitrogen. It occurs at 1500–1800 m altitude where annual rainfall ranges from 1900–2600(–5000) mm and relative humidity is permanently high. It is mainly found on sandy soils along creeks, but grows well on many soils, unless poor or leached. Boron deficiency causes stunting. Propagation is mainly by seed, no root suckers arise, but epicormic shoots are produced after damage e.g. by fire. Branches are easily damaged by strong wind.

Selected sources 108, 117.

Centrosema plumieri (Turpin ex Persoon) Benth.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Clitoria plumieri* Turpin ex Persoon.

Vernacular names Butterfly pea (En). Pois piant, cocotte ferme (Fr). Indonesia: kacang katropong (Sundanese).

Distribution Native to tropical America, introduced into Africa, Papua New Guinea, Sri Lanka, where it is also found naturalized. It is occasionally cultivated pantropically.

Uses A shade-tolerant cover crop in plantations of cocoa, rubber, coconut and oil palm, now largely replaced by *C. pubescens* Benth. Used as green manure in sugar cane and in grassland improvement.

Observations Perennial trailing and winding herb, almost glabrous, woody at base. Leaves trifoliolate; leaflets ovate-elliptical, 5–7 cm × 2–13 cm, subglabrous. Inflorescence an axillary raceme with 1–10 flowers, up to 7 cm long; calyx 7–8 mm long; standard white or purple, pubescent, 4–6 cm in diameter. Pod 8–20 cm × 9–16 mm, beak 1–2.5 cm long, 4-ribbed. Seed up to 1 cm long, dark brown to black. *C. plumieri* nodulates well, but is not adapted to acid soils. Green manure yield is up to 16 t/ha. In Florida (United States), *C. plumieri* performed better than *C. pubescens*; in Belize (Central America) 'CF 16-1' was reasonably productive.

Selected sources 52, 70, 96, 101, 174.

Centrosema virginianum (L.) Benth.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Clitoria virginiana* L.

Vernacular names Spurred butterfly pea (En).

Distribution Widely distributed from the southern United States to Uruguay and Peru. Cultivated mainly in the United States, in subtropical Australia, and occasionally elsewhere.

Uses Grown as a green manure and cover crop for erosion control and as a component of pastures. It also has some value as an ornamental.

Observations Perennial, scandent herb with slender stems. Leaves alternate, trifoliolate; leaflets ovate-lanceolate, 2–7 cm × 1–3 cm. Inflorescence an axillary raceme, up to 6 cm long, 2–4-flowered; flower purplish to white, 2.5–4 cm long; calyx deeply 5-lobed, 8–10 mm long; standard suborbicular, 2–2.5 cm in diameter; stamens 10, monadelphous. Pod straight, 4–13 cm × 3–5 mm, 16–20-seeded. Seed 3–4 mm long, whitish. *C. virginianum* is mainly found in the semi-arid tropics and the subtropics, rarely in the humid tropics. Selections from the lowland tropics require high temperatures, growth being reduced when the night temperature falls below 16°C. Some selections from tropical highlands or the subtropics survive light frost. It nodulates well with commercial centro (*Centrosema pubescens* Benth.) *Rhizobium*. Cultivars have been developed in Australia as alternatives for siratro (*Macroptilium atropurpureum* (DC.) Urban).

Selected sources 32, 33, 50, 70, 144, 147.

Ceratophyllum L.

CERATOPHYLLACEAE

Major species and synonyms

- *Ceratophyllum demersum* L., synonym: *C. tuberculatum* Cham.
- *Ceratophyllum submersum* L.

Vernacular names Hornwort (En). Indonesia: kancil (Indonesian), ganggang (Javanese), ganggeng (Sundanese). Cambodia: sara:y 'ânndaèt, sara:y kântuy chhkaè. Thailand: sarai-khwai (Ayutthaya), sarai-phungchado, sarai-hangma (Bangkok). Vietnam: rong du[oo]i ch[os].

Distribution Cosmopolitan; found throughout South-East Asia. *C. demersum* is generally more common than *C. submersum*. The former is not yet recorded from Peninsular Malaysia, the latter only rarely.

Uses Suitable for improving the water quality of fish ponds and to attract harmful insects in rice fields so these can be destroyed. *Ceratophyllum* may be used to oxygenate waste water, but only after the organic wastes have been decomposed to soluble inorganic matter.

Observations Monoecious, submerged, rootless freshwater plants. Leaves in whorls of 6–10, forked 2–4 times, with serrate segments. Flowers axillary, solitary, small. Fruit oblong, compressed, with 1 apical and 2 basal spines (*C. demersum*) or with a single apical spine (*C. submersum*). Flowers are submerged and pollination takes place under water. Plants often remain vegetative, but flower frequently in shallow water near Jakarta. It occurs in stagnant pools, slow running streams, shallow lakes, often gregarious. In Malesia, it ascends to over 1500 m altitude.

Selected sources 44, 51, 70, 114, 148.

Chamaecrista lechenaultiana (DC.) Degener

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia lechenaultiana* DC., *C. mimosoides* L. subsp. *lechenaultiana* (DC.) Ohashi.

Vernacular names Japanese tea senna (En). Thailand: sa-kham-khom. Vietnam: nroj kua dis (Hmong).

Distribution Tropical South and continental South-East Asia, but introduced and sometimes naturalized in Malesia. Often also cultivated elsewhere in the tropics and subtropics.

Uses A self-seeding green manure, recommended for humid areas at low altitudes. It can be grazed by cattle and buffaloes. In Japan, leaves are used in the preparation of some kinds of tea called 'kobo-cha' and 'nemu-cha'.

Observations Herb with woody base, up to 1.5 m tall, upright or prostrate, branches grey to yellow-pubescent, suffused with red. Leaves sensitive to the touch, pinnately compound; rachis 5–12 cm long; leaflets 8–30 pairs, sessile, asymmetrical, sickle-shaped, 4–12 mm × 2–3 mm, margin ciliate, with a prominent purple gland just below the lowest pair. Inflorescence a 3–4-flowered, short raceme; pedicel 7–10 mm long; petals yellow, lanceolate to obovate, 6–15 mm long; stamens 10, with short filaments. Pod flat, straight, 3–5 cm × 0.5 cm, glabrous to hairy, dehiscent, with 10–15 flat-ovoid black seeds of 4 mm × 3 mm. *C. lechenaultiana* occurs in open grassland and as a weed, from 500–1600 m altitude in Indo-China, up to 300 m in West Java. It responds well to pruning. *Lechenaultiana* is often misspelled as *'leschenaultiana'*.

Selected sources 8, 27, 43, 51, 53, 70, 149, 170.

Chamaecrista mimosoides (L.) E. Greene

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia mimosoides* L., *C. angustissima* Lamk, *C. procumbens* auct., non L.

Vernacular names Patwa grass (En). Indonesia: tuturiyan (Sundanese), dinding (Javanese), palia tunggal (Sumba). Philippines: katanda (Bukidnon). Thailand: ya-kraduk-ueng, ya-nieolek. Vietnam: tra ti[eef]n (Phu Kanh).

Distribution Possibly indigenous to continental tropical South-East Asia, now pantropical.

Uses Self-seeding green manure, providing a light ground cover and stabilizing loose sandy soils. Opinions on usefulness vary. It has been recommended as a shade and cover plant in tea plantations at about 1500 m altitude in India, but is also considered a weed in India and Sri Lanka. It is edible for cattle, reportedly relished by giraffe and some species of antelope, but also referred to as unsuitable for fodder as it contains toxins such as chrysophenol, an anthraquinone. In India the root is used medicinally against stomach pains.

Observations Erect to decumbent herb or low shrub, up to 1 m tall with pubescent branches. Leaves sensitive to the touch, pinnately compound, with 20–80 pairs of leaflets; petiole 3–10 mm long, with sessile gland below lowest pair of leaflets; rachis 3–10 cm long; leaflets sessile, unequal-sided, linear, 4–8 mm × 1 mm, sparsely hairy along the margin. Flowers axillary, solitary or 2–3 together in a raceme; pedicel 5–10 mm long; petals bright yellow, obovate to orbicular, 4–10 mm long; stamens 7–10. Pod flat, strap-shaped, 3–6 cm × 0.5 cm, 10–20-seeded, glabrous to hairy, dehiscent. Seed brown, flat, 4 mm × 2 mm. *C. mimosoides* occurs in open woodland and grassland, up to 2300 m altitude. It flowers year round. *C. mimosoides* is closely related to *C. lechenaultiana* (DC.) Degener; its smaller leaflets are much more sensitive to the touch.

Selected sources 27, 43, 51, 52, 53, 70, 149, 170.

Chamaecrista nictitans (L.) Moench subsp. patellaria (Collad.) Irwin & Barneby var. ramosa (Vogel) Irwin & Barneby

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia patellaria* DC. ex Collad.

Distribution Native to tropical America, introduced locally into Java.

Uses Cover crop producing a good ground cover but limited amounts of green matter. Its actual usefulness is yet to be confirmed.

Observations Annual, softly pilose, sometimes subwoody herb up to 1 m tall. Leaves pinnately compound with 10–30 pairs of leaflets; petiole with a gland below proximate pair of leaflets; leaflets linear-oblique, 7–15 mm × 1.5–3 mm, midrib close to distal margin. Inflorescence an axillary or supra-axillary raceme with 1–4 flowers; pedicel 2–4 mm long; petals of unequal size, obovate or orbicular, 4–6 mm long; stamens 9, 4 large and 5 small ones. Pod strap-shaped, 2.5–3.5 cm × 3–4 mm, black, dehiscent, 6–10-seeded. Seed rhomboid, about 4 mm × 3 mm, glossy dark brown. This plant is naturally well-supplied with root nodules and is free from common pests. It is considered a weed in Brazil. It resembles *Chamaecrista mimosoides* (L.) E. Greene, but grows more slowly than *C. lechenaultiana* (DC.) Degener.

Selected sources 27, 43, 70, 78.

Chamaecrista pumila (Lamk) K. Larsen

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia pumila* Lamk.

Vernacular names Indonesia: enceng-enceng (Javanese). Thailand: makham-bia, makham din. Vietnam: me d[aas]t.

Distribution Throughout tropical Asia and Australia.

Uses A useful ground cover and green manure, competing well with weeds. It is recommended in tea plantations in Indonesia. In India it is considered a weed in e.g. sorghum.

Observations Procumbent or erect woody herb or shrub up to 50 cm tall with pubescent branches. Leaves pinnately compound with 10–25 pairs of leaflets, sensitive to the touch; petiole 3–7 mm long, with a long stalked gland between the lowest pair of leaflets; rachis grooved alongside, 2–5 cm long; leaflets opposite, sessile, sublinear, 7–12 mm × 2–3 mm, glabrous or with few hairs on the midrib, apex rounded with a long mucro. Inflorescence a short, supra-axillary raceme bearing 1–3 flowers; pedicel pubescent, 4–6 mm long; sepals lanceolate, 5–6 mm long; petals bright yellow, unequal, oblong, 2–3 mm long with a short claw; stamens 5, subequal; ovary hairy. Pod flat, strap-shaped, 2–5 cm × 0.5 cm, dehiscent, 10–15-seeded. Seed flat, subrhomboidal, about 3 mm long, brown, smooth. *C. pumila* is often found on sandy soils near the coast, along roadsides, in dry deciduous forest, but also as a weed in rice fields, up to 300 m altitude in monsoon regions. Transplanting nursery-sown plants is preferable to direct sowing. Weeding several times after planting is required. Plants cover the soil after about 10 weeks and start flowering 6 weeks later. They can be dug in when starting to die off, after about 1 year.

Selected sources 8, 9, 43, 51, 53, 89, 97, 149.

Christia obcordata (Poiret) Bakh.f.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Hedysarum obcordatum* Poiret, *Lourea reniforme* (Loureiro) DC.

Vernacular names Indo-China: gop tölang-a. Thailand: phisua (Bangkok), sansai (northern).

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

Uses A productive leguminous cover crop grown in southern Japan. It has been tested in Malaysia.

Observations Perennial, rhizomatous, creeping herb, branches thread-like, up to 1 m long, pubescent. Leaves with 1–3 leaflets; petiole filiform, 1–3 cm long; terminal leaflet obcordate or rounded, reniform if single, 3–20 mm × 5–30 mm, with sparse long hairs on both sides; lateral leaflets obovate to rounded, 3–18 mm in diameter. Flowers in a terminal or axillary raceme 4–30 cm long; pedicel up to 6 mm long in fruit; calyx campanulate, hairy, 5–7 mm in fruit, with 5 triangular lobes; corolla violet or pink, nearly included in calyx; standard obovate, about 7 mm long. Pod included in the calyx, glabrous, brownish, with 2–5 rounded articles, each about 2 mm in diameter. *C. obcordata* occurs on dry slopes and roadsides, in grasslands and open vegetation up to 1000 m altitude.

Selected sources 8, 27, 48, 53, 170.

Clibadium surinamense L.

COMPOSITAE

Synonyms *Baillieria aspera* Aubl., *Clibadium asperum* (Aubl.) DC., *C. surinamense* L. var. *asperum* (Aubl.) Baker.

Vernacular names Jackass breadnut (En).

Distribution Native to Central and tropical South America; introduced and sometimes naturalized in other tropical areas.

Uses Suitable as a ground cover to reduce erosion. Also used as a fish poison.

Observations Shrub up to 6 m tall. Leaves opposite, ovate to ovate-oblong, 6–15 cm long, long-acuminate at the top. Inflorescence a head, corymbose, clustered, sessile, with few female ray-flowers and bisexual disk-flowers; involucre campanulate; corolla white; achene hirsute at the top. *C.*

surinamense occurs in South-East Asia as a weed in mahogany and rubber plantations. It is grown in combination with *Centrosema* spp. in Indonesia.

Selected sources 101, 130.

Clitoria laurifolia Poiret

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Clitoria cajanifolia* (Presl) Benth., *Martiusia laurifolia* (Poiret) Britton & Wilson.

Vernacular names Laurel-leaved clitoria, butterfly pea (En). Indonesia: urek-urekan (Javanese), kacang cepel (Sundanese). Malaysia: pepipam, rumput turi hutan.

Distribution Native to Central and tropical South America. Distributed and naturalized widely in the tropics since the 19th Century, particularly in South-East Asia.

Uses Widely grown as a green manure and cover crop in rubber and coffee plantations, and in contour strips to control erosion. Sometimes cultivated for fodder. In Indonesia the leaves are used to cure pimples.

Observations Perennial shrub with deep, woody roots. Stem semi-decumbent or erect, 20–90 cm tall, appressed-pubescent. Leaves trifoliolate, 5–10.5 cm long; petiole up to 5 mm long; leaflets oblong, 3–10 cm × 2 cm, glabrous above, sparsely puberulous below. Inflorescence a 1–2-flowered, axillary raceme; peduncle up to 4 cm long; calyx tubular, 2–3 cm long, lobes ovate or ovate-lanceolate; corolla purple to nearly white, 5–6 cm long. Pod linear-oblongoid, 2.5–5 cm × 8 mm, stipitate, glabrous, 3–7-seeded; valves convex, ridged. Seed globose to ovoid-globose, viscid, about 3 mm long, yellow-brown. *C. laurifolia* is common in thickets and open sites, along roadsides and on slopes, especially on sandy and red clay soils. It requires a humid, lowland tropical climate with about 2000 mm annual rainfall, but 500 mm is also reported. The sticky seed is often distributed by cattle. When cultivated, it is mostly broadcast, sometimes sown in rows. It requires little care once established.

Selected sources 8, 27, 47, 53, 70, 101.

Crotalaria alata Buch.-Ham. ex D. Don

LEGUMINOSAE – PAPILIONOIDEAE

Vernacular names Malaysia: kacang hantu darat. Laos: hingx ma:z, hingx ha:y (Louang Prabang). Thailand: hingmen noi, hinghoi (northern). Vietnam: drieo-atau (southern).

Distribution From Nepal and southern China throughout South-East Asia to New Guinea. Introduced and widely spread in Africa; occasionally cultivated elsewhere.

Uses A good green manure and cover crop, suitable as a mulch. It has been planted in contour hedges and has been reported as suitable for fodder, but in Queensland it is considered poisonous for cattle. Monocrotaline in the seeds may cause death in poultry.

Observations Suberect annual, up to 1 m tall. Branches ascending, with fine, long, spreading hairs. Leaves simple, elliptical to oblong, 4–9 cm × 1–3 cm, irregularly hairy on both sides; petiole 1–4 mm long; stipules continuing down the stem as a wing, 2–5 mm wide, apex hooked. Inflorescence a terminal or axillary raceme, 5–15 cm long, 4–12-flowered; bracts 4–8 mm long; calyx 2-lipped, 9–14 mm long, densely pubescent; corolla 9–14 mm long; standard elliptical-obovate, pale yellow, subglabrous; wings and keel about 8–10 mm long. Pod subcylindrical, 4–5 cm × 0.9–1.2 cm, glabrous, stipe 8–10 mm long. Seeds many, obliquely heart-shaped, 3–3.5 mm long, brown, smooth. *C. alata* occurs in pronounced monsoon areas, often as a weed, near the sea coast on sandy soils, also along rivers on rocky and peaty soils, up to 1500 m altitude. It is tolerant of fire and shade and deep-rooting.

Selected sources 27, 52, 53, 70, 101, 126, 170.

Crotalaria brevidens Benth.

LEGUMINOSAE – PAPILIONOIDEAE

Synonym *Crotalaria intermedia* Kotschy.

Vernacular names Slenderleaf crotalaria (En).

Distribution Africa, from northern Nigeria to the Sudan, Ethiopia and around Lake Victoria; introduced into South-East Asia and the Americas, naturalized in Hawaii.

Uses A cover crop and green manure, also grown as a fodder crop. It is generally considered non-toxic, although some forms contain toxins and reduce nematode populations in subsequent grass crops. The young leaves have a high protein content and are eaten as a vegetable in Kenya. Seeds contain a gum extractable by dry milling.

Observations Annual or short-lived perennial, rather variable herb, 0.5–2 m tall, branches numerous, with short appressed to spreading hairs. Leaves trifoliolate; petiole 2–6 cm long; leaflets linear to elliptical, 4–14 cm × 0.3–3.3 cm, puberulous below. Inflorescence a 10–50 cm long, terminal raceme, many-flowered; bracts linear, expanded at the base, 1–3.5 mm long; calyx becoming truncate at the base, deflexed against the pedicel, 3–8 mm long, hairy to glabrous; standard ovate to elliptical, clear yellow or cream with red-brown veins; wings and keel 1.2–2.4 cm long. Pod subsessile, narrow-cylindrical, curved at the ends, 3.5–5 cm × 0.5–0.7 cm, pubescent, with up to 80 seeds. Seed oblique-cordiform, up to 3 mm long, pale yellow or orange, smooth. *C. brevidens* is found in open and wooded grassland and seasonal swamps, from 600–2700 m altitude, sometimes ruderal. It is an active nitrogen-fixer.

Selected sources 47, 52, 126, 131, 136.

Crotalaria goreensis Guill. & Perr.

LEGUMINOSAE – PAPILIONOIDEAE

Vernacular names Gambia pea (En).

Distribution Widespread in tropical Africa, introduced into Asia, Australia and South America.

Uses Used as green manure for tobacco and sugar cane in Australia (Queensland). It has performed well in New Guinea.

Observations Annual or short-lived often bushy perennial, up to 2.5 m tall. Stem finely ribbed, densely covered with minute, appressed or spreading hairs. Leaves trifoliolate; petiole 3.5–6.5 cm long; stipules oblong-falcate, unequal-sided, 10–25 mm long; leaflets linear-oblanceolate to obovate, 2.5–8.5 cm × 0.8–2.5 cm, appressed-pubescent. Inflorescence a raceme, up to 24 cm long, many-flowered; calyx 3–5 mm long, hairy, lobes triangular, as long as the tube; standard ovate, yellow with orange, brown or purple; keel 8.5–10 mm long, wings a little shorter. Pod subsessile, oblong-ellipsoid, 15–20 mm × 7–9 mm, sparsely hairy, 12–16-seeded, brown or purplish. Seed oblong-reniform, about 4 mm long, minutely granulate, yellowish. *C. goreensis* is self-pollinating and nodulates well. It occurs in deciduous woodland and grassland and on disturbed soil, where ample moisture is available, at 600–1200 m altitude.

Selected sources 14, 52, 62, 92, 126, 170.

Crotalaria incana L.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Crotalaria pubescens* Moench.

Vernacular names Woolly rattlepod (En). Indonesia: orok-orok kebo (Java), jojorore (Ternate). Philippines: balai laua, putok-putokan (Tagalog). Thailand: hingmen-luang.

Distribution Occurring naturally in tropical South America and the Caribbean, now pantropical, including South-East Asia.

Uses Green manure, promising in coffee. It is found as a weed in oil-palm and rubber plantations. Cattle avoid eating it. Its cultivation was discontinued in Bogor, Indonesia, because it was attacked by insects. Toxins include pyrolizidine alkaloids. Flowers and unripe fruits are used as abortifacient in Paraguay, where the pods are a magic cure for mute and stuttering children.

Observations Annual, variable, bushy herb up to 1.5(–3.5) m tall and variously hairy. Leaves trifoliolate; stipules filiform, up to 2 cm long; petiole usually longer than leaflets; leaflets obovate, elliptical or rounded, 2.5–5 cm × 1.7–4.4 cm, thinly hairy below. Inflorescence a lax raceme, 10–30 cm long, 12–30(–60)-flowered; calyx 7–11 mm long, subglabrous to hairy, lobes about twice as long as the tube; standard elliptical, yellow, reddish-brown or purple veined, subglabrous; wings as long as the keel, 8–11.5 mm long; keel bent at a right angle in lower half, woolly hairy on the upper margin. Pod spindle or club-shaped, subsessile, 3–4.5 cm × 8–12 mm, hairy, 40–50-seeded. Seed obliquely heart-shaped, about 3 mm long, smooth or faintly papillose, pale brown, olive-green or mottled. *C. incana* is found in deciduous bushland, grassland, dry stream beds, river banks and as a weed in fields and waste places, usually preferring moist sites, up to 2300 m altitude.

Selected sources 8, 27, 48, 52, 53, 62, 70, 126, 170.

Crotalaria laburnifolia L.

LEGUMINOSAE – PAPILIONOIDEAE

Vernacular names Bird flower, velvety rattlebox (En). Pistache marron (Fr). Thailand: kinghai, tinghai (central).

Distribution Originally from eastern to southern Africa, now introduced and occasionally naturalized in tropical Asia and Australia.

Uses Green manure with good leaf production, but suffering from pests and soon becoming woody and probably no longer used. It is sometimes planted as an ornamental in Sri Lanka. Medicines prepared from the seed purify blood, and are used to treat sore throats and skin diseases and as an emmenagogue. Pyrolizidine alkaloids like anacrotine and madurensine have been extracted from the seeds in South Africa, the former being antispasmodic and possibly hepatotoxic. Seed also contains flavanone glycosides.

Observations Perennial, woody, very variable herb, 0.6–2 m tall, branches glabrous to sparsely pubescent. Leaves trifoliolate; petiole up to 13 cm long; leaflets narrowly oblong to elliptical, 1–10.5 cm × 0.5–5.5 cm, glabrous to hairy. Inflorescence a lax raceme, up to 50 cm long, many-flowered; calyx 1.2–1.7 cm long, subglabrous; standard ovate, 1.5–2 cm × 2–3 cm, yellow, red-veined; keel 2–3 cm long, strongly rounded with truncate beak, 1.5–2 times as long as the wings. Pod subcylindrical, 4.5–15 cm × 1 cm, on a stipe 2–10 cm long, glabrous, often mottled reddish when young. Seed obliquely heart-shaped, 4–5 mm long, brown or yellow-brown. In South-East Asia *C. laburnifolia* is often found near sea shores, in Africa in deciduous woodland, grassland, along roadsides and in fields, up to 1800 m altitude.

Selected sources 27, 52, 70, 92, 126, 174.

Crotalaria quinquefolia L.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Crotalaria heterophylla* L.f.

Vernacular names Tcha-tcha (En, Fr). Philippines: buli-laua, katanda (Tagalog), palpaltog (Ilokano). Cambodia: chângrô:ng sva: (Battambang). Thailand: hinghoi (northern). Vietnam: s[uj]c s[aj]c cao (Lâm Dông).

Distribution From India throughout South-East Asia to Australia; introduced and distributed pantropically.

Uses Excellent green manure, but heavily attacked by pests in Java during later stages of growth and producing hardly any seed. Cover crop and green manure in India and Vietnam. The flowers are eaten steamed as a vegetable. Pods are used for treating snake and millipede bites. Monocrotaline in the seed is toxic to poultry, occasionally fatal. As in other *Crotalaria* spp., the bark contains fibres.

Observations Annual herb or subshrub up to 2 m tall with few angularly furrowed branches. Leaves palmately 5-foliolate; stipules sickle-shaped, 2–5 mm long, persistent; petiole 1–6 cm long; leaflets linear-oblong, 3–8 cm × 0.5–1.5 cm, glabrous above, hairy below. Inflorescence a lax, terminal raceme, 10–20 cm long, rarely leaf-opposed; pedicel 5–10 mm long; calyx campanulate, 12 mm long, glabrous, with oblong mucronulate lobes of similar size; corolla yellow, pink-violet veined, larger than calyx; standard almost round, about 2 cm in diameter; wings oblong, about 17 mm × 8 mm; keel 16 mm × 9 mm, incurved in the middle. Pod cylindrical, compressed, 5–6 cm × 1–2 cm, glabrous, brown, up to 30-seeded. Seed reniform, about 4 mm × 3.5 mm, brownish, papillate. *C. quinquefolia* is found in open forest, swampy locations and ruderal sites, up to 900 m altitude.

Selected sources 8, 27, 53, 62, 70, 101, 170.

Crotalaria retusa L.

LEGUMINOSAE – PAPILIONOIDEAE

Vernacular names Devil bean, large yellow rattlebox, wedge-leaved crotalaria (En). Indonesia: orok-orok cina (Java), duku todore (Halmahera). Malaysia: giring badak. Philippines: buli-laua, potokan (Tagalog), palpaltog (Ilokano). Cambodia: chhë: krông sva: (Kampot), tra:ch kuël'.

Distribution Probably of Asian origin, now pantropical, also cultivated.

Uses Green manure and fibre crop, but it also occurs as a weed. Roots are used against coughing up blood, leaves mixed with those of *C. quinquefolia* L. act internally as well as externally against fever, scabies, lung diseases and impetigo. Flowers and leaves are sweet, edible as a vegetable, their alkaloid content being very low. The roasted dehulled seeds are eaten in Vietnam. It is also reported to yield toxins, such as the alkaloid monocrotaline and to have poisoned poultry and livestock in Nigeria. It is occasionally grown as an ornamental, and is used as a dye plant in East Africa.

Observations Annual herb or subshrub up to 1.2 m tall. Branches glabrous to appressed hairy. Leaves simple; blade oblanceolate to oblong, 3–10 cm × 1–4 cm, apex rounded or emarginate, glabrous above, silky pubescent below. Inflorescence an erect, terminal raceme, 15–30 cm long; pedicel 4–8 mm long; calyx about 10–14 mm long, subglabrous, upper teeth ovate, acute, 3 lower teeth narrower; corolla 2.5 cm long, yellow, tinged purple. Pod subcylindrical, 2.5–5 cm × 1–2 cm, glabrous, stipitate, 15–20-seeded. Seed heart-shaped, 5 mm × 3 mm, yellow-brown to blackish. *C. retusa* occurs in coastal grassland, along rivers, waste places and fields, up to 250 m altitude. It fixes nitrogen and is self-pollinating. The seed-coat is hard, and germination irregular. It is full-grown in two months. Damage caused by pests is common, but it is resistant to root-knot nematodes.

Selected sources 8, 52, 53, 62, 113, 126, 170, 174.

Crotalaria valetonii Backer

LEGUMINOSAE – PAPILIONOIDEAE

Distribution Originated in Indonesia (Java, Madura); occasionally also cultivated elsewhere.

Uses In the past grown as a green manure and cover crop in coffee and tea plantations, but its present use is not well known.

Observations Fast-growing subshrub up to 1 m tall. Branches rounded with long reddish hairs. Leaves simple, oblong, 3.5–9 cm × 2–4 cm, rounded-mucronulate at the apex, appressed hairs on both sides; petiole 2–5 mm long, hairy; stipules caducous. Inflorescence a terminal, almost horizontal, leaf-opposed raceme with 6–12 flowers; pedicel 5–8 mm long, with long hairs; calyx campanulate, tube 1–2 mm long, long-hairy, teeth sharply triangular, 9–13 mm long; corolla 17–20 mm. Pod ovoid-ellipsoid, 15 mm × 7 mm, hairy, stalked, 1-seeded. Seed heart-shaped, 4.8 mm × 3 mm, black. *C. valetonii* occurs in sunny dry locations, up to 150 m altitude. It also tolerates humid conditions. Under dry conditions it sets seed after 6 months and may live up to 1.5 years.

Selected sources 8, 53, 70, 101.

Crotalaria verrucosa L.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Crotalaria caerulaea* Jacq.

Vernacular names Blue rattleweed, purple rattlebox, warty crotalaria (En). Malaysia: gegiring jantan. Philippines: bulai laua (Tagalog), gulinggam (Sulu), reging (Bagobo). Burma (Myanmar): hing hai bay yai. Cambodia: voë(lli) châ:ng, khnâ:ng prâmat' (Pursat), châ:ngkrâ:ng tma:t. Laos: (ko: hnha:z) lem (Houa Pan). Thailand: kraphohphi (south-eastern), makhing-nu (northern), hinghai-baiyai (central). Vietnam: s[uj]c s[aj]c (southern).

Distribution Originating from tropical Asia, now pantropically distributed.

Uses Green manure. Roots are used against fever (Cambodia, Laos) and stomach pain (Vietnam). Used in India to purify blood, to cure skin diseases, and as emmenagogue. It produces a neutral seed-gum polysaccharide and the flowers produce kaempferol. Seed caused liver damage to test animals. It is a potential ornamental.

Observations Annual, subwoody herb, 0.5–1 m tall, with many quadrangular, velvety hairy, yellow branches. Leaves simple, ovate to elliptical, 5–14 cm × 4–9 cm, pubescent; petiole 4–8 mm long; stipules sickle-shaped, 5–20 mm × 4–14 mm, auricled, persistent. Inflorescence a lax raceme, 5–25 cm long, leaf-opposed, with up to 24 flowers; pedicel filiform, up to 5 mm long; bracts linear-acuminate, 4 mm long; calyx campanulate, 7–11 mm long, hairy, with subequal triangular-acuminate lobes; corolla blue; standard elliptical to suborbicular, 14 mm in diameter; wings ovate-oblong, 13 mm × 6 mm; keel 12 mm × 6 mm, incurved in the middle. Pod oblongoid, 3–5 cm × 0.8–1.2 cm, short stalked, about 16-seeded. Seed heart-shaped, 3 mm in diameter, blackish. *C. verrucosa* is found in fallow fields and on marshy ground, along rivers and roads, up to 1200 m altitude. It fixes nitrogen and is self-pollinating.

Selected sources 8, 48, 52, 53, 62, 96, 126.

Cyperus pedunculatus (R. Br.) Kern

CYPERACEAE

Synonyms *Mariscus pedunculatus* (R. Br.) Koyama, *Remirea maritima* Aubl., *R. pedunculata* R. Br.

Vernacular names Indonesia: teki laut (general), suga (Sula), takiu gumi-gumini (Northern Halmahera).

Distribution Pantropical; found throughout South-East Asia.

Uses Suitable to bind coastal sands and dunes. Dried plants are used in perfumes for their pleasant odour. An infusion of the root is said to be used in Brazil and Guyana as a sudorific and diuretic. The rhizome is astringent and diuretic.

Observations Slightly succulent herb with erect stems, 3–12 cm tall; rhizomes long, creeping. Leaves crowded, thick, canaliculate. Inflorescence consisting of 3–7 congested, sessile, ovoid or ellipsoid spikes each with about 30 spikelets. *C. pedunculatus* is locally abundant on sandy shores and dunes along the coast. There is some dispute whether to treat this species as a monotypic section within the genus *Cyperus* L. or as the monotypic genus *Remirea* Kerr.

Selected sources 51, 70, 74, 174.

Cyperus pilosus Vahl

CYPERACEAE

Synonyms *Cyperus obliquus* Nees, *C. pauciflorus* Steud., *C. piptolepis* Steud.

Vernacular names Indonesia: hilut (Sundanese), lambungan sapi (Javanese), rumput jeking (Indonesian). Malaysia: madarong darat (Peninsular). Philippines: paragi (Subanun). Vietnam: c[os]i l[oo]ng.

Distribution From western tropical Africa, north-eastern Africa, central Asia and Japan through tropical Asia towards tropical Australia.

Uses Ploughed in and used as a green manure in rice fields. It is eaten by cattle.

Observations Perennial, rhizomatous herb with slender stolons, up to 50(–110) cm tall. Inflorescence with rayed spikes and hispidulous rachises 2–3 cm long; spikelets 6–25 per spike, 2–2.5(–3) mm wide; glumes muticous; style with 3 stigmas. *C. pilosus* occurs in open wet sites, swamps, grasslands, on river banks, up to 1500 m altitude. Sometimes a troublesome weed and removed manually. It is closely related to *Cyperus procerus* Rottb., which it resembles.

Selected sources 27, 51, 75, 107, 150.

Cyrtococcum Stapf

GRAMINEAE

Major species and synonyms

- *Cyrtococcum accrescens* (Trin.) Stapf, synonym: *Panicum accrescens* Trin.
- *Cyrtococcum oxyphyllum* (Steud.) Stapf, synonyms: *C. pilipes* (Nees & Arn. ex Buse) A. Camus, *Panicum oxyphyllum* Steud., *P. pilipes* Nees & Arn. ex Buse.
- *Cyrtococcum patens* (L.) A. Camus, synonyms: *Panicum carinatum* Presl, *P. patens* L., *P. warburgii* Mez.
- *Cyrtococcum trigonum* (Retz.) A. Camus, synonym: *Panicum trigonum* Retz.

Vernacular names Indonesia: kasup (Sundanese), emprit-empritan ijo (Javanese), kamokamoro (Moluccas). Malaysia: rumput telur ikan, rumput metebong, rumput pahit (Peninsular). Philippines: malakauayan, tuad-tuaran, banig-usa (Tagalog). Thailand: ya-ngat (Trat), ya-rat (Satun), ya-yung (Chiang Mai). Vietnam: chi c[aaf]u d[ix]nh, c[of] cung.

Distribution From East Africa to Sri Lanka, India, China, Japan, Indo-China, and the Malesian region towards Australia and the Pacific islands.

Uses *Cyrtococcum* species have some value for erosion control in timber and tea plantations. They are readily eaten by cattle.

Observations Decumbent or prostrate perennial grasses up to 120 cm tall. Leaves up to 2 cm wide. Spikelets in large panicles, strongly laterally compressed, with one sterile and one fertile floret, distinctly gibbous at base, awnless; lower and upper glume unequal to subequal. The various species are found in shaded to heavily shaded sites on not too dry soil. Their nutritional value as forage is low.

Selected sources 19, 27, 36, 68, 70, 81, 91, 107, 148.

Desmodium tortuosum (Swartz) DC.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Desmodium purpureum* (Miller) Fawcett & Rendle.

Vernacular names Florida beggarweed, (twisted) tick trefoil, sweetheart (En). Indonesia: potong kujang.

Distribution Native to the Caribbean and Central America, introduced into Africa, Asia and Australia. In South-East Asia sometimes naturalized, e.g. in Indonesia (Java).

Uses Green manure and cover crop, covering the ground quickly and competing well with weeds. A digestible forage, used for hay or as a browse; also a weed in e.g. groundnut. Appreciated in coconut plantations in Tamil Nadu, India, and as goat fodder in the Caribbean. As suitable as lucerne in protein supplement for poultry feed. At present its popularity seems to be waning.

Observations Annual or perennial herb or shrub up to 1.5 m tall. Branches striate, hairs fine and dense. Leaves trifoliolate; petiole longer than leaflet, stipules lanceolate, 6–15 mm long; leaflets ovate to elliptical, 2–10(–14) cm × 1–7 cm. Inflorescence a lax, simple or branched panicle of racemes, 15–30 cm long; bracts lanceolate-acuminate, 6–8 mm long, with long hairs along the margin; flowers 2–3 together; pedicel filiform, 1–2 cm long; calyx 2–3 mm long; petals blue to purple, 4–5 mm long. Pod 1–3 cm × 3 mm, with 3–6 ovate-rounded joints, each 4–5 mm in diameter. *D. tortuosum* is found in disturbed areas, cultivated fields and grassland, on sandy or calcareous soils in coastal areas, up to 1200 m altitude.

Selected sources 8, 16, 17, 62, 92, 174.

Desmostachya bipinnata (L.) Stapf

GRAMINEAE

Synonyms *Eragrostis cynosuroides* (Retz.) P. Beauv., *Pogonarthria bipinnata* (L.) Chiov., *Stapfiola bipinnata* (L.) O. Kuntze.

Distribution From north-eastern Africa through Arabia, Iran and India, to South-East Asia.

Uses Suitable for erosion control in sandy areas and as a fodder in desert areas in the absence of other grasses. The culms may be used for thatching and rope making, and play a role in Hindu ceremonies. They are considered diuretic and are used against dysentery and menorrhagia. Its fibres have been used for the manufacture of paper, but only as additional material of up to 10% of the total.

Observations Tufted perennial grass up to 150 cm tall, with a thick scaly central rhizome and long lateral rhizomes. Leaves coarse. Spikelets sessile or subsessile along the rachis of short spikes which form a narrow spike-like panicle, many-flowered, strongly laterally compressed; glumes markedly unequal, 1-nerved. In South-East Asia *D. bipinnata* occurs on the edges of rice fields, in rock crevices, in savanna or scrub land, up to 200 m altitude.

Selected sources 19, 91, 174.

Digitaria fuscescens (Presl) Henr.

GRAMINEAE

Synonyms *Digitaria pseudo-ischaemum* Buse, *Paspalum micranthum* Desv.

Vernacular names Indonesia: kakawatan (Javanese), rumput tembagan (Aceh).

Distribution From Madagascar, Mauritius and Sri Lanka to southern China and the Pacific; throughout South-East Asia. Introduced into Africa and South America.

Uses Suitable for erosion control.

Observations Mat-forming perennial grass with creeping stolons; culm up to 40 cm tall. Leaves usually distichous, glabrous. Racemes 2–3(–5), inserted close to each other, with a winged rachis; spikelets ternate, 2-flowered, glabrous, 1.2–1.6 mm long; lower glume usually absent. *D. fuscescens* is locally common as a pioneer on sandy to rocky soils in disturbed sites, such as beaches and dunes, up to 1350 m altitude. It is suitable to cover slopes quickly, although sometimes it becomes a noxious weed.

Selected sources 91, 150, 169.

Dolichos trilobus L.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Dolichos falcatus* Klein ex Willd., not *Vigna trilobata* (L.) Verdc.

Distribution Tropical Asia, Africa and the Middle East.

Uses Green manure and fodder crop, component of grasslands.

Observations Perennial, climbing herb, up to 1 m long, with a woody rhizome. Leaves trifoliolate; petiole up to 7 cm long; stipules lanceolate, reflexed, up to 4 mm long; leaflets thin, suborbicular, ovate to oblong-ovate or rhomboid, up to 9 cm × 9 cm, glabrous to variously hairy. Inflorescence an axillary, 2–3-flowered, raceme; calyx tubular, with 5 short teeth; corolla white or pink, about 1 cm in diameter. Pod cylindrical, somewhat curved, 5–9 cm × 6–12 mm, 6–8-seeded. *D. trilobus* is found along roads, in grassland and at the margins of thickets and bamboo forest. In Indo-China it occurs on volcanic or limestone-derived soil up to 1100 m altitude.

Selected sources 8, 48, 52, 53, 101.

Enterolobium cyclocarpum (Willd.) Griseb.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Pithecellobium cyclocarpum* Martius.

Vernacular names Mexican walnut, pitchwood, earpod-tree (En).

Distribution Native to Central and northern South America, now occasionally grown all over the tropics.

Uses In tropical Central and South America and occasionally in South-East Asia, grown as a shade tree in coffee plantations. Young pods and seeds are eaten as a vegetable. Pods are used as a fodder. The bark and pods are occasionally used as a substitute for soap.

Observations Tree, 15–30 m tall, crown thin and spreading, up to 45 m wide. Leaves bipinnately compound, with 4–9 pairs of pinnae, each with 13–30 pairs of leaflets; leaflets narrowly oblong, 8–13 mm × 2–4 mm, apex acute. Flowers in glomerules (heads), 1–2.5 cm in diameter, white or greenish, on a 2–3 cm long peduncle. Pod flat, curved into a circle or spiral, 7–12 cm in diameter, blackish-brown. Seeds in 2 rows, dark brown, compressed ovoid-ellipsoid, 13–20 mm × 11 mm × 8 mm, with pale pleurogram.

Selected sources 51, 101, 170.

Eriocaulon L.

ERIOCAULACEAE

Major species and synonyms

- *Eriocaulon cinereum* R. Br.
- *Eriocaulon heterolepis* Steud.
- *Eriocaulon longifolium* Nees
- *Eriocaulon sexangulare* L., synonym: *E. wallichianum* Martius
- *Eriocaulon truncatum* Buch.-Ham. ex Martius.

Vernacular names Pipewort (En). Indonesia: babawangan (Sundanese). Malaysia: rumput butang, rumput kumpai benang, rumput suasa (Peninsular). Philippines: dundunsug (Panay Bisaya), bauang-bauangan (Bikol), dasdasnuk (Bontok). Cambodia: smau tum hu:. Laos: ho:m ka:w namz, (do:k) kata:yx, (do:k) kha:w, (do:k) hwà ngo:k. Thailand: ya-phomhok (Chanthaburi), ya-hauhok (Trang). Vietnam: chi c[or] d[uf]i tr[oos]ng.

Distribution *Eriocaulon* occurs in the tropics and subtropics of both hemispheres; the species mentioned are present throughout tropical and subtropical Asia.

Uses Ploughed in as a green manure in rice fields.

Observations Tufted, monoecious, sedge-like herbs. Leaves in a basal rosette or rarely closely spaced along the stem, linear. Inflorescence capitate, on axillary, leafless, ribbed stalk often overtopping the leaves; flowers minute, unisexual, each in the axil of a bract, 2–3-merous; sepals free or connate, often with characteristic shape, hirsute. Fruit a dehiscent capsule. Pipeworts are common in open moist to wet sites, some species are found typically in the lowland, others are confined to montane habitats up to at least 2000 m altitude. The species are difficult to identify and the name *Eriocaulon sexangulare* has often been misapplied to other species.

Selected sources 8, 27, 107, 110, 135, 142, 148, 150, 171, 174.

Eurya acuminata DC.

THEACEAE

Synonyms *Eurya japonica* auct., non Thunb., *E. monticola* Ridley, *E. wrayi* King.

Vernacular names Indonesia: ki sapu (Sundanese), lingsangan (Javanese), sala (Sumatra). Malaysia: medang melukut jantan, jerak merah, kelantang (Peninsular). Laos: txiv ntoo teb nple (Hmong, Xieng Khouang). Thailand: rangkai (south-eastern), plaisan (peninsular).

Distribution India, Sri Lanka, south-west China, Taiwan, Thailand; within the Malesian area in Peninsular Malaysia, Sumatra, Java, and Sulawesi.

Uses The leaves are used as green manure, medicinally for poulticing skin eruptions, and in China to adulterate tea. The soft, brownish wood is suitable as fuelwood and has been used for beams in house building but it splits easily.

Observations Dioecious or monoecious shrub or small tree up to 15 m tall. Twigs pubescent at the tip. Leaves distichous, lanceolate or ovate-oblong to obovate-oblong, 4.5–10 cm × 1.2–3 cm. Flowers in 1–3-flowered axillary fascicles, unisexual, actinomorphic, 5-merous, small, white; petals connate at base. Fruit a small, globose, glabrous, many-seeded berry. *E. acuminata* has an unpleasant pungent odour. It occurs in open sites, and is a common component of subalpine forest, up to 3000 m altitude. It is propagated by cuttings.

Selected sources 27, 40, 70, 149, 171, 174, 178.

Faidherbia albida (Del.) A. Chev.

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Acacia albida* Del.

Vernacular names Apple-ring acacia, white acacia (En). Arbre blanc (Fr).

Distribution Widespread in tropical and subtropical Africa and the Middle East; introduced into many other areas, including South-East Asia.

Uses Shade tree and soil improver in seasonally dry areas. The tree is excellent for interplanting as it is leafless during the rainy season and provides shade during the hot, dry season. Fuelwood is generally harvested by lopping branches from living trees. Foliage and pods supply forage, medicine, and toxins. The seeds contain about 27% protein. The bark contains tannins. The wood ash can be used for soap.

Observations Tree, 6–30 m tall, with rough, dark brown or greenish-grey bark and spreading branches. Young branches whitish. Leaves bipinnately compound; stipules spiny, up to 2 cm long, straight, not inflated; rachis with a conspicuous gland at junction of each of the 3–10 pairs of pinnae; leaflets 6–23 pairs, (2.5–)3.5–6(–12) mm × 0.7–2.5(–4) mm. Inflorescence a spike 3.5–14 cm long; peduncle 1.3–3.5 cm long; flowers cream; pedicel 0–2 mm long. Pod falcate or coiled, 6–25 cm × 2–5 cm, bright orange, thick, indehiscent, usually glabrous. Seed ellipsoid to lens-shaped, 9–11 mm × 6–8 mm; areole central, large, 7–9 mm × 4–6 mm. *F. albida* occurs most commonly on medium to light, neutral to acid soils up to 2500 m altitude and tolerates seasonal waterlogging and slight salinity. For good growth it requires about 650 mm annual rainfall, if groundwater is accessible it still grows well with only 250 mm. It would be worthwhile trying this tree in the driest parts of South-East Asia.

Selected sources 30, 52, 61, 101, 116, 176.

Fimbristylis dichotoma (L.) Vahl

CYPERACEAE

Synonyms *Fimbristylis annua* auct., non (All.) Roem. & Schultes, *F. diphylla* (Retz.) Vahl, *F. ramosii* Kük.

Vernacular names Indonesia: jukut mata munding (Sundanese), suket kodokan (Javanese), cikukok (Aceh). Malaysia: rumput purun batu, rumput parah, rumput kepala lalat (Peninsular). Papua New Guinea: balimbuli. Philippines: tabtabin (general), baliotas (Bagobo), bubaging (Subanun). Laos: kh'ôm pa:w no:yz (Savannakhet). Thailand: ya-niunu (Chiang Mai). Vietnam: c[or] qu[aw]m nh[aa]n d[oo]i.

Distribution Pantropical.

Uses Ploughed in as a green manure in rice fields. It is useful as a soil binder in erosion control. The leaves are used as a fodder. It is also used for matting but not preferred for that purpose.

Observations Annual or perennial herb with short rhizomes, forming large tussocks, up to 75(–100) cm tall. Leaves abruptly acuminate, 1.5–5 mm wide. Inflorescence simple to compound, up to 20 cm long; spikelets ovoid to oblong-ovoid, 5–10(–20) mm × 2.5–3(–5) mm; glumes arranged spirally, glabrous or sometimes minutely ciliate apically, with a green keel and darker coloured sides; style with a dilated base, ciliate, stigmas 2. Fruit a usually smooth nut. *F. dichotoma* is extremely variable. Annual forms have been accommodated in subsp. *depauperata* (R. Br.) Kern. It is a common weed of open locations, roadsides, tea and teak plantations, and dry rice fields, up to 1500(–2500) m altitude. It is sometimes troublesome and difficult to eradicate.

Selected sources 27, 25, 51, 70, 149, 150, 171.

Fimbristylis pauciflora R. Br.

CYPERACEAE

Synonyms *Fimbristylis filiformis* (Nees) Kunth, *F. malaccana* Boeck., *F. pumila* Benth.

Vernacular names Indonesia: rumput jani (Riau). Malaysia: rumput girah, rumput sapi, rumput jambak (Peninsular). Thailand: ya-preangmu (Chanthaburi), nuatmaeo (Trat). Vietnam: c[or] qu[aw]m l[oo]ng b[of].

Distribution Thailand, Indo-China, the Ryukyu Islands, the Carolines, Peninsular Malaysia, Sumatra, Borneo, the Moluccas, New Guinea and northern Australia.

Uses Ploughed in and used as a green manure in rice fields.

Observations Glabrous, perennial herb forming large clumps, up to 30 cm tall. Leaf blades absent or short. Inflorescence consisting of a single, terminal, narrow spikelet, 3–6 mm × 1–1.5 mm; glumes arranged spirally, muticous, pale; style slightly thickened at base, ciliate, with 2–3 stigmas. Fruit an obovoid, verruculose nut. *F. pauciflora* occurs in sunny or shaded, damp, sandy or clayey sites, on swamps edges, and in rice fields, up to 800 m altitude.

Selected sources 27, 51, 148.

Fimbristylis schoenoides (Retz.) Vahl

CYPERACEAE

Synonyms *Abildgaardia nervosa* Presl, *Fimbristylis bispicata* Nees, *F. longifolia* S.T. Blake.

Vernacular names Philippines: gumi gumi (Tagalog). Thailand: ya-hangnu (Trat). Vietnam c[or] qu[aw]m qu[ar] c[as]nh.

Distribution East Africa (rare), India, Indo-China, Taiwan, Peninsular Malaysia, Sumatra, Borneo, Java, the Lesser Sunda Islands (Bali and Nusa Tenggara), the Philippines, and tropical Australia; introduced into North America.

Uses Ploughed in as a green manure in rice fields.

Observations Densely tufted, glabrous perennial plant with short rhizomes, up to 45 cm tall. Leaves abruptly acuminate, about 1 mm wide, greyish-green or glaucous, with sharp edges. Inflorescence consisting of a single terminal spikelet, or with 1–2 more peduncled spikelets; spikelets many-flowered, 5–10 mm × 3–4 mm; glumes glabrous; stigmas 2. Fruit a smooth, distinctly stipitate nut. *F. schoenoides* is locally common in open grassland and fallow rice fields, especially on permeable soils, up to 400 m altitude.

Selected sources 51, 27, 148, 150.

Fuirena umbellata Rottb.

CYPERACEAE

Synonyms *Fuirena quinquangularis* Hassk., *F. philippinensis* Gand.

Vernacular names Indonesia: jukut wawalingian (Sundanese), kasabon (Javanese), rumput baku buluh (Indonesian). Malaysia: rumput kelukut, rumput lidah bengkerang, rumput buku buloh (Peninsular). Papua New Guinea: sinbora (Orokaiva). Thailand: ya-samkhom (Chiang Mai). Vietnam: c[or] c[uws]ng hoa t[as]n.

Distribution Widely distributed in the tropics and subtropics, including South-East Asia.

Uses Ploughed in as a green manure in rice fields.

Observations Sturdy perennial plant with short rhizomes, up to 110 cm tall. Stem conspicuously 4–5-angled, leafy. Leaves flat, (5–)8–15(–25) mm wide, with 5 prominent nerves. Spikelets densely clustered in a terminal and several axillary inflorescences; glumes pilose, awned; perianth segments obovate, narrowed at base. *F. umbellata* is common in open wet locations, sometimes in secondary forest, up to 1800 m altitude.

Selected sources 51, 27, 148, 174.

Galactia striata (Jacq.) Urban

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Galactia tenuiflora* (Klein ex Willd.) Wight & Arn., *Glycine striata* Jacq., *Glycine tenuiflora* Klein ex Willd.

Vernacular names Vietnam: (d[aa]y) long (Phu Khanh).

Distribution Probably originating from tropical America, it is now distributed pantropically; including in South-East Asia.

Uses It has been tested as a green manure crop in Java with little success. A fodder crop for marginal areas, often in mixtures with grasses. Its specific chemicals are under investigation for curing blood diseases and cancers.

Observations Slender, climbing or trailing perennial herb, 1–4 m long, with a woody rhizome. Leaves trifoliolate; stipules linear, about 5 mm long; leaflets oblong, 2–6.5 cm × 1–3 cm, subglabrous above, densely appressed-pubescent beneath. Inflorescence an axillary raceme, slender, 1–10-flowered; peduncle 5–30 cm long; flowers 1–3 together; pedicel 1.5–2 mm long; calyx 6–9 mm long, puberulous; corolla white to pink, about 1 cm long. Pod curved, flat, 3–7.5 cm × 5–9 mm, usually 7–8-seeded. Seed up to 5.5 mm × 3.5 mm × 2.5 mm, yellowish-brown to blackish-red. *G. striata* is extremely variable. It nodulates and fixes nitrogen. It is found in grassland and bushland up to 1300 m altitude. It flowers throughout the year in Java. In the literature it is mostly referred to as *G. tenuiflora*.

Selected sources 8, 48, 52, 53, 62.

Grevillea banksii R. Br.

PROTEACEAE

Distribution Native to south-eastern Queensland, introduced into Indonesia, Malaysia, Madagascar and South Africa. Naturalized in Madagascar.

Uses *G. banksii* produces fuelwood and poles and forms effective wind-breaks in regions of high rainfall. Cultivar 'Fosteri' is a dense shrub used in fences. Prunings provide a promising fodder for goats. It is also grown as an ornamental.

Observations Shrub or small, slender tree up to 4–10 m tall, rarely prostrate. Branchlets slightly ridged by decurrent leaf bases, tomentose. Leaves alternate, pinnatipartite, 6–12-lobed, (8–)14–30 cm long; petiole 3–5 cm long; lobes asymmetrical, broadly linear to lanceolate, glabrous above, ferrugineous-silky beneath. Inflorescence a terminal or axillary (in one of the upper leaves), dense, subcylindrical raceme, 5–10(–21) cm long; peduncle 1–4 cm long, tomentose; rachis villous; pedicel 3–10 mm long, villous; flower red, yellowish or almost white, sometimes greenish or red; perianth suboblong, tube 13–20 mm × 3–4 mm, tomentose outside, glabrous inside, limb obliquely ovate. Fruit an obliquely ovoid follicle with persistent style, 15–24 mm × 9–10 mm × 4–5 mm, coriaceous and dehiscing on one side, 1–2-seeded. Seed 8–11 mm × 3.5–4 mm × 1 mm, narrowly winged, smooth, shiny. It flowers year-round in Java and Peninsular Malaysia. If the fruits are not picked timely, they split open and the seeds are scattered. Fully viable seed can be obtained from 3–4-year-old trees. Several hybrids of *G. banksii* are cultivated as ornamentals. The flowers, fruits and seeds contain cyanogenic glycosides. Some cultivars may cause allergic contact dermatitis. In Queensland, *G. banksii* occurs on various soils, but mainly on compact sandy ones in flat areas, from 250–2000 m altitude. It is moderately frost-tolerant.

Selected sources 51, 99, 105, 124.

Grevillea pteridifolia Knight

PROTEACEAE

Synonyms *Grevillea chrysodendron* R. Br.

Vernacular names Scarlet grevillea (En).

Distribution Native to the northern parts of western Australia, the Northern Territory and Queensland, introduced into India and undergoing testing in several countries in South-East Asia and Africa.

Uses *G. pteridifolia* yields fuelwood and poles. It is an effective wind-break. Prunings provide fodder for goats. Dried foliage has been used as an elastic stuffing for mattresses.

Observations Small tree, up to 5–6 m tall. Branches hairy with alternate pinnate leaves, 25–45 cm long. Leaves deeply pinnatifid or pinnate, coriaceous; segments broadly linear to lanceolate, glabrous above, silky beneath. Inflorescence a terminal raceme, dense, secund, 5–10 cm long; flowers yellow-orange; perianth tomentose outside, glabrous inside, tube 13–20 mm × 3–4 mm. Fruit an oblique, coriaceous follicle, dehiscing on one side, 1–2-seeded. Flowering occurs year-round in Java and Peninsular Malaysia. *G. pteridifolia* is suitable for planting on wasteland soils with a texture varying from pulverized lateritic soil to sandy loam, including loose soils on dumps of coal and bauxite mines, where it regenerates spontaneously. It requires a mean annual rainfall of 1000–1500 mm, and is found from 250–2000 m altitude. It tolerates some frost and can withstand a dry season of 6–8 months. Propagation is usually by seed that has been soaked in water for 24 hours. Germination takes 25–30 days. Seedlings are ready for planting when they are 10–15 cm tall bearing 7–8 leaves. The coppicing ability of *G. pteridifolia* is poor.

Selected sources 18, 66, 128, 129.

Gymnostoma rumphianum (Miquel) L.A.S. Johnson

CASUARINACEAE

Synonyms *Casuarina rumphiana* Miquel.

Vernacular names Indonesia: pohon kasowari, ila (Moluccas). Philippines: mountain agoho (Pilipino), agoho del monte.

Distribution Indonesia (Sulawesi and the Moluccas) and the Philippines.

Uses A useful firewood and nitrogen fixer with potential for intercropping. It yields good quality charcoal. The wood can be used for house construction (beams, posts, etc.) and light construction work, and yields a good quality pulp. It is a potential ornamental.

Observations Monoecious tree, up to 20 m tall. Twigs needle-like, dark greyish-green, hanging in tassels from larger branches. Leaves reduced to tiny scales. Flowers small, arranged in a lax 1–1.5 cm long terminal spike. Fruit a compound globose cone-like structure of 3 cm in diameter. *G. rumphianum* usually occurs gregariously in primary forest, at 100–1000 m altitude, forming almost pure stands along sandy sea shores in the Philippines. It grows more vigorously at higher elevations.

Selected sources 12, 47, 70, 116, 133, 178.

Gymnostoma sumatranum (Junghuhn ex de Vriese) L.A.S. Johnson

CASUARINACEAE

Synonyms *Casuarina sumatrana* Junghuhn ex de Vriese.

Vernacular names Indonesia: cemara sumatra (Indonesian). Malaysia: ru Sumatra (Peninsular), ru ronang (Sarawak), rhu bukit. Philippines: maribuhok (Bisaya). Thailand: son-pattawia (Bangkok).

Distribution All over South-East Asia, occasionally also cultivated.

Uses Cultivated for fuelwood in Sarawak, where it is also a popular ornamental. It also yields excellent charcoal. The timber is used in the Philippines, but supplies are limited. Also planted as an ornamental. It has been proposed to be grown as a Christmas tree.

Observations Monoecious tree, 5–10 m tall. Twigs needle-like, pale green, 5–40 cm long, articulate, articles 2–6 mm. Leaves reduced, in whorls of 4 tiny scales. Fruit a compound cone-like structure, 2–3 cm in diameter. *G. sumatranum* occurs on lowland podsols; it can fix nitrogen.

Selected sources 8, 25, 133.

Indigofera longiracemosa Boiv. ex Baillon

LEGUMINOSAE – PAPILIONOIDEAE

Distribution Kenya, Tanzania, Madagascar and India; introduced in Indonesia.

Uses Green manure, but its present utilization in South-East Asia is doubtful. Formerly also used in Africa as a source of indigo.

Observations Branching, rather woody herb, up to 130 cm tall. Branches slender, with few small bristles. Leaves pinnately compound; stipules subulate, about 2 mm long; petiole 1.5 cm long; leaflets elliptical-lanceolate, up to 2 cm × 1 cm, blackish when dried, sparsely strigose. Inflorescence a many-flowered, sessile raceme, up to 10 cm long; bracts linear-lanceolate, 1 mm long, caducous; pedicel about 1 mm long, strongly reflexed after flowering; calyx tubular, brown strigose, up to 1.2 mm long, lobes longer than the tube; corolla densely brown-strigose outside. Pod subcylindrical, up to 2 cm × 2.5 mm, straight, pointed, sparsely bristly, brown, 5–6-seeded. *I. longiracemosa* is found in coastal areas, up to 100 m altitude in Africa. In Java it is suitable at about 1650 m altitude, but is attacked by pests at lower altitudes. The life-cycle is about 2 years.

Selected sources 8, 52, 70.

Indigofera zollingeriana Miquel

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Indigofera teysmannii* Miquel, *I. benthamiana* Hance.

Vernacular names Indonesia: marmojo gunung (Java). Philippines: balabalatong, tinatinaan (Tagalog), balabalatungan (Bikol). Laos: kh'a:m ho:y, khi:z mo:d, s'a:z kh'a:m. Thailand: khram-chang, khram-luang (northern). Vietnam: mu[oof]ng c[as]nh r[awr]nh.

Distribution Widely distributed in South-East Asia, southern China and Taiwan. Occasionally introduced elsewhere (e.g. in Sri Lanka).

Uses A shade plant for young tea, cocoa and coffee. Also used as a green manure and cover crop in coconut and tea plantations in Sri Lanka.

Observations Erect shrub or small tree, up to 12 m tall. Branches subsericeous with minute brown or white, biramous, appressed hairs. Leaves imparipinnate; stipules linear, up to 8 mm long; leaflets 11–23, elliptical to ovate, 2–8 cm × 1–3 cm. Inflorescence an axillary, many-flowered raceme, 8–10 cm long; flowers about 0.5 cm long; calyx brown-sericeous, 2 mm long; corolla whitish, pink or dark purple; standard ovate, up to 5 mm × 4 mm, dorsally sericeous. Pod subcylindrical, 2.5–4.5 cm × 0.5 cm, glabrous, beaked, about 16-seeded. *I. zollingeriana* occurs mainly on coral strands and sandy beaches, up to 850 m altitude.

Selected sources 8, 23, 39, 53, 170, 174, 179.

Inocarpus fagifer (Parkinson) Fosberg

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Inocarpus edulis* J.R. & G. Forster. Note: *I. fagiferus* is an often used orthographic variant of *I. fagifer*.

Vernacular names Otaheite chestnut, Polynesian chestnut, Tahiti chestnut (En). Inocarpe comestible (Fr). Indonesia: gayam (Java), bosua (Manado, Ternate). Malaysia: kerepit, kopit. Papua New Guinea: aila, lala, ivi. Philippines: kayam.

Distribution Probably originated in eastern Malesia and taken to Micronesia, Melanesia and Polynesia by Malay-Polynesian migrants, who are thought to have carried the seeds as food on their voyages. It is occasionally also cultivated elsewhere in the tropics (e.g. in Peninsular Malaysia, Sumatra, Borneo, Java).

Uses *I. fagifer* is a common tree in home gardens in the Pacific where it provides shade and firewood. Nearly ripe seeds are eaten after boiling or roasting in hot ashes and taste like chestnut. A popular Polynesian dish is prepared from grated seed mixed with coconut meat and coconut milk, wrapped in green leaves and baked in a stone oven. Seeds are also stored in underground pits after partial fermentation, as is done with breadfruit (*Artocarpus altilis* (Parkinson) Fosberg). The hard timber is used for making moulds and bed frames. In Borneo and Java tannin from the bark is taken internally as a remedy against intestinal disorders. The foliage is fed to cattle.

Observations Often several-stemmed, evergreen tree, with straggling appearance and drooping branches, up to 30 m tall and 65 cm in trunk diameter. Trunk often irregularly fluted, sometimes with stout buttresses, 1–3 m long; bark dark brown, slightly flaky, inner bark yielding a red exudate. Leaves alternate, simple; petiole 0.5–1.5 cm long; stipules small; blade oblong, 10–50 cm × 4–18 cm, thinly leathery, shiny yellowish-green, pink when young, glabrous, drooping. Inflorescence an axillary spike, 1–17 cm long, simple or

2–5-fid; flowers small, 5-merous, pungently fragrant; calyx tubular with 2–5 teeth; petals 5, subequal, 1–1.5 cm long, white or yellow, apex recurved; stamens 10 in 2 series, alternately long and short. Pod very variable, 1-seeded, flattened, reniform or wedge-shaped, 5–10 cm × 5–8 cm × 4–5 cm, indehiscent, keeled, ribbed or smooth, mostly densely, finely pubescent when young. Seed up to 8 cm long, with very hard seed-coat and white endosperm.
In Java, *I. fagifer* flowers from January to June and in September. Fruit set is poor. Plants start bearing fruit when about 8 years old. The fruit may float for over one month in seawater, but the seed quickly loses its viability. A second species, *I. papuanus* Kostermans, whose specific distinctness is questioned, occurs in the rain forest of New Guinea; its fruit is somewhat smaller, red and inedible. *I. fagifer* is resistant to flooding and grows in swamps and on the banks of estuaries and streams, even in brackish water. It is one of the most common species on the islands of the Pacific, where it occurs up to 500 m altitude. In brackish tidal swamp forest in Johor, Malaysia, it locally dominates the undergrowth.

Selected sources 79, 104, 127, 137, 170.

Ipomoea carnea Jacq. subsp. fistulosa (Martius ex Choissy) D.F. Austin

CONVOLVULACEAE

Synonyms *Ipomoea crassicaulis* (Benth.) B.L. Robinson, *I. fistulosa* Martius ex Choissy.

Vernacular names Shrubby morning glory (Am). Indonesia: kangkungan (Javanese).

Distribution Native to the Americas, from Florida and Mexico through the Caribbean to Brazil and Paraguay, spread throughout the Pacific and South-East Asia, up to Pakistan. Occasionally cultivated in South-East Asia and India.

Uses Grown as a hedge and green manure. Leaves are eaten as a vegetable by the Madurese.

Observations Perennial, erect or ascending shrub, 1–3 m tall, sometimes twining to 5 m long. Branches terete or angular, stout, containing a milky juice. Leaves ovate to ovate-oblong, 6–25 cm × 4–17 cm, densely puberulent, subglabrescent, base cordate to truncate, apex acuminate, mucronulate. Inflorescence terminal or axillary, cymosely flowered; peduncle stout, 5–10 cm long; bracts ovate, early deciduous; pedicel 1–1.5 cm long, puberulent; calyx with 5 nectaries between sepals; sepals 5, orbicular, ovate to nearly circular, subequal, 5–6 mm long, puberulent; corolla pink or pale lilac, inside often dark purple towards the base, tubular to funnel-shaped, 7.5–9 cm long; stamens 5, with very unequal filaments. Fruit an ovoid capsule, 1.5–2 cm long, pale brown, mucronate, finely puberulent basally, incompletely 4-celled or 2-celled, 4-valved. Seed about 1 cm long, black, brown sericeous. *I. carnea* subsp. *fistulosa* occurs at low altitude, along rivers and canals, sometimes on beaches; locally abundant. It is shrubby when exposed, twining when shaded. It flowers throughout the year, except during cool periods. Propagation is by cuttings. *I. carnea* ssp. *fistulosa* is toxic to livestock.

Selected sources 6, 51, 174.

Kandelia candel (L.) Druce

RHIZOPHORACEAE

Synonyms *Kandelia rheedii* Wight & Arnott, *Rhizophora candel* L.

Vernacular names Brunei: lingajong, lingajong laut, pulut-pulut. Malaysia: lingayong, bakau aleh-aleh, beus. Thailand: rangkathae. Vietnam: v[ej]t [dd][if]a, v[ej]t thang.

Distribution Coastal areas of India, Burma (Myanmar), Thailand, Indo-China, eastern China, Taiwan, Japan, Peninsular Malaysia, north-eastern Sumatra, and Borneo (West Kalimantan, Brunei, and Sabah).

Uses Used as a green manure. The wood is used as fuelwood, for charcoal production and for temporary constructions. The bark is suitable for tanning heavy leather and for dyeing in red and brown colours.

Observations Evergreen shrub or small tree, up to 7 m tall. Stem base thickened, without buttresses or pneumatophores; bark reddish or greyish-brown, spongy. Leaves decussate, elliptical-oblong or narrowly so, to obovate-oblong, 6–13 cm × 2–6 cm. Flowers in an axillary, cymose inflorescence; calyx deeply 5-lobed, the lobes reflexed in fruit; petals white, multifid; stamens many. Fruit ovoid, with the sharply pointed hypocotyl developing while still on the tree. *K. candel* occurs locally on banks of tidal rivers among other mangrove species, but is rather rare. The bark contains about 17% tannin.

Selected sources 27, 51, 53, 149, 174, 178.

Lepturus repens (G. Forster) R. Br.

GRAMINEAE

Synonyms *Monerma repens* (Forster f.) P. Beauvois.

Distribution From East Africa, the islands in the Indian Ocean and Sri Lanka, throughout South-East Asia to Australia and Polynesia.

Uses Useful as a sand binder.

Observations Stoloniferous, perennial grass up to 40 cm tall. Leaves rigid, bluish-green, very rough on the upper surface. Spikelets 1-flowered, sessile, alternate along and sunken in the readily disarticulating rachis of a single, cylindrical, spike up to 15 cm long; lower glume absent; upper glume coriaceous and acuminate to long-tailed. *L. repens* is found on sandy shores, dunes, coastal rocks, and along saline lagoons.

Selected sources 19, 70, 91.

Leucaena pulverulenta (Schldl.) Benth.

LEGUMINOSAE – MIMOSOIDEAE

Vernacular names Chalky leucaena, giant ipil-ipil (En).

Distribution Originating from Mexico, now introduced and occasionally cultivated in tropical Asia and Africa. It arrived in Indonesia in 1900.

Uses *L. pulverulenta* is grown as a shade tree in coffee plantations, as a green manure and as fuelwood. It is also used as a fodder crop, lower in mimosine content than *L. leucocephala* (Lamk) de Wit.

Observations Shrub or bush-like tree up to 12 m tall. Young parts white pubescent. Leaves with 10–20 pairs of pinnae; leaflets 15–30 pairs per pinna, linear, 2–6 mm long. Inflorescence an oblong glomerule, 1–2 cm in diameter; flowers densely white strigose. Pod flat, 10–27 cm × 1.5–2 cm. *L. pulverulenta* is found in West Java around Bandung at about 700 m altitude. It hybridizes with *L. leucocephala* and is used in breeding programmes.

Selected sources 51, 77, 118.

Limnophila sessiliflora Blume

SCROPHULARIACEAE

Synonyms *Ambulia sessiliflora* (Vahl) Baill. ex Wettst., *Hottonia sessiliflora* Vahl, *Stemodia sessiliflora* (Blume) F. v. Muell.

Distribution From India and Nepal to Burma (Myanmar), Vietnam, western China, North Korea, Japan, and the Mariana Islands; within the Malesian region in Peninsular Malaysia, Java, and Borneo.

Uses Suitable for improving the water quality of fish ponds by capturing floating mud particles.

Observations Amphibious perennial plant, submerged at first but growing out to about 20 cm above the water surface. Leaves on aerial stem verticillate, elliptical-lanceolate, 4–12(–20) mm long, entire to serrate or variously lacerate or dissected. Flowers solitary, axillary, sessile or subsessile; bracteoles absent or minute; calyx tubular, 5-lobed; corolla 2-lipped, (5–)8–10.5 mm long, blue, violet to purple, lower lip 3-lobed. Fruit a capsule with 4 bifid valves. *L. sessiliflora* is locally common in shallow ponds, swamps and lakes usually with a muddy bottom, up to 1000 m altitude.

Selected sources 8, 53, 70, 123.

Mastersia bakeri (Koorders) Backer ex Heyne

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Mucuna bakeri* Koorders, *Mastersia borneensis* Harms.

Vernacular names Indonesia: tatamulak (Minahasa, northern Sulawesi), naneke nomoro, rarau (Halmahera, Moluccas).

Distribution Northern Borneo, northern and central Sulawesi, the Moluccas. Occasionally cultivated in eastern Indonesia.

Uses Grown as a cover crop e.g. in coconut plantations in northern Sulawesi, quickly forming a good ground cover, nodulating well and preventing the establishment of an *Imperata* grass cover.

Observations Herbaceous to woody, climbing herb, 5–18 m long. Branches 1.5–4 cm in diameter. Leaves trifoliolate; stipules 3.5–6 mm × 1.5–4 mm; petiole 8–15 cm long; leaflets elliptical to broadly ovate, 4.5–15 cm × 3.5–14 cm, acumen about 5 mm long, usually pubescent on both surfaces, glands occasionally present. Inflorescence a pseudoraceme, 6–30 cm long; flowers up to 2 cm long; calyx tubular, 4-lobed; standard elliptical to broadly ovate, 8–14 mm × 6–9 mm, claw usually absent; wings 8–14 mm × 2.5–4 mm, clawed; keel 12–18 mm × 6 mm, clawed, lateral pocket present. Pod 5–13 cm × 2–3 cm, winged along both edges, 5–20-seeded. Seed reniform, dark greyish-brown, arranged longitudinally, rim aril brownish-white. *M. bakeri* occurs in primary and secondary forest, especially in open spots and on wasteland, up to 900 m altitude.

Selected sources 8, 70, 167.

Microcos tomentosa J.E. Smith

TILIACEAE

Synonyms *Grewia paniculata* Roxb. ex DC., *G. blumei* Hassk., *G. cumingiana* Turcz.

Vernacular names Indonesia: talok (Indonesian), dluwak (Javanese), darowak (Sundanese). Malaysia: cenderai, cenerah, jenerai. Cambodia: popli:ë. Laos: kh'o:m sôm (Vientiane). Thailand: khom-som (north-eastern), khom-kliang (south-eastern). Vietnam: c[of] ke.

Distribution Throughout South-East Asia, southern China and eastern India.

Uses The wood is used for fuel, charcoal making and timber for indoor construction. Because of its light weight, strength and elasticity it is suitable for making tool handles, agricultural implements and sporting goods.

Observations Shrub or bushy tree, up to 17 m tall and up to 40 cm in trunk diameter. Crown dense, rounded or cylindrical, rather drab green. Trunk often fluted. Bark dark grey to brownish buff, entire, slightly flaky. Branches arching out and drooping. Leaves obovate, 7.5–20 cm × 3–9 cm, hairy on both sides, margin serrate, undulate to entire on the lower half, 3-nerved from leaf base. Inflorescence a terminal or axillary panicle, 3–15 cm long; flowers 5-merous; sepals spathulate; petals triangular, 2–3 mm × 0.5 mm. Fruit a globose to ellipsoid drupe, 1–1.5 cm × 0.5–1 cm, skin hairy, leathery, green, turning black when ripe. *M. tomentosa* occurs in moist deciduous and evergreen forest; in Java and Malaysia, very common but scattered in secondary forest, from 0–600 m altitude. *M. tomentosa* should not be confused with *Microcos paniculata* L. (synonym *Grewia microcos* L.) or *Grewia tomentosa* Juss., especially as various authors disagree about whether the genera *Grewia* L. and *Microcos* L. should be united.

Selected sources 8, 28, 85.

Mischocarpus sundaicus Blume

SAPINDACEAE

Synonyms *Cupania erythrorhachis* Miquel, *Mischocarpus lessertianus* Ridley, *Schleichera revoluta* Turcz.

Vernacular names Indonesia: ki howe (Sundanese), bangkongan (Javanese), pulas laut (Bangka). Malaysia: medang serai, ludai bulan, mutan riba (Peninsular). Philippines: malasalab (Pilipino). Cambodia: sânndaèk préi. Thailand: khaokwang (Nakhom Si Thammarat), baekphrai (Surat Thani).

Distribution From India throughout South-East Asia to northern and eastern Australia.

Uses The wood yields a good quality charcoal. A decoction of the roots is used medicinally against coughs. It is probably a poisonous plant.

Observations Monoecious shrub or small to medium-sized tree, up to 10(–30) m tall. Leaves alternate, usually compound with (1–)3–7(–9) leaflets, with domatia. Inflorescence axillary or pseudoterminal, thyrsoid and branched; sepals fused at base; petals absent or strongly reduced (in Peninsular Malaysia only); ovary 3-celled. Fruit an obpyriform capsule, 7–17(–20) mm long, glabrous or very sparsely puberulous. *M. sundaicus* occurs in primary and secondary forest, between 800–1600 m altitude.

Selected sources 27, 51, 70, 139, 148, 161.

Mundulea sericea (Willd.) A. Chev.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Cytisus sericeus* Willd., *Tephrosia suberosa* DC.

Vernacular names Malaysia: kattutuvaram, supti (Tamil).

Distribution Widespread in tropical Africa, India and Sri Lanka. Probably introduced into South-East Asia. Occasionally cultivated.

Uses A mulch and green manure crop, also fish poison and insecticide containing rotenone in leaves, bark and seeds. The bark repels crocodiles in East Africa.

Observations Robust, spreading shrub or small tree, 2–7 m tall. Bark corky, smooth to fissured; young branches velvety. Leaves pinnately compound; rachis velvety, up to 10 cm long including a petiole of 1–2 cm; leaflets in about 6 pairs, subopposite, rather leathery, ovate-oblong to lanceolate, up to 4 cm × 1.4 cm, apex rounded, with few, minute hairs or glabrous above. Inflorescence a velvety, axillary pseudoraceme, 5–13 cm long; flowers in pairs; pedicel 1–1.5 cm long; calyx up to 6 mm long; standard about 18 mm × 15 mm, dorsally hairy, claw curved, inrolled. Pod borne almost horizontally, linear, 5–9 cm long, tapering at the base, tip pointed, velvety, yellowish-brown, often constricted between the 4–9 seeds. Seed reniform, about 4 mm × 3 mm × 2 mm, dark green. *M. sericea* occurs in open sites in lowland evergreen forest, bushland and deciduous woodland, up to 2000 m altitude. It is propagated by seed, but more easily by cuttings.

Selected sources 52, 88, 96, 170.

Myrica javanica Blume

MYRICACEAE

Vernacular names Indonesia: ki teke (Sundanese), picisan, wuru ketek (Javanese). Philippines: hindang (Central Bisaya).

Distribution Throughout Malesia.

Uses The wood is valued as fuel and makes excellent charcoal. It is used for reforestation and as an amenity tree. The fruits are edible though insipid.

Observations Much branched, monoecious tree or shrub, 2–10 m tall, with crooked stem and rather dense crown. Branchlets greyish-black, with yellow glands when young. Leaves elliptical to obovate, 4–14 cm × 2–7.5 cm, apex rounded, sometimes emarginate, shallowly serrate, coriaceous, with many sessile, yellow, caducous glands. Male inflorescence a catkin, solitary or variously grouped into larger aggregates, 4–18 cm long, usually branched towards the apex; bract ovate, acute, 2–3 mm long; male flowers in axil of bracteole, studded with persistent yellow glands; tepals absent; stamens 4; filaments connate for greater part; female inflorescence an axillary catkin, solitary, unbranched or branched sparingly, 3–7 cm long; bract 1.5–2 mm long; female flowers 5 or more together, imbricate; bracteoles 2; tepals absent; ovary ellipsoid-ovoid, studded with round tubercles. Fruit a berry, 1–2 per catkin, broadly ellipsoid, with many yellow glands, black. *M. javanica* flowers throughout the year. It occurs from 900–3300 m altitude and prefers sunny, open sites, often on volcanic ridges where it is a pioneer species becoming gregarious. In dense forest it is often dominant.

Selected sources 51, 85.

Ottelia alismoides (L.) Persoon

HYDROCHARITACEAE

Synonyms *Ottelia condorensis* Gagnep., *O. japonica* Miquel, *O. javanica* Miquel.

Vernacular names Indonesia: cowehan (Javanese), eceng hai-hai (Sundanese), keladi air (Indonesian). Malaysia: keladi ayer. Philippines: kalabua (general), damong-ilalim (Tagalog), lanting (Bikol). Cambodia: sla:b chrâva:. Laos: kas'è:ng, 'o:b 'è:b (Vientiane). Thailand: santawa (central), santawa-baiyai (Bangkok). Vietnam: m[ax] d[eef] n[uw][ows]c.

Distribution From north-eastern Africa through India eastward to China and Japan, throughout South-East Asia towards the Solomon Islands and tropical Australia. It has been introduced into southern Italy and North America.

Uses The plants are used to improve the water quality in fish ponds by capturing floating mud particles. The petioles and leaves are eaten as a vegetable with excellent flavour, the leaves are used in Thailand for seasoning rice. The fruit is also edible. The plant is used in topical treatment of haemorrhoids, and applied as a poultice against fever. It is also grown as an aquarium plant.

Observations Partly or fully submerged freshwater plant. Floating leaves broadly ovate to cordate-reniform; petiole sheathing at base. Flowers bisexual, sessile on an elliptical prominently winged 'spathe', 3-merous; petals obovate, white with a yellow-spotted base. Fruit oblong-elliptical, rostrate, crowned by the 3 sepals. *O. alismoides* is common in stagnant water and slow streams, often growing gregariously up to 700(–1000) m altitude. It is locally regarded as a troublesome aquatic weed and removed manually.

Selected sources 101, 25, 51, 70, 114, 159, 150, 171, 174.

Paraserianthes lophantha (Willd.) Nielsen

LEGUMINOSAE - MIMOSOIDEAE

Synonyms *Acacia montana* Jungh., *Albizia montana* (Jungh.) Benth.

Vernacular names Indonesia: kemlandingan gunung, mlandingan gunung (Javanese), ki haruman (Sundanese).

Distribution *P. lophantha* has a disjunct distribution: subsp. *lophantha* occurs in south-western Australia and subsp. *montana* (Jungh.) Nielsen in Indonesia (Sumatra, Java, Bali and Flores). It is occasionally cultivated also elsewhere.

Uses It is occasionally planted as a shade tree or for soil improvement in agriculture and forestry. The wood has been used for curing tobacco, but it is of poor fuel quality. In Java the seed may be used as a vegetable as a substitute for petai (*Parkia speciosa* Hassk.) or as a flavouring to replace jengkol (*Archidendron jiringa* (Jack) I.C. Nielsen). In South Africa *P. lophantha* subsp. *lophantha* has become an invasive weed after introduction.

Observations Shrub or tree, up to 10 m tall and 30 cm in diameter. Leaves bipinnately compound; petiole 2.2–6 cm long; rachis 11–25 cm long; pinnae (6–)9–13 pairs, to 12 cm long; leaflets (13–)15–34 pairs per pinna, oblong, 5–11 mm × 1.5–3.5 mm, base very asymmetrically truncate-rounded. Inflorescence a solitary or compound spike in a distal leaf axil; spike 5.2–11(–18) cm long; calyx and corolla green. Pod thinly chartaceous, oblongoid, stalked, 5.5–9.5(–1) cm × 1.4–2.6 cm, apiculate at the apex. Seed compressed ellipsoid, 6 mm × 4 mm × 2 mm, black. *P. lophantha* subsp. *montana* occurs in light montane forest, elfin forest, grass plains, often on crater slopes and in stony, open sites at (600–)1500–3250 m altitude. Trees start flowering and fruiting when 5–6 years old. Seeds germinate easily after fire or acid treatment.

Selected sources 27, 51, 70.

Paulownia Siebold & Zucc.

SCROPHULARIACEAE

Major species and synonyms
- *Paulownia elongata* S.Y. Hu.
- *Paulownia fortunei* (Seemann) Hemsley.
- *Paulownia tomentosa* (Thunb.) Steud., synonym: *P. imperialis* Sieb. & Zucc.

Vernacular names Philippines: kiri (general). Laos: s'o:k, s'o:z, s'o: phôk (northern).

Distribution Native to India, northern Indo-China, China, Taiwan and Japan; introduced into Thailand and the Philippines, occasionally cultivated as an ornamental elsewhere in South-East Asia.

Uses The wood yields excellent charcoal used for high class fireworks and gunpowder. It is also used for beams and poles. The lightweight timber is highly valued in Taiwan and Japan, and suitable for wood work, musical instruments, sandals, delicate furniture, linings, cabinets, badminton rackets, and also for fishing net floats, boxes and crates. In China, *P. tomentosa* is planted for erosion control and intercropped with wheat. Wood and bark are reported to have astringent properties. Several species are used for reforestation in Thailand, and their use is being promoted in East Asia. *P. tomentosa* was introduced into the Philippines for wood producing plantations. *P. fortunei* seems capable of cleaning air polluted with chlorine.

Observations Small deciduous trees up to 20 m tall. Leaves opposite, ovate to broadly ovate, cordate at base, entire or slightly 3–5-lobed, usually tomentose below. Flowers in 3–5-flowered cymes; calyx campanulate, 5-lobed; corolla zygomorphic, shortly 5-lobed, slightly 2-lipped; stamens 4. Fruit a dehiscent capsule. Seed winged. The trees are easy to propagate by means of cuttings. Their growth is very rapid: mean annual diameter increment is 6.5 cm, and mean annual height increment is 1.72 m. The wood is comparatively soft, white or reddish-brown, and has a beautiful grain. Its air-dry density is about 320 kg/m^3.

Selected sources 15, 53, 112, 116, 174.

Peristrophe paniculata (Forsskal) Brummitt

ACANTHACEAE

Synonyms *Justicia bicalyculata* (Retz.) Vahl, *Peristrophe bicalyculata* (Retz.) Nees.

Distribution From Africa and Arabia to India, Indo-China, Thailand, and Peninsular Malaysia.

Uses Suitable as a green manure and as a fodder for horses. An essential oil obtained from the plant shows tuberculostatic activity in vitro.

Observations Erect, hispid herb or undershrub, up to 180 cm tall. Leaves ovate, acuminate, pubescent. Inflorescence a lax panicle with axillary cymes, terminal on the inflorescence branch, with 2 linear bracts at its base; flowers reddish, purple or pink. Fruit a pointed capsule. *P. paniculata* occurs in forest undergrowth, hedges, and wasteland.

Selected sources 27, 51, 135, 174, 182.

Phragmites australis (Cav.) Trin. ex Steudel

GRAMINEAE

Synonyms *Phragmites communis* Trin., *P. vulgaris* (Lamk) Crépin.

Vernacular names Common reed (En). Roseau (Fr). Indonesia: glagah asu, plumpung (Javanese), bayongbong (Sundanese). Malaysia: tebu salah, rumput gedabong. Philippines: tambo (Tagalog), bagang (Bisaya), lupi (Bikol). Laos: 'o:z no:yz. Thailand: o, o-noi (northern), o-lek (central). Vietnam: c[aa]y s[aaj]y.

Distribution Almost cosmopolitan, even in Arctic regions.

Uses Used to stabilize river and lake banks, for desalinization, weed control and initial soil preparation of newly reclaimed polders, biological purification of waste water (helophyte filter), roofing and hedging, fuel, and paper manufacture. Young shoots are eaten as a vegetable in China.

Observations Perennial grass, up to 4.5(–6) m tall with stout, creeping rhizomes and stolons. Leaf sheaths loose, overlapping; ligule consisting of hairs, up to 1.5 mm long; blade flat, up to 60 cm × 0.8–6 cm, greyish-green, glabrous or covered with whitish powder. Inflorescence a dense panicle, feathery, nodding at the top, 15–40 cm long, brownish to purplish; spikelets 2–6-flowered, 10–18 mm long; florets exceeded by 6–10 mm long hairs of the rachilla. *P. australis* occurs in moist and wet locations, but often also on firm ground, up to 2200 m altitude. Propagation is by planting rhizomes or by sowing. In new polders aerial sowing has been practised. *Phragmites karka* (Retz.) Trin. ex Steudel is more common in the moist tropics of South-East Asia, Australia and Africa, and can be used for the same purposes. Apart from all beneficial roles, reeds may become weedy and overgrow canals and drains, necessitating cumbersome cleaning operations.

Selected sources 8, 56, 71, 164.

Phyllanthus ciccoides Muell. Arg.

EUPHORBIACEAE

Synonyms *Flueggeopsis microspermus* K. Schum., *Phyllanthus novae-hollandiae* Baillon non Muell. Arg., *P. baccatus* F. Muell. ex Benth.

Vernacular names Solomon Islands: sasale.

Distribution From New Guinea to the New Hebrides, the Solomon Islands, the Santa Cruz Islands, and Australia (Northern Territory and Western Australia).

Uses In the Solomon Islands planted as a fallow crop, for live fences, and as a support tree for yams (*Dioscorea* spp.). The wood yields an average quality fuel. It is quite heavy and used for beams and posts in house building, and is also suitable for digging sticks used e.g. in taro (*Colocasia esculenta* (L.) Schott) cultivation. The pounded leaves are boiled in a mixture with other ingredients in order to stain *Pandanus* leaves black for traditional mat making.

Observations Small, monoecious tree or shrub up to 10 m tall. Branchlets with flowers and about 10 leaves, glabrous or white pubescent. Leaves alternate, simple, entire, broadly ovate, glabrous or white pubescent, 1.5–4.5 cm long, obtuse or shortly acuminate; stipule 1 mm long. Flowers in a fascicle; male flower 1 mm long; female flower with caducous tepals; ovary 6-locular. *P. ciccoides* occurs in disturbed montane rain forest, tall secondary forest, garden regrowth, and in *Imperata* grass infested sites, on stream banks and in steep hill forest, up to 1900 m altitude. It grows rapidly and can be propagated by cuttings.

Selected sources 2, 3, 38, 67, 177.

Prosopis cineraria (L.) Druce

LEGUMINOSAE – MIMOSOIDEAE

Synonyms *Prosopis spicigera* L.

Distribution Occurring naturally from Saudi Arabia to India, cultivated in many semi-arid tropical countries. In South-East Asia it is grown in Java.

Uses *P. cineraria* is grown for fuelwood for cooking and heating and provides excellent charcoal with an energy value of about 25 000 kJ/kg. Farmers in northern India often plant annual crops beneath it to make use of the higher soil fertility and to protect the crop against extreme weather conditions. It is used to reforest denuded areas such as sand dunes.

Observations Shrub or small tree with an open crown, up to 6.5 m tall with scattered internodal prickles, but without stipular thorns. Leaves bipinnate with 1–3 pairs of pinnae; leaflets 7–14 pairs, 4–15 mm × 2–4.5 mm. Inflorescence a raceme, 5–10 cm long, often combined into paniculate aggregates; petals yellow. Pod slender, elongated, subcylindrical, 8–19 cm × 4–7 mm, constricted between the seeds. Seed ovoid, about 6 mm long. *P. cineraria* grows in regions with 75–850 mm annual rainfall and a long dry season. It withstands high temperatures (up to 50°C) and light frost (up to –6°C) and tolerates alkaline and slightly saline soils. It may become a noxious weed in more humid areas.

Selected sources 8, 51, 70, 116, 140.

Pseudarthria viscida (L.) Wight & Arnott

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Hedysarum viscidum* L., *Desmodium timoriense* DC., *D. viscidum* (L.) DC.

Distribution From Pakistan to Burma (Myanmar) and in Indonesia (East Java, Lesser Sunda Islands (Bali and Nusa Tenggara), Sulawesi, Moluccas).

Uses A potential green manure. In traditional medicine the roots are used against a variety of ailments.

Observations Ascending, much branched herb, up to 120 cm tall, often clothed with hooked hairs. Stem slender, with fine grey hairs. Leaves distichous, trifoliolate; leaflets obovate-rhomboid, 4–10 cm × 3–5 cm, apex obtuse or acute, lateral leaflets obliquely elliptical-obovate, grey pubescent. Inflorescence an axillary or terminal raceme, sometimes branched, up to 20 cm long; flowers in fascicles of 2 or more, purplish to pink; pedicel 4–7 mm long. Pod linear, 1.2–2 cm × 5–7 mm, pubescent, 4–6-seeded, not articulate. Seed brownish-black. *P. viscida* is found up to 1200 m altitude, in dry regions, in grassy fields, roadsides and thickets.

Selected sources 8, 73, 103, 174.

Reissantia cassinoides (DC.) Ding Hou

CELASTRACEAE

Synonyms *Hippocratea beccarii* Tuyn., *H. glaga* Korth.

Vernacular names Indonesia: areuy mangender (Sundanese).

Distribution Peninsular Thailand, southern Sumatra, Bangka, West Java, Timor, and Borneo (Sabah, Sarawak).

Uses Used as fuelwood. The scorched leaves are used as an ingredient of sambal, and medicinally, mixed with *Alyxia* sp. ('adas pulasari'), against rheumatism. The juice from the stem is drunk against fever.

Observations Liana. Leaves decussate, broadly elliptical to ovate-oblong, 7–15 cm long, margin entire or remotely crenulate. Inflorescence dichotomously cymose, with supplementary branchlets in the dichotomies, 4.5–8.5 cm long; flowers subsessile, small; calyx divided almost to the base; petals 5, pale yellow or yellowish-green; disk inconspicuous; stamens 3; ovary 3-celled, with 4–8 ovules in each cell. Fruit a capsule. *R. cassinoides* occurs in lowland forest up to 500 m altitude.

Selected sources 51, 70.

Rhynchosia rufescens (Willd.) DC.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Glycine rufescens* Willd., *Cyanospermum javanicum* Miquel.

Distribution India, Bangladesh, Sri Lanka, Cambodia, Java.

Uses A component of natural fallow vegetation, worked into the soil as a green manure. It is not a cover crop.

Observations Deep rooting, viscid herb, up to 1.5 m tall. Branches trailing, long, short grey pubescent. Leaves trifoliolate; petiole 2.5–5 cm long; stipules minute, caducous; leaflets ovate to oblong, 2.5–7.5 cm × 1–4 cm, pubescent. Inflorescence a lax, subsessile raceme, up to 15 cm long, 2–10-flowered; pedicel 3–6 mm long; calyx campanulate, 5-lobed, about 13 mm long, persistent in fruit; corolla yellow, about 13 mm long. Pod flattened-globose, 11 mm × 5 mm, finely downy, 1-seeded. *R. rufescens* occurs in open country, brushwood and hedges, up to 900 m altitude. Initial growth is slow. It produces no prostrate stems but trailing shoots and is richly nodulating. It is not harmed by diseases and pests and is suitable for monsoon areas.

Selected sources 8, 53, 70, 73.

Rhynchospora corymbosa (L.) Britton

CYPERACEAE

Synonyms *Rhynchospora articulata* (Roxb.) Roem. & Schultes, *R. aurea* Vahl.

Vernacular names Indonesia: ilat rawa (Sundanese), suket brem (Javanese), rumput sendayan (Indonesian). Malaysia: sendayan piah, rumput pepara, rumput serian (Peninsular). Philippines: agas (general), bariu-bariu (Bikol), salagata (Maranao). Thailand: ya-khombang (Nakhon Si Thammarat), ya-baikhom (Bangkok). Vietnam: c[os]i d[aaf]u h[oof]ng ch[uf]y.

Distribution Pantropical, including South-East Asia.

Uses Ploughed in as a green manure in rice fields. The stems are used for making mats, sandals and baskets.

Observations A perennial, tillering herb with short rhizomes, up to 100(–150) cm tall. Stem triangular, leafy. Leaves flat, rough along the margins, 8–20 mm wide. Inflorescence 20–40 cm long, consisting of 2–5 distant clusters of subsessile and rayed spikes; spikelets 2–3-flowered, rusty brown, lower floret bisexual, upper one or ones male; perianth segments 6 in the bisexual flower, bristle-like; style with a broad conical base. *R. corymbosa* is common and often dominant e.g. in open swampy sites, rice fields, and on river banks, up to 1300 m altitude.

Selected sources 25, 27, 51, 148, 150, 174.

Ruppia maritima L.

POTAMOGETONACEAE

Synonyms *Ruppia cirrhosa* (Petagna) Grande, *R. rostella* Koch, *R. spiralis* L. ex Dumort.

Vernacular names Ditch grass, tassel pondweed (En). Vietnam: h[ar]i kim.

Distribution Cosmopolitan; throughout South-East Asia.

Uses Applied to clarify and improve the water quality of fish ponds in salt water or brackish water. It is also important as a fish food.

Observations Submerged, salt water or brackish water plant. Leaves alternate, linear, up to 10 cm long; stipules membranous and fused to form a sheath. Inflorescence axillary, with 4–6 flowers, on a peduncle which elongates in fruit; flowers bisexual; perianth absent; stamens 2; carpels 2–3. Fruit ovoid, on a stipe up to 30 mm long. *R. maritima* is uncommon in salt water and brackish water swamps.

Selected sources 27, 53, 70, 101, 174.

Sagittaria guayanensis Kunth subsp. lappula (D. Don) Bogin

ALISMATACEAE

Synonyms *Lophiocarpus guayanensis* (Kunth) Micheli, *Sagittaria cordifolia* Roxb., *S. lappula* D. Don.

Vernacular names Indonesia: keladi air, kelipok padang (Indonesian), enceng (Sundanese). Malaysia: keladi air, kelipok padang (Peninsular).

Distribution Tropical Africa and South-East Asia to East Asia (including Taiwan); in the Malesian region in Peninsular Malaysia, Sumatra, Java, and Sulawesi.

Uses Ploughed in as a green manure in rice fields. The leaves are sometimes used to feed pigs.

Observations Laticiferous perennial freshwater plant. Leaves floating, in a rosette, ovate with a deeply cordate base; petiole sheathing. Inflorescence a raceme with 2–6 whorls of 2–3 flowers, the lower 1–4 whorls with bisexual flowers, the upper whorls with male ones; flowers 3-merous, with closely appressed sepals; petals white with a yellowish base; carpels many. Fruit an elliptical achene, with a broad, bluntly spiny crest. *S. guayanensis* often occurs gregariously in ditches and wet rice fields, up to 1000 m altitude. Subsp. *lappula* is the only one occurring in South-East Asia; subsp. *guayanensis* is found in tropical America. The plants rapidly reappear as a weed after ploughing and may become troublesome. Manual removal just before flowering is recommended.

Selected sources 27, 51, 150, 174.

Salix tetrasperma Roxb.

SALICACEAE

Synonyms *Salix azaolana* Blanco, *S. horsfieldiana* Miquel.

Vernacular names Indian willow (En). Indonesia: dalu-dalu, leri. Malaysia: dedalu india, sendalu, nalu air. Philippines: bai-bai. Burma (Myanmar): momaka. Cambodia: sâmpaèt. Laos: kh'aiz kha:w, kh'aiz ngi:wz, kh'aiz nunz (north-western). Thailand: khlai (Pattani), khrai nun (Northern), sanun (Central).

Distribution From Afghanistan and the Punjab eastwards throughout South-East Asia and southern China; in Malesia in Peninsular Malaysia, Sumatra, Java, Lesser Sunda Islands (Bali and Nusa Tenggara), East Kalimantan and the Philippines. In Peninsular Malaysia, only the male sex has been introduced.

Uses Planted on the bunds of wet rice fields in Peninsular Malaysia for soil protection. Also planted in regularly pollarded and coppiced hedges to delimit field boundaries. Used medicinally as a febrifuge. The timber is occasionally used for construction purposes, wash tubs and other household utensils.

Observations Shrub or tree, up to 25 m tall, usually smaller. Leaves elliptical to lanceolate, (6–)8–16(–24) cm × (2–)2.5–4(–6) cm. Inflorescence a catkin on the branches of the previous flush, on short twigs; male ones more or less pendulous, 4–12 cm long, female ones more straight, 4–12 cm long. Found along watercourses and banks of pools and lakes, in Sumatra up to 1500 m altitude, in the Philippines to medium altitudes. *S. tetrasperma* is generally grown from cuttings.

Selected sources 27, 34, 51, 133.

Salvia occidentalis Swartz

LABIATAE

Synonyms *Salvia procumbens* Ruiz & Pavon.

Vernacular names Indonesia: langon, legetan warak, randa nunut (Javanese).

Distribution Occurring naturally throughout tropical America to Florida. Introduced into Indonesia.

Uses Tested as a cover crop in Indonesia. Its present utilization is unknown.

Observations Strongly branched, foetid, annual herb, up to 1.6 m tall. Leaves ovate to rhomboid, 2–6 cm long, apex acute, base cuneate, margin serrate, upper surface appressed hairy, lower surface hirtellous, or both sides glabrous. Inflorescence an interrupted spike with mostly 6-flowered whorls; calyx 2 mm long (3 mm in fruits), hairy, glandulose, upper lip rounded-truncate, lower lips ovate-acuminate; corolla blue, tube 2.5 mm long. *S. occidentalis* is naturalized in Java, especially in the eastern parts, up to 850 m altitude. It is suitable for heavy clay, quickly providing an adequate cover. Once established it prevents the formation of an *Imperata* grass cover.

Selected sources 93, 101.

Saurauia Willd.

ACTINIDIACEAE

Major species and synonyms

- *Saurauia distasosa* Korth., synonym: *S. junghuhnii* Choisy.
- *Saurauia fragrans* Hoogl., synonym: *S. tristyla* auct., non DC.
- *Saurauia napaulensis* DC.
- *Saurauia pentapetala* (Jack) Hoogl., synonyms: *S. nudiflora* DC. var. *angustifolia* Craib, *S. tristyla* auct., non DC.
- *Saurauia roxburghii* Wall., synonym: *S. tristyla* auct., non DC.
- *Saurauia tristyla* DC.

Vernacular names Malaysia: kelapong, lengadir (Peninsular). Philippines: kalimug (Tagalog). Thailand: chasamkaeo (Nakhon Si Thammarat), samkaeo (peninsular), chasan (Chiang Mai). Vietnam: chi n[os]ng, d[uw][ow]ng d[af]o.

Distribution A large genus occurring from northern India and Nepal throughout South-East Asia to the Ryukyu Islands, northern Australia and Fiji (about 250 species); also in Central and South America (about 70 species). *S. napaulensis* has possibly been introduced into Peninsular Malaysia.

Uses Of some use as firewood. The fruits are edible but rather insipid. *S. napaulensis* is used in India and Nepal as a fodder and for erosion control, and as an ornamental in Sri Lanka. *S. distasosa* is cultivated in Java as a hedge plant.

Observations Shrubs or small trees up to 15(–20) m tall, covered with scales and hairs. Bark greyish-brown to reddish, inner bark pink, orange or red. Leaves arranged spirally, simple. Inflorescence axillary or clustered on young twigs, cymose, corymbose or paniculate, sometimes with solitary flowers; flowers 5-merous, regular, bisexual; sepals free, persistent in fruit; petals connate at base, notched, white to pink or mauve. Fruit a berry, splitting open and exposing the numerous seeds embedded in slimy sweet-tasting jelly. *Saurauia* spp. often occur along creeks in primary forest, but also in secondary forest or disturbed sites, up to 2000 m altitude, but are most common between 500 and 1200 m. Uncertainty has existed about the true identity, especially of *S. tristyla*, leading to some confusion in the past. True *S. tristyla* is confined to Sulawesi and the Moluccas.

Selected sources 8, 27, 51, 72, 135, 148, 149.

Senna divaricata (Nees & Blume) Lock

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia divaricata* Nees & Blume.

Vernacular names Indonesia: ontobogo, aringin, ketepeng (Javanese). Philippines: ataatab (Igorot).

Distribution Probably native to South America. Introduced into Indonesia (Java, Bali) and the Philippines (Luzon).

Uses Used as a green manure in coffee plantations and as a temporary wind-break.

Observations Shrub, 2–5 m tall. Leaves with 6–11 pairs of leaflets; rachis with an orange-reddish gland between the lower and upper leaflet pairs; leaflets elliptical-oblong, 1.5–4.5 cm × 0.5–1.5 cm, apex obtuse or rounded. Inflorescence an axillary raceme, single or paired; peduncle 1.5–3 cm long, bearing 2–3 flowers; bracts caducous; petals broadly ovate, 1.5–2.5 cm long, bright yellow; stamens 10, 3 large and 7 smaller ones. Pod straight or curved, strap-shaped, 13–22.5 cm × 5–8 mm, 15–50-seeded. *S. divaricata* is found in Central and East Java, at 300–1700 m altitude, often along watercourses, on marshy soils, and in clearings, never very frequent. Dried leaves are delicately black punctate or mottled.

Selected sources 8, 43, 70.

Senna septemtrionalis (Viv.) Irwin & Barneby

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia floribunda* auct., non Cavanilles, *C. laevigata* Willd.

Vernacular names Arsenic bush, Dooley weed, smooth senna (En). Indonesia: sentung (Javanese), kasingsat (Sundanese), gelanggang (Sumatra). Thailand: khilek-america (northern). Vietnam: b[oo] cap nur[oo]c.

Distribution South and Central America, possibly originated in Mexico; naturalized in Java, rare in Indo-China, as an escape from cultivation. At present, it is widespread in the tropics, cultivated or as a weed.

Uses Green manure and hedge plant. It is often grown as a shade plant in coffee plantations. The seeds are occasionally eaten as a pulse by tribal people in India; they have negligible anti-nutritional factors that are easily inactivated by cooking. Seed meal is used as fodder. Seeds are a coffee substitute in Guatemala. In Sumatra young leaves are eaten as a vegetable.

Observations Glabrous herb or shrub up to 4(–7) m tall. Branchlets fistular with membranous septa within. Leaves with 3–5 pairs of leaflets; rachis 6–12 cm long with a gland between all or at least the 2 lowest pairs of leaflets; leaflets ovate to elliptical, 4–11 cm × 2–3.5 cm, apex long-acuminate, glaucous below. Inflorescence an axillary or terminal raceme, 5–10 cm long; flowers 4–10; pedicel up to 2.5 cm long; sepals very unequal, glabrous; petals suborbicular, 1–2 cm in diameter, yellow; stamens 10, 3 long, 4 short, 3 reduced ones with empty anthers. Pod cylindrical, 6–10 cm × 8–15 mm, dehiscing along ventral suture, 40–50-deeded. Seed ovoid, 6–8 mm in diameter, olive-green, shiny. *S. septemtrionalis* is found on roadsides, forest edges, fallow land, plantations, from 900–2500 m altitude, although also recorded as low as 25 m.

Selected sources 8, 43, 51, 52, 53, 106, 170.

Senna surattensis (Burm.f.) Irwin & Barneby

LEGUMINOSAE – CAESALPINIOIDEAE

Synonyms *Cassia glauca* Lamk, *C. suffruticosa* Heyne ex Roth, *C. surattensis* Burm.f.

Vernacular names Glaucous cassia (En). Indonesia: kembang kuning. Malaysia: gelenggang. Laos: (do:k) sake:, sak heng? (Luang Prabang). Thailand: khilek-ban (northern), songbadan (Central). Vietnam: (c[aa]y) b[of] c[aj]p, mu[ows]ng bi[eer]n, ho[ef] hoa.

Distribution Indigenous to South and South-East Asia; now cultivated throughout the tropics.

Uses Often interplanted in young teak plantations and used as a shade tree in the Philippines. It is a popular ornamental e.g. in Hawaii, Taiwan and Hong Kong, being rather insensitive to SO_2 pollution. Young leaves are cooked and eaten as a vegetable. In traditional medicine a decoction of the roots is used against gonorrhoea, the leaves against dysentery and the flowers as a purgative.

Observations Shrub or treelet up to 7 m tall. Young branches glabrous to puberulous. Leaves with 4–9 pairs of leaflets; petiole 1.5–5 cm long; rachis up to 15 cm long, with a clavate gland between the 2–4 lower pairs of leaflets; leaflets ovate to ovate-oblong, 3–10 cm × 1–5 cm, glabrous above, sparsely hairy and glacous below. Inflorescence an axillary raceme, 5–13 cm long, 10–20-flowered; pedicel 1–4 cm long; outer sepals 2, rounded, 3–5 mm long, inner sepals 3, up to 7 mm long; petals subequal, ovate-oblong, 2–3 cm long, yellow, claw 1–3 mm long; stamens 10 with thick filaments, one 3–4 mm, others 1–2 mm long. Pod flat, strap-shaped, 15–20 cm × 12–18 mm, glabrous, 20–35-seeded. Seed 1 cm long, black, shiny. *S. surattensis* does not nodulate. It favours teak forest and marshy soils, up to 300 m altitude.

Selected sources 8, 27, 43, 51, 53, 70, 97, 170.

Sesbania javanica Miquel

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Sesbania aculeata* (Willd.) Pers. var. *paludosa* (Roxb.) Baker, *S. paludosa* (Roxb.) Prain, *S. roxburghii* Merrill.

Vernacular names Cambodia: snaô. Laos: sanô:.

Distribution From India and China throughout South-East Asia to Australia.

Uses Used as a green manure and hedge plant in wet areas. The leaves are used for forage and as a vegetable. In Cambodia flowers are prepared with sugar or salt and eaten.

Observations Herb or subshrub, 1–5 m tall, softly woody at the base. Stem and leaves glabrous. Leaves with 10–30 pairs of leaflets; petiole very short; leaflets subopposite, linear-oblong, 0.5–4 cm × 2–7 mm, apex broadly rounded to truncate and mucronulate. Inflorescence a raceme up to 11 cm long with 5–14 flowers; pedicel 5–14 mm long; calyx tube 6–8 mm, teeth 2 mm long; corolla 2–3 cm long, orange-yellow with purple markings on the back of the standard. Pod flat cylindrical, 20–30 cm × 4–5 mm, with about 45 seeds. Seed globose-ellipsoid, 3.5–5 mm × 2.5 mm, greenish-olive to dark brown or blackish. In permanent swamps or along watercourses, up to 500 m altitude.

Selected sources 8, 26, 53, 62, 101, 170.

Spinifex littoreus (Burm.f.) Merrill

GRAMINEAE

Synonyms *Spinifex squarrosus* L., *Stipa littorea* Burm.f., *Stipa spinifex* L.

Vernacular names Waterpink (En). Indonesia: rumput angin (Indonesian), suket kretanan (Javanese), jukut tiyara (Sundanese). Thailand: ya-loilom, ya-linglom (Songkhla). Vietnam: c[or] ch[oos]ng c[as]t bay.

Distribution On coasts from India and Sri Lanka throughout South-East Asia to Taiwan and southern Japan.

Uses Useful as a sand binder in unstable coastal dunes.

Observations Stout, dioecious, stoloniferous grass up to 90 cm tall, with rigid, spiny leaves. Spikelets in racemes subtended by large bract-like spatheoles which are fascicled into large capitate spiny structures of up to 30 cm in diameter. *S. littoreus* is fairly common along sandy shores and dunes.

Selected sources 19, 27, 91, 101, 148, 174, 181.

Sporobolus humilis Presl subsp. minor Veldk.

GRAMINEAE

Synonyms *Sporobolus tremulus* auct., non (Willd.) Kunth.

Distribution Pakistan and India, possibly in Indo-China. In the Malesian region only in Java and the Philippines.

Uses Useful for erosion control. It may prove valuable as a fodder.

Observations Tufted and mat-forming perennial grass with short rhizomes and long slender stolons. Leaves very narrow. Spikelets 1-flowered, 1.4–2.1 mm long, glabrous, not awned, in contracted, spiciform panicle of 1–3 cm × 2–4 mm; glumes slightly shorter than the spikelet. *S. humilis* subsp. *minor* is found near the coast and inland in open scrub vegetation and along wet rice fields; in India up to 750 m altitude. Subsp. *humilis*, which is found in Indo-China, Java and the Philippines, has a less compact habit, larger panicles and smaller spikelets.

Selected sources 7, 19, 70.

Struchium sparganophora (L.) O. Kuntze

COMPOSITAE

Synonyms *Ethulia sparganophora* L., *Sparganophorus sparganophora* (L.) Jeffrey, *Sparganophorus vaillantii* Cranz.

Vernacular names Portebandeau (Fr). Indonesia: awa lanaru, pacar hutang (Java).

Distribution Originated in tropical America; introduced and widely naturalized elsewhere and now pantropical.

Uses Ploughed in as green manure in rice fields. It is eaten by cattle. In Africa, the leaves are eaten as a vegetable.

Observations Herb up to 80 cm tall. Leaves alternate, subsessile or shortly petioled, elliptical or oblong-obovate, 5–16 cm long, sub-entire to shallowly crenate-serrate, glandular. Inflorescence an axillary, sessile head, 1–8 together, small, many-flowered, semi-globose; flowers all tubular; corolla white or pale violet; anthers sagittate; pappus an irregularly dentate cup. *S. sparganophora* is a frequent weed of slightly shaded, moist sites, roadsides, river banks, and waste places, up to 700 m altitude.

Selected sources 8, 27, 82, 86, 101.

Tephrosia noctiflora Bojer ex Baker

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Tephrosia subamoena* Prain, *T. hookeriana* Wight & Arnott var. *amoena* Prain.

Vernacular names Indonesia: nila hutan (Indonesian), tom sapi, tom gatal (Sumatra). Malaysia: petai balong kecil (Penang), kolo thakarai (Tamil), kacang bulu.

Distribution Native to tropical and subtropical Africa and probably India; naturalized in Indonesia, Papua New Guinea, Australia and in the Antilles. Occasionally cultivated pantropically.

Uses A cover crop and green manure plant, that can be cut several times, grown in wet rice fields, in young rubber and coconut plantations. It is sometimes planted as a contour hedge; also used as fish poison.

Observations Sparsely branched, annual herb or shrub, 1.5–2 m tall. Stem densely covered with pale brown, spreading and appressed hairs. Leaves imparipinnately compound with 12–25 leaflets; petiole 1–2.5 cm long; rachis 6–12.5 cm long; leaflets obovate to elliptical, 1–4.5 cm × 3–10 mm, mucronate, glabrous above, appressed hairy below. Inflorescence a terminal, axillary or leaf-opposed pseudoraceme to 35 cm long; peduncle 3–16 cm long; flowers in clusters of 1–5 in axil of narrow bracts; pedicel 2–5 mm long; calyx 5–7 mm long, densely hairy; standard 10–13 mm long and wide, purple towards the centre, margins white; wings 5–8 mm long, purple above, white below; keel purple. Pod 3–6 cm × 0.5 cm, 5–10-seeded, covered with rust-coloured hairs. Seed reniform, plump, about 3.5 mm long, dark brown, reticulate. *T. noctiflora* is found naturalized in Java up to 700 m altitude, in grassy areas, ruderal locations, and river banks. Young plants do not withstand heavy rain, older plants withstand waterlogging. It is self-pollinating and nodulates well. The aerial parts contain gamma-glutamyltyraminine. *T. noctiflora* is often confused with *T. purpurea* (L.) Persoon.

Selected sources 8, 21, 62, 70, 101, 170, 174.

Tephrosia pumila (Lamk) Persoon

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Tephrosia timoriensis* DC.

Distribution Pantropical, possibly originated in Madagascar.

Uses A green manure crop.

Observations Annual herb or short-lived perennial, 30–60 cm tall, branched from the base, stem with long hairs. Leaves imparipinnate, up to 6.5 cm long; stipules linear, setaceous; leaflets 2–7 pairs, elliptical to obovate, 3–27 mm × 1–9 mm, truncate or emarginate at the apex. Inflorescence a terminal or leaf-opposed pseudoraceme, up to 10 cm long, 2–6-flowered; flowers 3–7 mm long; pedicel 1.5–3 mm long; calyx teeth long, thin; corolla white turning pink, standard 3–6 mm long. Pod linear, 2–4.5 cm × 3–5 mm, finely downy, 5–14-seeded. Seed quadrangular, up to 3.5 mm long. *T. pumila* is found in low-lying areas with little rainfall, beaches, arable fields, grasslands, river banks, on limestone, coral and stony soils, up to 100 m altitude. The fruit contains various flavonoids.

Selected sources 8, 21, 70, 73, 113, 170.

Tephrosia villosa (L.) Persoon

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Galega villosa* L., *Tephrosia incana* (Roxb.) Sweet.

Distribution Possibly native to Africa and India, now distributed in tropical and subtropical Africa, from Pakistan to Indo-China and naturalized in Indonesia (Java, Lesser Sunda Islands (Bali and Nusa Tenggara)). Occasionally also cultivated elsewhere.

Uses A green manure and annual cover crop in Africa, tested in Indonesia. Leaf juice is used to treat dropsy and diabetes in India.

Observations Annual or perennial bushy herb, 0.3–1.3 m tall. Stem white tomentose. Leaves imparipinnately compound with 7–19 leaflets, up to 10 cm long; stipules 2–5 mm long; leaflets obovate to elliptical, up to 21 mm × 9 mm, hairy on both sides, each side with 4–8 pairs of distinct veins. Flowers in a terminal or upper axillary pseudoraceme 8–22 cm long; pedicel with densely matted hairs, 2–4 mm long; calyx densely matted-hairy, tube about 2 mm long, lobes long-acuminate, to 9 mm long; standard transversely elliptical to broadly ovate, up to 7 mm × 10 mm, dorsally with dense brown hairs. Pod strongly curved, up to 4 cm × 6 mm, densely silvery or brown-tomentose, hairs to 2 mm long, 4–10-seeded. Seed rectangular, with short hard excrescences, up to 3.5 mm × 2.5 mm. *T. villosa* occurs in open fields, floodplains, often on sandy soils, up to 150 m altitude. It is tolerant of a long dry season and of heavy rain. In Africa it is appreciated for its dense foliage. The roots and leaves contain rotenoids.

Selected sources 8, 21, 23, 52, 101, 113.

Tithonia diversifolia (Hemsley) A. Gray

COMPOSITAE

Synonyms *Mirasolia diversifolia* Hemsley.

Vernacular names Mexican sunflower (En). Indonesia: harsaga, kembang mbulan (Javanese), srengenge leutik (Sundanese). Thailand: daoru-ang-yipun, thantawan-nu, benchamat-nam (Bangkok).

Distribution Native to Mexico and Central

America; introduced into most tropical countries, often naturalized.

Uses Used as a green manure, for erosion control on steep roadsides and in tea plantations, as an impenetrable hedge plant, in fire-breaks, and as an ornamental. The wood is collected for fuel, e.g. in Java. The flower heads are used medicinally for wounds and bruises, and contain insecticidal substances.

Observations Perennial shrub with subterranean stolons, up to 9 m tall. Leaves alternate, ovate, ovate-rhomboid, or ovate-oblong, 7–32 cm long, serrate, short-haired and minutely glandular. Inflorescence an axillary or terminal, solitary head, 6–14 cm in diameter, with both ray and tubular flowers; peduncle much thickened upwards; corolla yellow; anthers black with a yellow top; pappus consisting of a few scales and 2–3 awns. *T. diversifolia* occurs at (0–)200–1500 m altitude. It tolerates regular heavy pruning. In Ivory Coast, annual biomass yields of 60 t/ha have been obtained at cutting intervals of 4 months. The leaves have a nitrogen content of 4%. It sometimes becomes weedy.

Selected sources 8, 101, 148, 174.

Tridax procumbens L.

COMPOSITAE

Vernacular names Mexican daisy, coat buttons (En). Indonesia: gletang (Indonesian), katumpang (Sundanese, Javanese). Malaysia: kancing baju (Peninsular). Thailand: tintukkae (Suphan Buri).

Distribution Originally from Central America; introduced and now naturalized in many tropical countries.

Uses Proposed as a cover crop, but its actual use and value are questionable. The leaves are cooked and eaten as a vegetable, and are also useful as a fodder. They are used medicinally against bronchial catarrh, dysentery, and diarrhoea. Leaf juice possesses antiseptic, insecticidal, and parasiticidal properties.

Observations Perennial herb with creeping stems which are obliquely erect at the apex, up to 75 cm long. Leaves opposite, ovate-elliptical, 0.5–5 cm long, coarsely serrate or lobed, hispid. Inflorescence a terminal, solitary head, about 2 cm in diameter, on peduncle 10–30 cm long, with ray and tubular flowers; involucre campanulate, about 3-seriate; flowers with yellow corolla; pappus bristles long-plumose. *T. procumbens* is found in sunny, dry locations, especially sandy and rocky sites like roadsides, railways, dunes, and waste places, up to 1000 m altitude. Occasionally it is a troublesome weed.

Selected sources 8, 27, 70, 148, 174.

Uraria crinita (L.) Desv. ex DC.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Hedysarum crinitum* L., *Uraria crinita* (L.) Desv. ex DC. var. *macrostachya* (Wallich) Schindler.

Vernacular names Indonesia: ekor kucing (general), buntut careuh (Sundanese), uler-uleran (Javanese). Malaysia: pokok ekur anjing, serengan hutan, keretak babi. Singapore: pokok ekor anis, seringau. Cambodia: chô:l hôk, kântuy châchâ:k (trâcha:k), kântuy kâ-ngaôk. Laos: (do:k) ha:ng kh'a:ngx, ha:ng süa. Thailand: hangmachok, hangkrarok. Vietnam: b[oo]n b[oo]n, (c[aa]y) du[oo]i ch[oo]n.

Distribution From India and southern China throughout South-East Asia.

Uses Used locally as green manure and cover crop. Different plant parts are used to cure dysentery, diarrhoea and in the treatment of enlarged spleen and liver. It is also applied against pustules, tumors and fistulae. The whole plant is effective in driving out intestinal worms and other parasites and is sometimes used as a carminative for children. The leaves are used to kill lice. Sometimes also cultivated as ornamental.

Observations Erect subshrub, 0.5–2 m tall. Branches terete, densely pubescent. Leaves pinnately compound, upper leaves 3–7-foliolate, lower ones 3-foliolate; petiole 10–13 cm long, pubescent; stipules free, about 1 cm long; stipels 3 mm long; leaflets ovate to lanceolate, 8–16 cm × 1.5–5.5 cm, apex acute, glabrous above, hairy beneath. Inflorescence a terminal, cylindrical, densely flowered raceme, (7–)12–30(–50) cm long; lower bracts empty, upper ones with 2 flowers, lanceolate, 10–20 mm × 3–6 mm; pedicel 3–15 mm long; with long bristles; calyx tube short, 2 upper teeth up to 6 mm long, 3 lower teeth up to 7 mm long; corolla purplish pink; standard obovate, 6–10 mm × 6–8 mm, glabrous; wings shorter than keel, clawed; keel 7–9 mm long, clawed; stamens 10, diadelphous. Pod 2–4(–7)-jointed, constricted between joints, indehiscent, shiny black, hairy. Seed reniform-globose, compressed, 1.5–2 mm in diameter, brown. *U. crinita* is common in dry grassland, open forest, waste places, roadsides, sandy areas and occasionally in deciduous forest, but not in waterlogged locations, up to 800 m altitude in Java and 1500 m in Indo-China.

Selected sources 8, 53, 174.

Uraria lagopodioides (L.) Desv. ex DC.

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Hedysarum lagopodioides* L., *Uraria alopecuroides* (Roxb.) Sweet.

Vernacular names Tick trefoil (En). Indonesia: ekor tupai (general), buntut rase (Javanese), rai-rai (Ternate). Malaysia: pokok korat tanah, ekur anjing. Philippines: basing karan (Bagobo), ikugkuting (Subanun). Cambodia: kântuy kâm'prôk. Laos: bai khi:z hno:n no:yz, ha:ng ma:z. Thailand: ya-hangon. Vietnam: du[oo]i ch[oo]n.

Distribution From northern India throughout South-East Asia to Australia, extending into the Pacific up to New Caledonia.

Uses Grown locally as a green manure in India and Indonesia. It is widely used medicinally. A decoction of leaves and roots is used for the treatment of dysentery and diarrhoea. In India, aqueous and alcoholic extracts of the plants are used to treat intermittent fever and chest inflammation. An aqueous extract of the leaves has abortifacient properties.

Observations Suffrutescent herb, often creeping, up to 1.5 m long. Branches terete, densely pubescent, glabrescent. Leaves alternate, partially 3-foliolate, partially or rarely all 1-foliolate; petiole up to 4 cm long; stipules lanceolate, 4–8 mm long, acuminate, persistent; stipels 1–4 mm long; leaflets variable, elliptical or ovate, 2.5–7 cm × 1–6.5 cm, apex obtuse or slightly emarginate, lower surface densely hairy. Inflorescence a simple, terminal, dense, cylindrical pseudoraceme, 2.5–10 cm long; bracts ovate, acuminate, 6–8 mm long, containing 2 flowers, silky, persistent; pedicel 4–8 mm long, densely pubescent; calyx campanulate, 7 mm long; corolla 5–6 mm long, pinkish violet or bluish violet; standard broadly obovate, 5–7 mm × 4.5–6.5 mm; wings 2 mm long, with short claw; keel longer than wings, curved. Pod 1–2-jointed, joints up to 3 mm long, grey or black. Seed 2 mm × 1.2 mm, brown. *U. lagopodioides* occurs commonly in dry grassland, open forest, waste places, roadsides, sandy areas and occasionally in deciduous forest, but not in waterlogged locations, up to 2000 m altitude.

Selected sources 8, 53, 170, 174.

Utricularia aurea Lour.

LENTIBULARIACEAE

Synonyms *Utricularia fasciculata* Roxb., *U. flexuosa* Vahl p.p., *U. reclinata* Hassk.

Vernacular names Bladderwort (En). Indonesia: rumput gelembung (Indonesian), ganggang jepun (Javanese), klanibu udang (Kalimantan). Malaysia: lumut ekor kucing, lumut ekor kuning (Peninsular). Cambodia: sara:y. Laos: nè:x ha:ng kaix, nè:x ha:ng kh'wa:y, nè:x khaix khied (Vientiane). Thailand: saaraai khaao nieo (central), saaraai naa (Bangkok), nae khruea (Chiang Mai).

Distribution Widely distributed from India to Indo-China, China and Japan, throughout South-East Asia to Australia.

Uses Regarded as an aquatic weed, sometimes troublesome, but also used to improve the water quality of fish ponds.

Observations Submerged, carnivorous, free-floating freshwater plant. Stem modified into a whorled foliar organ with forked filiform segments and bladders to capture insects or small fry. Inflorescence erect, with 5–10 flowers; flowers zygomorphic, yellow; calyx 2-lobed; corolla spurred. Fruit a globose circumscissile capsule with numerous compressed, 5-angled seeds. *U. aurea* is common in deep to shallow stagnant or slow-flowing water, in rice fields, and sometimes in swamp forest, up to 1200(–1500) m altitude.

Selected sources 27, 70, 51, 148, 156, 150, 171.

Vigna pilosa (Willd.) Baker

LEGUMINOSAE – PAPILIONOIDEAE

Synonyms *Dolichos pilosus* Willd., *Dysolobium pilosum* (Willd.) Maréchal, *Dolichovigna pilosa* (Willd.) Hasokawa.

Distribution South and South-East Asia and Taiwan. Occasionally cultivated also elswhere.

Uses Green manure and cover crop for both sunny conditions and light shade.

Observations Climbing herb, 1–3 m long. Branches tender, white-hairy. Leaves trifoliolate; petiole 3–5 cm long; leaflets ovate to oblong-acuminate, 2–19 cm × 1–7.5 cm, rounded at the base, obtuse-mucronate at the apex; stipules triangular, about 3 mm long. Inflorescence an axillary pseudoraceme, up to 12 cm long, many-flowered; pedicel up to 6 mm long; calyx campanulate, hairy, 4-lobed, upper lobe with a bifid apex, lowest lobe longest; corolla pink, about 1.5 cm long; standard rounded, minutely auricled at the base;

wings oblong, about 0.5 cm long; keel with obtuse beak, about 1 cm long. Pod linear, compressed, 6–14 cm × 5–7 mm, densely hirsute, brown, style persistent, 5–12-seeded. Seed almost cylindrical, 5–7 mm × 4 mm, black. *V. pilosa* is often found in hedges, bamboo forest and deforested areas, on clay soils at low elevation, up to 1000 m altitude. It is slow to establish, covering the soil after about 3 months and providing sufficient litter after 6 months. It withstands waterlogging. In Java, flowering is from March to November, but seed production is low.

Selected sources 53, 97, 168.

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4 Auxiliary plants with other primary use

Tentative list of species in other commodity groups (parenthesis), which are used also as auxiliary plants. Synonyms in the indented lines.

Acacia catechu (L.f.) Willd. (dye and tannin-producing plants)
Acacia leptocarpa A. Cunn. ex Benth. (timber trees)
Acacia leucophloea (Roxb.) Willd. (dye and tannin-producing plants)
Acacia mangium Willd. (timber trees)
Acacia mearnsii De Wild. (dye and tannin-producing plants)
    Acacia decurrens auct., non Willd.
    Acacia decurrens (Wendl.) Willd. var. *mollis* Lindley
Acacia nilotica (L.) Willd. ex Del. (dye and tannin-producing plants)
    Acacia arabica (Lamk) Willd.
Acrocarpus fraxinifolius Arnott (timber trees)
Acronychia pedunculata (L.) Miquel (timber trees)
    Acronychia laurifolia Blume
Adenanthera pavonina L. (timber trees)
Adinandra dumosa Jack (timber trees)
Aeschynomene americana L. (forages)
    Aeschynomene javanica Miquel
Aeschynomene falcata (Poiret) DC. (forages)
Agrostistachys borneensis Beccari (timber trees)
Agrostistachys gaudichaudii Muell. Arg. (fibre plants)
Ailanthus altissima (Miller) Swingle (medicinal and poisonous plants)
Ailanthus integrifolia Lamk (timber trees)
Ailanthus triphysa (Dennst.) Alston (timber trees)
    Ailanthus glandulosa Desf.
    Ailanthus vilmoriniana Dode
Alangium chinense (Loureiro) Harms (timber trees)
Albizia lebbeck (L.) Benth. (forages, timber trees)
Albizia lebbekoides (DC.) Benth. (dye and tannin-producing plants)
Aleurites moluccana (L.) Willd. (spices)
Allium fistulosum L. (vegetables)
Allium sativum L. (vegetables)
Allophylus cobbe (L.) Raeuschel (timber trees)
    Allophylus cochinchinensis P.H. Lecomte
    Allophylus fulvinervis Blume
    Allophylus glaber Roxb.
    Allophylus ternatus Loureiro
Alphitonia excelsa (Fenzl) Reissek ex Endl. (timber trees)
    Alphitonia moluccana Teijsm. & Binnend.
Alphonsea elliptica Hook.f. & Thomson (timber trees)
Alternanthera ficoidea (L.) P. Beauv. var. *versicolor* (Lem.) Backer (medicinal and poisonous plants)

Alternanthera amoena Backer & v. Slooten
Alternanthera bettzickiana (Regel) Nicholson
Alternanthera ficoidea (L.) P. Beauv. var. *bettzickiana* (Nicholson) Backer
Alternanthera manillensis (Walp.) Kanis
Alternanthera tenella Colla var. *versicolor* (Lem.) Veldk.
Alternanthera philoxeroides (Mart.) Griseb. (vegetables)
Alysicarpus vaginalis (L.) DC. (forages)
Alysicarpus nummularifolius (Willd.) DC.
Anacardium occidentale L. (edible fruits and nuts)
Andropogon nardus L. (essential-oil plants)
Andropogon nardus L. var. *tortilis* (Presl) Merrill (misapplied to *Andropogon nardus* L.)
Cymbopogon citratus (DC.) Stapf (misapplied to *Andropogon nardus* L.)
Anogeissus latifolia (Roxb. ex DC.) Wallich ex Guill. & Perr. (timber trees)
Anthocephalus chinensis (Lamk) A. Rich. ex Walp. (timber trees)
Anthocephalus cadamba (Roxb.) Miquel
Anthocephalus indicus A. Rich.
Neolamarckia cadamba (Roxb.) Bosser
Antidesma bunius (L.) Sprengel (edible fruits and nuts)
Antidesma ghaesembilla Gaertner (edible fruits and nuts)
Arachis glabrata Benth. (forages)
Arachis pintoi Krap. & Greg. (forages)
Archidendron ellipticum (Blume) I.C. Nielsen (timber trees)
Archidendron jiringa (Jack) I.C. Nielsen (vegetables)
Pithecellobium jiringa (Jack) Prain
Pithecellobium lobatum Benth.
Areca catechu L. (stimulants)
Arenga pinnata (Wurmb) Merrill (plants yielding non-seed carbohydrates)
Artocarpus altilis (Parkinson) Fosberg (edible fruits and nuts)
Artocarpus camansi Blanco
Artocarpus communis J.R. & G. Forster
Artocarpus heterophyllus Lamk (edible fruits and nuts)
Artocarpus integer (Thunberg) Merrill (edible fruits and nuts)
Artocarpus champeden (Loureiro) Stokes
Arundo donax L. (fibre plants)
Asystasia gangetica (L.) T. Anderson (forages)
Atuna racemosa Raf. (timber trees)
Avicennia alba Blume (timber trees)
Avicennia marina (Forsskal) Vierh. (timber trees)
Avicennia intermedia Griffith
Avicennia officinalis L. (timber trees)
Avicennia rumphiana Hallier f. (timber trees)
Avicennia lanata Ridley
Axonopus compressus (Swartz) P. Beauv. (forages)
Azadirachta excelsa (Jack) Jacobs (timber trees)
Azolla pinnata R. Br. (cryptogams)
Baccaurea Loureiro (edible fruits and nuts)
Bambusa bambos (L.) Voss (bamboos)
Bambusa blumeana J.A. & J.H. Schultes (bamboos)

Bambusa multiplex (Loureiro) Raeuschel ex J.A. & J.H. Schultes (bamboos)
Bambusa tulda Roxb. (bamboos)
Barringtonia asiatica (L.) Kurz (timber trees)
Bauhinia macrostachya Wallich (timber trees)
Bauhinia malabarica Roxb. (timber trees)
Bixa orellana L. (dye and tannin-producing plants)
Bischofia javanica Blume (timber trees)
Bombax ceiba L. (timber trees)
    Bombax malabaricum DC.
    Gossampinus malabarica (DC.) Merrill
Bombax valetonii Hochr. (timber trees)
    Bombax insigne Wallich
Borassus flabellifer L. (plants yielding non-seed carbohydrates)
Bothriochloa pertusa (L.) A. Camus (forages)
Bouea macrophylla Griffith (edible fruits and nuts)
Brachiaria brizantha (A. Rich.) Stapf (forages)
Brachiaria decumbens Stapf (forages)
Brachiaria dictyoneura (Fig. & De Not.) Stapf (forages)
Brachiaria distachya (L.) Stapf (forages)
    Panicum distachyum L.
Brachiaria humidicola (Rendle) Schweick. (forages)
Brachiaria mutica (Forsskal) Stapf (forages)
Brachiaria ramosa (L.) Stapf (forages)
    Panicum ramosum L.
Brachiaria subquadripara (Trin.) Hitchc. (forages)
Broussonetia luzonica (Blanco) Bureau (timber trees)
Bruguiera gymnorhiza (L.) Savigny (dye and tannin-producing plants)
    Bruguiera conjugata Merrill
Bruguiera parviflora (Roxb.) Wight & Arnott ex Griffith (timber trees)
Buchanania arborescens (Blume) Blume (timber trees)
Buchanania latifolia Roxb. (edible fruits and nuts)
    Buchanania lanzan Sprengel
Butea monosperma (Lamk) Taubert (dye and tannin-producing plants)
Caesalpinia sappan L. (dye and tannin-producing plants)
Cajanus cajan (L.) Millspaugh (pulses)
    Cajanus indicus Sprengel
Callicarpa arborea Roxb. (timber trees)
Callicarpa longifolia Lamk (medicinal and poisonous plants)
Callicarpa maingayi King & Gamble (timber trees)
Calophyllum inophyllum L. (timber trees)
Calophyllum pauciflorum A.C. Smith (timber trees)
Calophyllum peekelii Lauterb. (timber trees)
Calophyllum soulattri Burm.f. (timber trees)
Calopogonium caeruleum (Benth.) Sauv. (forages)
Calotropis gigantea (L.) Dryander (medicinal and poisonous plants)
Camellia sinensis (L.) Kuntze (stimulants)
    Thea sinensis L.
Canarium indicum L. (edible fruits and nuts)
    Canarium amboinense Hochr.

Canarium commune L.
Canarium moluccanum Blume
Canarium zephyrinum Rumphius
Canarium ovatum Engl. (edible fruits and nuts)
Canarium patentinervium Miquel (edible fruits and nuts)
Canarium vulgare Leenh. (timber trees)
Canavalia ensiformis (L.) DC. (forages)
Canavalia gladiata (Jacq.) DC. (vegetables)
Carallia brachiata (Loureiro) Merrill (timber trees)
Caryota mitis Loureiro (plants yielding non-seed carbohydrates)
Casimiroa edulis Llave & Lex. (edible fruits and nuts)
Cassia auriculata L. (dye and tannin-producing plants)
Cassia fistula L. (medicinal and poisonous plants)
Cassia obtusifolia L. (vegetables)
Cassia occidentalis L. (stimulants)
Cassia tora L. (medicinal and poisonous plants)
Castanea sativa Miller (edible fruits and nuts)
Castanopsis acuminatissima (Blume) A. DC. (timber trees)
Castanea acuminatissima Blume
Cecropia peltata L. (medicinal and poisonous plants)
Cedrela odorata L. (timber trees)
Ceiba pentandra (L.) Gaertner (fibre plants)
Centella asiatica (L.) Urban (medicinal and poisonous plants)
Hydrocotyle asiatica L.
Centrosema macrocarpum Benth. (forages)
Cerbera manghas L. (medicinal and poisonous plants)
Ceriops decandra (Griffith) Ding Hou (dye and tannin-producing plants)
Ceriops roxburghiana Arnott
Ceriops tagal (Perr.) C.B. Robinson (dye and tannin-producing plants)
Ceriops candolleana Arnott
Chrysopogon aciculatus (Retzius) Trinius (forages)
Chrysopogon orientalis (Desv.) A. Camus (forages)
Chydenanthus excelsus (Blume) Miers (medicinal and poisonous plants)
Cinnamomum culitlawan (L.) Kosterm. (medicinal and poisonous plants)
Cleistanthus collinus (Roxb.) Benth. (timber trees)
Cleistanthus hirsutulus Hook.f. (timber trees)
Clitoria ternatea L. (forages)
Cocos nucifera L. (vegetable oils and fats)
Codariocalyx gyroides (Roxb. ex Link) Hassk. (forages)
Desmodium gyroides (Roxb. ex Link) DC.
Cola nitida (Ventenat) Schott & Endl. (stimulants)
Combretocarpus rotundatus (Miquel) Danser (timber trees)
Cordia dichotoma Forster f. (medicinal and poisonous plants)
Cordia subcordata Lamk (timber trees)
Corypha utan Lamk (fibre plants)
Corypha elata Roxb.
Cosmos caudatus Kunth (vegetables)
Crateva magna (Loureiro) DC. (medicinal and poisonous plants)
Crateva nurvala Ham.

Cratoxylum arborescens (Vahl) Blume (timber trees)
Cratoxylum formosum (Jack) Dyer (timber trees)
Cratoxylum glaucum Korth. (timber trees)
Cratoxylum sumatranum (Jack) Blume (timber trees)
  Cratoxylum celebicum Blume
  Cratoxylum clandestinum Blume
  Cratoxylum hypericinum (Blume) Merrill
Crotalaria juncea L. (forages)
Cyatocalyx sumatranus R. Scheffer (timber trees)
Cymbopogon citratus (DC.) Stapf (essential-oil plants)
  Andropogon citratus DC.
Cymbopogon nardus Rendle (essential-oil plants)
  Andropogon martini auct., non Roxb.
Cynodon dactylon (L.) Pers. (forages)
Cynodon nlemfuensis Vanderyst (forages)
Cynometra malaccensis Knaap-v. Meeuwen (timber trees)
Cynometra ramiflora L. (timber trees)
Cyperus haspan L. (forages)
  Cyperus iria L.
Cyperus stoloniferus Retzius (medicinal and poisonous plants)
  Cyperus bulboso-stoloniferus Steud.
  Cyperus carrii Kük.
  Cyperus lamprocarpus Nees
Cytisus palmensis (Christ) Hutch. (forages)
Dacrydium elatum (Roxb.) Wallich ex Hook. (timber trees)
  Dacrydium junghuhnii Miquel
Dalbergia latifolia Roxb. (timber trees)
Dalbergia sissoo Roxb. ex DC. (timber trees)
Decaspermum parviflorum (Lamk) A.J. Scott (timber trees)
Dendrocnide stimulans (L.f.) Chew (medicinal and poisonous plants)
  Laportea stimulans Miquel
Desmodium gangeticum (L.) DC. (medicinal and poisonous plants)
Desmodium heterocarpon (L.) DC. (forages)
Desmodium heterocarpon (L.) DC. subsp. *ovalifolium* (Prain) Ohashi (forages)
Desmodium heterophyllum (Willd.) DC. (forages)
Desmodium intortum (Miller) Urban (forages)
Desmodium triflorum (L.) DC. (forages)
  Desmodium parvifolium Blanco
  Hedysarum triflorum L. (pro parte)
  Meibomia triflora (L.) Kuntze
Dialium cochinchinense Pierre (timber trees)
Dichrostachys cinerea (L.) Wight & Arnott (medicinal and poisonous plants)
Dicranopteris linearis (Burm.f.) Underw. var. *linearis* (cryptogams)
  Gleichenia linearis Clarke
Digitaria ciliaris (Retzius) Koeler (forages)
Digitaria milanjiana (Rendle) Stapf (forages)
Dillenia indica L. (timber trees)
Dillenia pentagyna Roxb. (timber trees)
Diospyros frutescens Blume (timber trees)

Diospyros maritima Blume (timber trees)
Diospyros nutans King & Gamble (timber trees)
Dipterocarpus cornutus Dyer (timber trees)
Dipterocarpus retusus Blume (timber trees)
    Dipterocarpus trinervis Blume
Dipteryx odorata (Aublet) Willd. (spices)
Dodonaea viscosa Jacq. (medicinal and poisonous plants)
Dolichandrone spathacea (L.f.) K. Schumann (timber trees)
Dracontomelon dao (Blanco) Merrill & Rolfe (timber trees)
Durio zibethinus Murray (edible fruits and nuts)
Elaeis guineensis N.J. Jacquin (vegetable oils and fats)
Elateriospermum tapos Blume (timber trees)
Eleusine coracana (L.) Gaertner cv. group Finger Millet (cereals)
Endospermum diadenum (Miquel) Airy Shaw (timber trees)
Endospermum moluccanum (Teijsm. & Binnend.) Kurz (timber trees)
    Endospermum labios Schodde
Endospermum peltatum Merrill (timber trees)
Eragrostis unioloides (Retzius) Nees ex Steudel (forages)
Eucalyptus alba Reinw. ex Blume (timber trees)
Eucalyptus citriodora Hook. (timber trees)
Eucalyptus deglupta Blume (timber trees)
Eucalyptus grandis W. Hill ex Maiden (timber trees)
Eucalyptus platyphylla F. v. Mueller (timber trees)
Eucalyptus robusta J.E. Smith (timber trees)
Eucalyptus saligna J.E. Smith (timber trees)
Eucalyptus torreliana F. v. Mueller (timber trees)
Euphorbia tirucalli L. (medicinal and poisonous plants)
Excoecaria agallocha L. (medicinal and poisonous plants)
Excoecaria indica (Willd.) Muell. Arg. (dye and tannin-producing plants)
    Sapium indicum Willd.
Fagopyrum esculentum Moench (cereals)
Fagraea crenulata Maingay ex C.B. Clarke (timber trees)
Fagraea fragrans Roxb. (timber trees)
Fagraea racemosa Jack ex Wallich (timber trees)
Fernandoa macroloba (Miquel) v. Steenis (timber trees)
Ficus altissima Blume (fibre plants)
Ficus decaisnei Steudel (spices)
    Ficus trematocarpa Miquel
Ficus religiosa L. (medicinal and poisonous plants)
Ficus rumphii Blume (medicinal and poisonous plants)
Ficus subcordata Blume (forages)
Ficus variegata Blume (plants producing exudates)
Ficus virens Aiton (fibre plants)
    Ficus infectoria Roxb.
Fimbristylis globulosa (Retzius) Kunth (fibre plants)
    Fimbristylis globulosa (Retzius) Kunth var. *torresiana* Clarke
Fimbristylis miliacea (L.) Vahl (forages)
Flemingia lineata (L.) Roxb. ex Aiton f. (medicinal and poisonous plants)
Ganophyllum falcatum Blume (timber trees)

Garcinia multiflora Champ. (edible fruits and nuts)
Gigantochloa hasskarliana (Kurz) Backer ex K. Heyne (bamboos)
Gigantochloa pseudoarundinacea (Steudel) Widjaja (bamboos)
Glochidion brunneum Hook.f. (dye and tannin-producing plants)
 Glochidion goniocarpum Hook.f.
Glochidion lutescens Blume (timber trees)
 Glochidion kollmannianum (Muell. Arg.) J.J. Smith
Glycine max (L.) Merrill (pulses)
Gmelina arborea Roxb. (timber trees)
Gordonia multinervis King (timber trees)
Gossypium hirsutum L. (fibre plants)
Greenia corymbosa K. Schumann (medicinal and poisonous plants)
Halfordia papuana Lauterb. (timber trees)
Helianthus annuus L. (vegetable oils and fats)
Helicia cochinchinensis Loureiro (edible fruits and nuts)
Heritiera littoralis Aiton (timber trees)
 Heritiera minor (Gaertner) Lamk
Hevea brasiliensis (Willd. ex A.L. Jussieu) Muell. Arg. (plants producing exudates)
Hibiscus macrophyllus Roxb. ex Hornem (timber trees)
Hibiscus schyzopetalus (Mast.) Hook.f. (timber trees)
Hibiscus tiliaceus L. (fibre plants)
Hibiscus tiliaceus L. subsp. *similis* (Blume) Borssum Waalkes (ornamental plants)
 Hibiscus similis Blume
Hippomane mancinella L. (medicinal and poisonous plants)
Homalium foetidum (Roxb.) Benth. (timber trees)
Hopea odorata Roxb. (timber trees)
Hullettia dumosa King ex Hook.f. (edible fruits and nuts)
Hydnocarpus anthelmintica Pierre ex Gagnepain (vegetable oils and fats)
Hydrilla verticillata (L.f.) Royle (forages)
Hydrocotyle sibthorpioides Lamk (vegetables)
Hymenachne amplexicaulis (Rudge) Nees (forages)
 Hymenachne myurus Beauv.
Imperata cylindrica (L.) Raeuschel (forages)
Indigofera arrecta Hochst. ex A. Richard (dye and tannin-producing plants)
Indigofera galegoides DC. (medicinal and poisonous plants)
Indigofera linnaei Ali (medicinal and poisonous plants)
 Indigofera enneaphylla L.
Indigofera tinctoria L. (dye and tannin-producing plants)
 Indigofera sumatrana Gaertner
Inga laurina (Swartz) Willd. (ornamental plants)
Isachne globosa (Thunberg ex Murray) Kuntze (forages)
Ischaemum ciliare Retzius (forages)
Ischaemum muticum L. (forages)
Ischaemum rugosum Salisb. (forages)
Ischaemum timorense Kunth (forages)
Jatropha curcas L. (medicinal and poisonous plants)
Khaya anthotheca (Welw.) C. DC. (timber trees)

Koompassia excelsa (Beccari) Taubert (timber trees)
  Koompassia parvifolia Prain ex King
Koompassia malaccensis Maingay ex Benth. (timber trees)
Lablab purpureus (L.) Sweet (pulses)
  Dolichos lablab L.
Lagerstroemia indica L. (ornamental plants)
Lannea coromandelica (Houtt.) Merrill (ornamental plants)
  Lannea grandis (Dennst.) Engl.
Lantana camara L. (medicinal and poisonous plants)
  Lantana aculeata L.
Lathyrus sativus L. (pulses)
Lens culinaris Medikus (pulses)
Lepisanthes senegalensis (Poiret) Leenh. (timber trees)
Lepisanthes tetraphylla (Vahl) Radlk. (timber trees)
Leptospermum amboinense Blume (timber trees)
Leptospermum javanicum Blume (timber trees)
Licania splendens (Korth.) Prance (timber trees)
  Angelesia splendens Korth.
Limnocharis flava (L.) Buchenau (vegetables)
Limonia acidissima L. (edible fruits and nuts)
  Feronia elephantum Correa
  Feronia limonia (L.) Swingle
Lindera pipericarpa Boerl. (spices)
Lithocarpus coopertus (Blanco) Rehder (timber trees)
Lithocarpus elegans (Blume) Hatus. ex Soepadmo (timber trees)
Lithocarpus encleisacarpus (Korth.) A. Camus (timber trees)
Lithocarpus lampadarius (Gamble) A. Camus (timber trees)
  Quercus lampadaria (Gamble) Burkill
Lophostemon confertus (R. Br.) Peter G. Wilson & J.T. Waterhouse (timber trees)
Ludwigia hyssopifolia (G. Don) Exell (medicinal and poisonous plants)
  Jussiaea linifolia Vahl
Lumnitzera littorea (Jack) Voigt (timber trees)
  Lumnitzera coccinea Wight & Arnott
Lumnitzera racemosa Willd. (timber trees)
Lycopodium carinatum Desv. (cryptogams)
  Lycopodium cernuum L.
Macaranga heynei I.M. Johnston (medicinal and poisonous plants)
  Macaranga rubiginosa Ridley
Macaranga hullettii King ex Hook.f. (medicinal and poisonous plants)
Macaranga peltata (Roxb.) Muell. Arg. (plants producing exudates)
  Macaranga roxburghii Wight
Macaranga triloba (Blume) Muell. Arg. (dye and tannin-producing plants)
Macroptilium atropurpureum (DC.) Urban (forages)
Macroptilium lathyroides (L.) Urban (forages)
  Phaseolus lathyroides L.
Macroptilium longepedunculatum (Benth.) Urban (forages)
Macrotyloma uniflorum (Lamk) Verdc. (pulses)
Mallotus paniculatus (Lamk) Muell. Arg. (timber trees)

Mallotus philippensis (Lamk) Muell. Arg. (dye and tannin-producing plants)
Mangifera indica L. (edible fruits and nuts)
Manihot esculenta Crantz (plants yielding non-seed carbohydrates)
Manilkara kauki (L.) Dubard (timber trees)
Maniltoa polyandra (Roxb.) Harms (timber trees)
    Cynometra polyandra Roxb.
Maranthes corymbosa Blume (timber trees)
    Parinarium corymbosum (Blume) Miquel
    Parinarium griffithianum Benth.
Medicago sativa L. (forages)
Meiogyne virgata (Blume) Miquel (timber trees)
Melaleuca leucadendra (L.) L. (essential-oil plants)
    Melaleuca viridiflora Blume
Melaleuca quinquenervia (Cav.) S.T. Blake (essential-oil plants)
Melanolepis multiglandulosa (Reinw. ex Blume) H.G. Reichenbach & Zollinger (medicinal and poisonous plants)
    Mallotus moluccanus Muell. Arg.
    Melanolepis moluccana Pax & K. Hoffm.
Melastoma malabathricum L. (medicinal and poisonous plants)
Melastoma polyanthum Blume (medicinal and poisonous plants)
    Melastoma malabathricum L. f. *polyanthum* L.
Melientha suavis Pierre (vegetables)
Melochia umbellata (Houtt.) O. Stapf (ornamental plants)
Memecylon caeruleum Jack (timber trees)
Memecylon edule Roxb. (timber trees)
Metroxylon sagu Rottboell (plants yielding non-seed carbohydrates)
Mezzettia parviflora Beccari (timber trees)
Microcos lanceolata (Miquel) Burret (timber trees)
    Grewia miqueliana Kurz
Mimosa pudica L. (forages)
Mimosa sepiaria Benth. (ornamental plants)
Mimusops elengi L. (timber trees)
    Mimusops elengi L. var. *parvifolia* (R. Br.) H.J. Lam
    Mimusops parvifolia R. Br.
Morinda citrifolia L. (dye and tannin-producing plants)
    Morinda bracteata Roxb.
Moringa oleifera Lamk (vegetables)
Morus alba L. (forages)
Morus macroura Miquel (timber trees)
Muntingia calabura L. (edible fruits and nuts)
Musa L. (Musa AAB group) (plants yielding non-seed carbohydrates)
Myriophyllum aquaticum (J.M. da Conceicao Vellozo) Verdc. (vegetables)
    Myriophyllum brasiliense Cambess.
Myriostachya wightiana (Nees) Hook.f. (forages)
Neonotonia wightii (Wight & Arnott) Lackey (forages)
Neoscortechinia kingii (Hook.f.) Pax & K. Hoffm. (timber trees)
Nephelium L. (edible fruits and nuts)
Nyctanthes arbor-tristis L. (dye and tannin-producing plants)
Ochanostachys amentacea Masters (timber trees)

Ochroma pyramydale (Cav. ex Lamk) Urban (timber trees)
Oryza sativa L. (cereals)
Oxalis corniculata L. (medicinal and poisonous plants)
Pachyrhizus erosus (L.) Urban (plants yielding non-seed carbohydrates)
Panicum repens L. (forages)
Parameria polyneura Hook.f. (medicinal and poisonous plants)
Parastemon urophyllus (Wallich ex A. DC.) A. DC. (timber trees)
Parastemon versteeghii Merrill & Perry (timber trees)
Parinari costata (Korth.) Blume (timber trees)
Parinari oblongifolia Hook.f. (timber trees)
Parinari papuana C.T. White (timber trees)
Parishia insignis Hook.f. (timber trees)
Parkia singularis Miquel (timber trees)
Parkia speciosa Hassk. (vegetables)
Parkinsonia aculeata L. (ornamental plants)
Paspalum conjugatum Bergius (forages)
Paspalum dilatatum Poiret (forages)
Paspalum distichum L. (forages)
Paspalum notatum Flueggé (forages)
Paspalum plicatulum Michaux (forages)
Paspalum scrobiculatum L. (forages)
Passiflora foetida L. (edible fruits and nuts)
Passiflora laurifolia L. (edible fruits and nuts)
Pavetta indica L. (medicinal and poisonous plants)
Pavetta tomentosa Roxb. (medicinal and poisonous plants)
Pellacalyx axillaris Korth. (timber trees)
Pellacalyx saccardianus Scortechini (timber trees)
Peltophorum pterocarpum (DC.) Backer ex K. Heyne (dye and tannin-producing plants)
Pennisetum clandestinum Hochst. ex Chiov. (forages)
Pennisetum glaucum (L.) R. Br. (cereals)
Pennisetum polystachyon (L.) Schultes (forages)
Pennisetum purpureum Schumach. (forages)
Phalaris arundinacea L. (forages)
Phaseolus lunatus L. (pulses)
Phoenix sylvestris (L.) Roxb. (plants yielding non-seed carbohydrates)
Phragmites karka (Retzius) Trinius ex Steudel (fibre plants)
    Phragmites communis Trinius (misapplied to *Phragmites karka* (Retzius) Trinius ex Steudel)
Phyllanthus emblica L. (dye and tannin-producing plants)
    Emblica officinalis Gaertner
Pinus caribaea Morelet (timber trees)
Pinus merkusii Junghuhn & de Vriese (timber trees)
Pinus oocarpa Schiede ex Schlechtendal (timber trees)
Pistia stratiotes L. (forages)
Pisum sativum L. (pulses)
Pithecellobium dulce (Roxb.) Benth. (edible fruits and nuts)
Pittosporum ferrugineum Aiton (timber trees)
Ploiarium alternifolium (Vahl) Melchior (timber trees)

Polyalthia glauca (Hassk.) F. v. Mueller (timber trees)
Pometia pinnata J.R. Forster & J.G. Forster (timber trees)
Poncirus trifoliata (L.) Raf. (ornamental plants)
Citrus trifoliata L.
Potentilla indica (H.C. Andrews) Wolf (edible fruits and nuts)
Pouteria sapota (Jacq.) H.E. Moore & Stearn (edible fruits and nuts)
Prunus arborea (Blume) Kalkman (timber trees)
Prunus grisea (Blume) Kalkman (timber trees)
Psidium guajava L. (edible fruits and nuts)
Psophocarpus tetragonolobus (L.) DC. (vegetables)
Pternandra coerulescens Jack (timber trees)
Pterocarpus indicus Willd. (timber trees)
Ptychopyxis glochidiifolia Airy Shaw (timber trees)
Pueraria montana (Lour.) Merrill var. *lobata* (Willd.) Maesen & Almeida (medicinal and poisonous plants)
Pueraria triloba (Houtt.) Makino
Quercus argentata Korth. (timber trees)
Quercus lineata Blume (timber trees)
Reissantia indica (Willd.) Halle (medicinal and poisonous plants)
Hippocratea indica Willd.
Reutealis trisperma (Blanco) Airy Shaw (vegetable oils and fats)
Aleurites trisperma Blanco
Rhizophora mucronata Poiret (dye and tannin-producing plants)
Rhodamnia cinerea Jack (timber trees)
Rhodoleia championi Hook. (timber trees)
Ricinus communis L. (vegetable oils and fats)
Saccharum officinarum L. (plants yielding non-seed carbohydrates)
Saccharum spontaneum L. (forages)
Salacca zalacca (Gaertner) Voss (edible fruits and nuts)
Sandoricum koetjape (Burm.f.) Merrill (edible fruits and nuts)
Sapindus saponaria L. (medicinal and poisonous plants)
Sapindus mukorossi Gaertner
Sapium baccatum Roxb. (timber trees)
Sapium sebiferum (L.) Roxb. (vegetable oils and fats)
Schima wallichii (DC.) Korth. (timber trees)
Schizostachyum brachycladum Kurz (bamboos)
Schizostachyum jaculans Holttum (bamboos)
Scirpus erectus Poiret (forages)
Scirpus grossus L.f. (fibre plants)
Scirpus lacustris L. (fibre plants)
Secale cereale L. (cereals)
Securinega virosa (Roxb. ex Willd.) Baillon (dye and tannin-producing plants)
Semecarpus anacardium L.f. (edible fruits and nuts)
Semecarpus cassuvium Roxb. (edible fruits and nuts)
Senna obtusifolia (L.) Irwin & Barneby (vegetables)
Cassia obtusifolia L.
Sesamum orientale L. (vegetable oils and fats)
Sesamum indicum L.
Sesbania grandiflora (L.) Poiret (forages)

Sesbania sesban (L.) Merrill (forages)
  Sesbania aegyptiaca Poiret
Shorea laevis Ridley (timber trees)
Siphonodon celastrineus Griffith (timber trees)
Sonneratia alba J. Smith (timber trees)
Sonneratia caseolaris (L.) Engl. (vegetables)
  Sonneratia acida L.f.
Sorghum bicolor (L.) Moench (cereals)
Spondias mombin L. (edible fruits and nuts)
Spondias purpurea L. (edible fruits and nuts)
Stenotaphrum secundatum (Walter) Kuntze (forages)
Sterculia foetida L. (timber trees)
Sterculia insularis R. Br. (timber trees)
  Sterculia treubii Hochr.
Strychnos axillaris Colebr. (medicinal and poisonous plants)
  Strychnos mucronata A.W. Hill
  Strychnos pubescens C.B. Clarke
Strychnos colubrina L. (medicinal and poisonous plants)
  Strychnos multiflora Benth.
  Strychnos potatorum auct., non L.f.
Stylosanthes guianensis (Aublet) Swartz (forages)
Styrax paralleloneurum Perkins (plants producing exudates)
  Styrax sumatrana J.J. Smith
Suregada glomerulata (Blume) Baillon (medicinal and poisonous plants)
  Gelonium glomerulatum (Blume) Hassk.
Suregada multiflora (A.L. Jussieu) Baillon (ornamental plants)
  Gelonium multiflorum A.L. Jussieu
Symplocos cochinchinensis (Loureiro) S. Moore (dye and tannin-producing plants)
Syzygium aqueum (Burm.f.) Alston (edible fruits and nuts)
  Eugenia aquea Burm.f.
  Eugenia grandis Wight
Syzygium cumini (L.) Skeels (edible fruits and nuts)
Syzygium pycnanthum Merrill & Perry (edible fruits and nuts)
  Eugenia densiflora (Blume) Duthie
Tamarindus indica L. (edible fruits and nuts)
Tarennoidea wallichii (Hook.f.) Tirveng. & Sastre (timber trees)
Teijsmanniodendron pteropodum (Miquel) Bakh. (timber trees)
  Vitex peralata King
  Vitex philippinensis H.J. Lam
  Vitex pteropoda Miquel
Tephrosia sinapou (Buchoz) A. Chev. (medicinal and poisonous plants)
  Tephrosia toxicaria (Swartz) Pers.
Teramnus labialis (L.f.) Sprengel (vegetables)
Terminalia arjuna (Roxb. ex DC.) Wight & Arnott (dye and tannin-producing plants)
Terminalia bellirica (Gaertner) Roxb. (dye and tannin-producing plants)
Terminalia catappa L. (dye and tannin-producing plants)
Terminalia copelandii Elmer (timber trees)

Terminalia megalocarpa Exell (timber trees)
Theobroma cacao L. (stimulants)
  Theobroma pentagona Bernoulli
Thyrsostachys siamensis Gamble (bamboos)
Thysanolaena latifolia (Roxb. ex Hornem.) Honda (forages)
  Thysanolaena maxima (Roxb.) Kuntze
Timonius flavescens (Jack) Baker (timber trees)
  Timonius peduncularis Ridley
Timonius timon (Sprengel) Merrill (timber trees)
Toona sinensis (A.L. Jussieu) M.J. Roemer (timber trees)
Trema cannabina Loureiro (vegetables)
  Trema virgata (Planchon) Blume
Trichospermum javanicum Blume (fibre plants)
  Trichospermum kurzii King
Triphasia trifolia (Burm.f.) P. Wilson (edible fruits and nuts)
  Triphasia aurantiola Loureiro
Tripsacum andersonii J.R. Gray (forages)
Tristaniopsis merguensis (Griffith) P.G. Wilson & J.T. Waterhouse (timber trees)
Tristaniopsis obovata (Benn.) P.G. Wilson & J.T. Waterhouse (timber trees)
  Tristania obovata Benn.
Tristaniopsis whiteana (Griffith) P.G. Wilson & J.T. Waterhouse (timber trees)
Triticum aestivum L. (cereals)
Typha angustifolia L. (fibre plants)
  Typha domingensis Pers. var. *javanica* Geze
Urochloa mosambicensis (Hack.) Dandy (forages)
Urophyllum streptopodium Wallich ex Hook.f. (timber trees)
Vaccinium bracteatum Thunb. (edible fruits and nuts)
Vaccinium myrtoides (Blume) Miquel (edible fruits and nuts)
Vatica paiciflora (Korth.) Blume (timber trees)
Vatica rassak (Korth.) Blume (timber trees)
Ventilago madraspatana Gaertner (dye and tannin-producing plants)
Vernicia montana Loureiro (vegetable oils and fats)
  Aleurites montana (Loureiro) Wilson
Vetiveria zizanioides (L.) Nash (essential-oil plants)
Vicia faba L. (pulses)
Vigna aconitifolia (Jacq.) Maréchal (pulses)
  Phaseolus aconitifolius Jacq.
Vigna angularis (Willd.) Ohwi & Ohashi (pulses)
  Phaseolus angularis (Willd.) W.F. Wight
Vigna dalzelliana (Kuntze) Verdc. (pulses)
Vigna mungo (L.) Hepper (pulses)
  Phaseolus mungo L.
Vigna parkeri Baker (forages)
Vigna radiata (L.) Wilczek (pulses)
  Phaseolus aureus Roxb.
  Phaseolus radiatus L.
Vigna umbellata (Thunberg) Ohwi & Ohashi (pulses)
  Phaseolus calcaratus Roxb.

Vigna unguiculata (L.) Walp. cv. group Unguiculata (pulses)
  Vigna sinensis (L.) Hassk.
  Vigna unguiculata (L.) Walp. subsp. *unguiculata*
Viola odorata L. (ornamental plants)
Vitex parviflora A.L. Jussieu (timber trees)
Vitex pinnata L. (timber trees)
Vitex vestita Wallich ex Schauer (timber trees)
Whiteodendron moultonianum (W.W. Smith) v. Steenis (timber trees)
Wrightia pubescens R. Br. (timber trees)
Wrightia tinctoria R. Br. (dye and tannin-producing plants)
Xanthophyllum flavescens Roxb. (timber trees)
  Xanthophyllum excelsum (Blume) Miquel
Xanthostemon verus (Roxb.) P.G. Wilson (timber trees)
Xylocarpus granatum Koenig (dye and tannin-producing plants)
  Carapa obovata Blume
  Xylocarpus obovatus (Blume) Juss.
Xylocarpus mekongensis Pierre (dye and tannin-producing plants)
  Carapa moluccensis Watson
  Xylocarpus australasicus Ridley
  Xylocarpus gangeticus (Prain) Parkinson
Xylocarpus moluccensis (Lamk) M. Roemer (dye and tannin-producing plants)
  Carapa moluccensis Lamk
Yushania niitakayamensis (Hayata) Keng f. (bamboos)
  Arundinaria niitakayamensis Hayata
Zea mays L. (cereals)
Ziziphus mauritiana Lamk (edible fruits and nuts)
  Ziziphus jujuba (L.) Gaertner
Ziziphus oenoplia (L.) Miller (dye and tannin-producing plants)
Zoysia matrella (L.) Merrill (forages)

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Acronyms of organizations

- AB–DLO: Instituut voor Agrobiologisch en Bodemvruchtbaarheidsonderzoek–Dienst Landbouwkundig Onderzoek (Wageningen, the Netherlands).
- ACIAR: Australian Centre for International Agricultural Research (Canberra, Australia).
- ATFGRC–CSIRO: Australian Tropical Forage Genetic Resource Centre (Brisbane, Australia).
- ATSC–CSIRO: Australian Tree Seed Centre (Queen Victoria Terrace, Australia).
- AVRDC: Asian Vegetable Research and Development Center (Shanhua, Tainan, Taiwan).
- BIOTROP: South-East Asian Regional Centre for Tropical Biology (Bogor, Indonesia).
- CATIE: Centro Agronómico Tropical de Investigación y Enseñanza (Turrialba, Costa Rica).
- CENARGEN: Centro Nacional de Recursos Genéticos (Brasilia, Brazil).
- CENRAD: Centre for Environment, Renewable Natural Resources Management, Research and Development (Ibadan, Nigeria).
- CIAT: International Center for Tropical Agriculture (Cali, Columbia).
- CMU: Central Mindanao University (Davao, Mindanao, the Philippines).
- COGREDA: Consultative Group for Research and Development of Acacias (Udorn Thani, Thailand).
- CSIR: Council for Scientific and Industrial Research (New Delhi, India).
- CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia).
- DANIDA: Danish International Development Agency (Copenhagen, Denmark).
- EMBRAPA: Empresa Brasileira de Pesquisa Agropecuária (Brasilia, Brazil).
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy).
- F/FRED: Forestry/Fuelwood Research and Development Project (Bangkok, Thailand).
- FPRDI: Forest Products Research and Development Institute (Los Baños, the Philippines).
- FRIM: Forest Research Institute Malaysia (Kepong, Malaysia).
- GTZ: Deutsche Gesellschaft für Technische Zusammenarbeit (Eschborn, Germany).
- HITAHR: Hawaii Institute of Tropical Agriculture and Human Resources (Honolulu, Hawaii, United States).
- IAWA: International Association of Wood Anatomists (Utrecht, the Netherlands).
- IBPGR: now IPGRI.

- ICRAF: International Centre for Research in Agroforestry (Nairobi, Kenya).
- ICRISAT: International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India).
- IDRC: International Development Research Centre (Ottawa, Canada).
- IEBR: Institute of Ecology and Biological Resources (Hanoi, Vietnam).
- IITA: International Institute of Tropical Agriculture (Ibadan, Nigeria).
- ILDIS: International Legume Databank and Information System (Kew, United Kingdom).
- ILRI: International Livestock Research Institute (Nairobi, Kenya).
- IPB: Institute of Plant Breeding, University of the Philippines (Los Baños, the Philippines).
- IPGRI: International Plant Genetic Resources Institute (Rome, Italy).
- IRRI: International Rice Research Institute (Los Baños, the Philippines).
- LIPI: Indonesian Institute of Sciences (Jakarta, Indonesia).
- MARDI: Malaysian Agricultural Research and Development Institute (Serdang, Malaysia).
- MARIF: Malang Research Institute for Food Crops (Malang, Indonesia).
- NBPGR: National Bureau of Plant Genetic Resources (New Delhi, India).
- NFTA: Nitrogen Fixing Tree Association (Waimanolo, Hawaii, United States).
- NSDB: National Science Development Board (Laguna, the Philippines).
- ORSTOM: Office de la Recherche Scientifique et Technique Outre-Mer (Paris, France).
- PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (Los Baños, the Philippines).
- PORIM: Palm Oil Research Institute of Malaysia (Kuala Lumpur, Malaysia).
- PROSEA: Plant Resources of South-East Asia (Bogor, Indonesia).
- QDPI: Queensland Department of Primary Industries (Brisbane, Australia).
- RDCB: Research and Development Centre for Biology (Bogor, Indonesia).
- RRIM: Rubber Research Institute Malaysia (Kuala Lumpur, Malaysia).
- TARC: Tropical Agricultural Research Center (Tsukuba, Japan).
- TISTR: Thailand Institute of Scientific and Technological Research (Bangkok, Thailand).
- TNAU: Tamil Nadu Agricultural University (Coimbatore, Tamil Nadu, India).
- UNITECH: Papua New Guinea University of Technology (Lae, Papua New Guinea).
- UPLB: University of the Philippines at Los Baños (Los Baños, the Philippines).
- USDA: United States Department of Agriculture (Washington, D.C., United States).
- VISCA: Visayas State College of Agriculture (Leyte, the Philippines).
- WAU: Wageningen Agricultural University (Wageningen, the Netherlands).

Glossary

abaxial: on the side facing away from the axis or stem (dorsal)
abortifacient: inducing abortion
abortive: imperfectly developed
abscission: the natural detachment of leaves, branches, flowers or fruits
accession: in germplasm collections: plant material of a particular collection, usually indicated with a number
accrescent: increasing in size with age
achene: a small dry indehiscent one-seeded fruit
acropetal: from the base toward the apex
actinomorphic: radially symmetrical; applied to flowers which can be bisected in more than one vertical plane
aculeate: furnished with prickles; prickly
acumen: the point of an acuminate leaf; the drip-tip
acuminate: ending in a narrowed, tapering point with concave sides
acute: sharp; ending in a point with straight or slightly convex sides
adaxial: on the side facing the axis (ventral)
adnate: united with another part; with unlike parts fused, e.g. ovary and calyx tube
adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems
aerenchyma: a spongy tissue having large thin-walled cells and large intercellular spaces, serving for aeration or floating tissue
afforestation: the establishment of forest crops by artificial methods such as planting or sowing
agroforestry: land-use systems in which trees or shrubs are grown in association with crops (agricultural crops or pastures) in a spatial arrangement or a rotation and in which there are both ecological and economic interactions between the trees or shrubs and the other components of the system
air layering: a form of layering in which soil (rooting medium) is brought to the branch to be layered; the ball of soil in a polythene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated
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
allelopathy: the reputed baneful influence of one living plant upon another due to secretion of toxic substances
alley cropping: growing field crops between hedgerows of nutrient-cycling trees or shrubs which are periodically pruned during the cropping season to reduce shading and to provide green manure for the field crops
alluvium: soil material deposited by running water in recent geological time
alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled
analgesic: producing insensibility to pain without loss of consciousness
anastomosis: cross connection of branches or roots; union of one vein or parenchyme band with another, the connection forming a reticulation
andosol: a young tropical soil originating from weathering of volcanic ash
annual: a plant which completes its life cycle in one year
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*
antipyretic: an agent that reduces fever
antispasmodic: an agent that prevents or relieves

spasms or a remedy for spasms
antrorse: directed upwards (opposed to retrorse)
apetalous: without petals or with a single perianth
apex (plural apices): tip or summit of an organ
apical: at the apex of any structure
apiculate: ending abruptly in a short point
apomict: an organism reproducing by apomixis
apomixis: reproduction by seed formed without sexual fusion (apomictic)
appendix (botany): a name given to appendages of any kind, e.g. in *Araceae* the sterile top part of the spadix
appressed (adpressed): lying flat for the whole length of the organ
arachnoid: like a cobweb
arboreal: of, relating to, or resembling a tree; inhabiting or frequenting trees
arbuscular: branched like a tree
architectural model: model describing the branching habit of a tree as determined by the pattern of activity of axes, the pattern including timing, positioning and fate (e.g. terminating in an inflorescence) of active axes
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)
arillate: possessing an aril
arillode: a false aril, a coat of the seed not arising from the placenta
arilloid: like an aril
aristate: awned
armed: bearing some form of spines
article: a segment of a constricted pod or fruit, as in *Desmodium*
articulate: jointed, or with places where separation takes place naturally
articulation: a joint, popularly applied to nodes of grasses
ascending: curving or sloping upwards
astringent: an agent or substance causing shrinkage of mucous membranes or raw or exposed tissues
attenuate: gradually tapering
Attims' architectural model: habit of growth determined by axes with continuous growth, differentiated into a monopodial trunk and equivalent branches; branching takes place either continuously or diffusely. Flowering is always lateral and does not affect shoot construction
auricle: a small lobe or ear
auriculate: eared, having auricles
awn: a bristle-like appendage, especially occurring on the glumes of grasses
axil: the upper angle between the leaf and the stem
axillary: arising from the axil
Ayurvedic: traditional Hindu system of medicine based largely on homeopathy and naturopathy
barbellate: with short stiff straight hairs
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 originally Indonesian method of hand-printing textiles by coating parts of the fabric with wax to resist dye, dipping in a cold dye solution, boiling off the wax, and repeating the process for each colour used
beak: a long, prominent and substantial point, applied particularly to prolongations of fruits
beaked: used of fruits which end in a long point
bearded: awned; having tufts of hairs
berry: a juicy indehiscent fruit with the seeds immersed in pulp; usually several-seeded without a stony layer surrounding the seeds
biennial: a plant which flowers, fruits and dies in its second year or season
bifid: divided in two, usually equal parts
bilabiate: two-lipped
bipinnate: when the primary divisions (pinnae) of a pinnate leaf are themselves pinnate
biramous: having two branches
bisexual: having both sexes present and functional in the same flower
blade: the expanded part, e.g. of a leaf or petal
bole: the main trunk of a tree, generally from the base up to the first main branch
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
bristle: a stiff hair or a hair-like stiff slender body
broadcast: to sow seed scattered, not in lines or pockets
bulbous: having bulbs or having the form or function of a bulb
bush: a low thick shrub without a distinct trunk
butt: the base of the trunk from which the roots spring
buttress: the enlargement of the base of trunks of 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
caespitose: growing in tufts
calorific value: the heat produced by the combustion of a unit weight of a fuel
calyx: the outer envelope of the flower, consisting of sepals, free or united
cambium (plural cambia): a layer of nascent tissue between the wood and bark, adding elements to both
campanulate: bell-shaped
canaliculate: channeled, with a longitudinal groove
canopy: the uppermost leafy layer of a tree, forest or crop
capitate: headed, like the head of a pin in some stigmas, or collected into compact headlike clusters as in some inflorescences
capsule: a dry dehiscent fruit composed of two or more carpels and either splitting when ripe into valves, or opening by slits or pores
carinal: relating to the keel in aestivation (the manner in which the parts of a flower are folded up before expansion) when the keel (carina) includes the other parts of the flower
carminative: expelling gas from the stomach and intestines; a carminative medicine
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
catch-cropping: a form of intercropping in which a perennial crop (e.g. cocoa) is interplanted in its juvenile stage with a secondary annual or short-perennial crop (e.g. banana) to obtain revenues during the interim period, to check weeds, to provide shade and to control the spread of insect pests; a form of sequential cropping in which, for instance, a green manure crop procedes the main crop
catkin: a close bracteate, often pendulous spike, usually with unisexual flowers
caudate: with a tail-like appendage
chartaceous: papery
chasmogamous: of flowers that are pollinated when open; c.f. cleistogamous
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 wood chips
ciliate: with a fringe of hairs along the edge
ciliolate: fringed with small hairs
cladode: a branch of a single internode simulating a leaf
clavate: club-shaped or thickened towards the end
claw: the narrow part of a petal or sepal
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
coherent: the incorporation of one part with another, as the petals to form a tubular corolla
coleorhiza: the sheath of a monocotyledonous embryo, when pierced by the true radicle
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
collar: the boundary between the above- and underground portion of the axis of a plant
column: a tube of connate stamen filaments
compatibility: in floral biology: capable of cross- or self-fertilization; in plant propagation: stock–scion combinations resulting in a lasting union
compound: of two or more similar parts in one organ, as in a compound leaf or compound fruit
compression parallel to grain: a measure for the compression strength parallel to the direction of the fibres
concave: hollow
concolorous: 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)
connate: united or joined
contorted: twisted or bent
convex: having a more or less rounded surface
coppice: a small wood which is regularly cut at stated intervals, the new growth arising from the stools
cordate: heart-shaped, as seen at the base of a leaf, which is deeply notched
cordiform: heart-shaped
coriaceous: of leathery texture
corolla: the inner envelope of the flower consisting of free or united petals
corrugate(d): wrinkled
cortex: the bark or rind
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 close-growing crop primarily grown for the purpose of protecting and improving soil between periods of regular crop production or between trees or vines in orchards and plantations
crenate: the margin notched with blunt or rounded teeth
crenulate: slightly crenate, with small teeth
cross-pollination: the transfer of pollen from one flower to the stigma of a flower of another plant which is not of the same clone
crown: the aerial expanse of a tree, not including the trunk (corona); a short rootstock with leaves; the base of a tufted, herbaceous, perennial grass
crustaceous: of brittle texture
culm: the stem of grasses and sedges
cultigen: a plant species or race that has arisen or is known only in cultivation
cultivar (cv., plural cvs): an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety; a cultivar name should always be written with an initial capital letter and given single quotation marks (e.g. banana 'Gros Michel')
cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals
cupular: furnished with or subtended by a cupule or small cuplike structure
cuspidate: abruptly tipped with a sharp rigid point
cutting: portion of a plant, used for vegetative propagation
cyme: a determinate inflorescence, often flat-topped, in which each growing point ends in a flower and the central flowers open first
cymose: bearing cymes or inflorescences related to cymes
damping-off: a disease of seeds or seedlings caused by fungi which cause various effects, from failure to germinate to the dying off of the seedling
deciduous: shedding or prone to shedding, applied to leaves, petals, etc.
decoction: a preparation made by boiling a medicinal plant in water
decumbent: reclining or lying on the ground, but with the summit ascending
decurrent: extending down and adnate to the petiole or stem, as occurs in some leaves
decussate: of leaves, arranged in opposite pairs on the stem, with each pair perpendicular to the preceding pair
deflexed (reflexed): abruptly recurved; bent downwards or backwards
dehiscent: opening spontaneously when ripe, e.g. capsules, anthers
deltoid: shaped like an equal-sided triangle
dentate: margin prominently toothed with the pointed teeth directed outwards
denticulate: minutely toothed
determinate: of inflorescences, when the terminal or central flower of an inflorescence opens first and the prolongation of the axis is arrested; of shoot growth, when extension growth takes the form of a flush, i.e. only the previously formed leaf primordia unfold; for pulses also used to indicate bush-shaped plants with short duration flowering in one plane
diad (dyad): a body of 2 units
diadelphous: in two bundles
dichasium (plural dichasia): a cymose inflorescence with 2 equal or nearly equal lateral branches arising below the terminal flower, this pattern being repeated or not (compound and simple dichasium respectively)
dichotomous: forked, parted by pairs
dieback: the dying off of parts of the above-ground structure of the plant, generally from the top downward
digestibility: the proportion of a foodstuff taken into the digestive tract that is absorbed into the body
digitate: a compound leaf whose leaflets diverge from the same point like the fingers of a hand
dimorphic: of two forms, as may occur with branches, etc.
dioecious: with unisexual flowers and with the staminate and pistillate flowers on different plants (dioecy)
diploid: with two sets of chromosomes (genomes), as occurs in somatic or body cells; usually written $2n$, having twice the basic chromosome number of the haploid germ cells
discoid: resembling a disk or discus, being flat and circular
discolorous: dissimilarly coloured on both sides or throughout; of a different colour as a specified structure
disk: a fleshy or elevated development of the receptacle within the calyx, corolla or stamens, often lobed and nectariferous
distal: situated farthest from the place of attach-

ment

distichous: regularly arranged in two opposite rows on either side of an axis

diuretic (diureticum): an agent increasing the urinary discharge

domatium (plural domatia): a modified projection that provides shelter for other organisms

dormancy: a term used to denote the inability of a resting plant or plant part (e.g. the seed, bulb, tuber, or in tree crops usually the buds) to grow or to leaf out, even under favourable environmental conditions

dorsal: back; referring to the back or outer surface of a part or organ (abaxial)

dorsifixed: attached by the back, as in the case of the attachment of anthers to a filament

downy: covered with very short and weak soft hairs

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

ecotype: a biotype resulting from selection in a particular habitat

ectomycorrhiza: see mycorrhiza

eglandulose (eglandular): without glands

ellipsoid: a solid which is elliptical in outline

elliptical: oval in outline but widest about the middle

emarginate: notched at the extremity

embryo: the rudimentary plant within a seed, developed from a zygote (sexual) or from other nuclei in the embryo sac or cells of the nucellus or integuments (apomictic)

emergent: of a tree, one of which the crown reaches distinctly above the forest canopy

emetic: an agent that induces vomiting

emmenagogue: substance promoting flow of menstrual discharge

endemic: exclusively native to a specified or comparatively small region; also used as a noun for a taxon thus distributed

endocarp: the innermost layer of the pericarp or fruit wall

endomycorrhiza: see: mycorrhiza

endosperm: the starchy or oily nutritive material stored within some seeds, sometimes referred to as albumen; it is triploid, having arisen from the triple fusion of a sperm nucleus and the two polar nuclei of the embryo sac

energy value: the heat produced by the combustion of a unit weight of a fuel or food (= calorific value)

entire (botany): with an even margin without teeth, lobes, etc.

eosiniphylic: that can be coloured with red fluorescent eosin dye

ephemeral: lasting for a day or less, e.g. the staminate inflorescences in *Pandanus*

epicalyx: an involucre of bracts below the flower, resembling an extra calyx

epicormic branching: branches arising from buds in the bark of the main stem, most commonly occurring in trees under crown stress; also called water sprouts

epidermis: the true cellular skin or covering of a plant below the cuticle

epigeal: above the ground; in epigeal germination the cotyledons are raised above the ground

epipetalous: borne upon or placed before the petals

epiphyte: a plant that grows on another plant but without deriving nourishment from it

erect: directed towards summit, not decumbent

erecto-patent: between spreading and erect

evapotranspiration: loss of water from the soil by evaporation from the surface and by transpiration from the plants growing thereon

evergreen: bearing foliage all year long; a plant that changes its leaves gradually

exocarp: the outer layer of the pericarp or fruit wall

expectorant: an agent tending to promote discharge of mucus from the respiratory tract

exsert, exserted: protrude beyond, as stamens beyond the tube of the corolla

ex situ: in an artificial environment or unnatural habitat

exstipulate: without stipules

extra-axillary: beyond or outside the axil

extrafloral: of nectaries, beyond the flower

extrorse: directed outward, as the dehiscence of an anther

falcate: sickle-shaped

fallow: land resting from cropping, often covered by natural vegetation or planted with fast growing herbs, shrubs or trees (fallow crop)

fascicle: a cluster of flowers, leaves, etc., arising from the same point

fasciculate: connected or drawn into a fascicle

febrifuge: an agent serving to reduce fever

fermentation: a chemical change accompanied by effervescence and suggestive of changes produced in organic materials by yeasts

ferruginous: rust-coloured

fertile (botany): capable of completing fertilization and producing seed; producing seed capable of germination; having functional sexual organs

fertilization: union of the gametes (egg and sperm)

to form a zygote
fibreboard: = hardboard
fibrous: composed of or rich in fibres
filament: thread; the stalk supporting the anther
filiform: slender; threadlike
fimbriate: fringed
fire-break: a barrier or wide strip of land on which the native vegetation has been changed or cleared, that acts as a buffer to fire-spread so that fires burning into them can be more easily controlled
fissured: provided with fissures (cracks of considerable length and depth), e.g. in the bark of some trees
flabellate: fan-shaped, dilated in a wedge-shape, sometimes plaited (folded)
flavonoid: water-soluble phenolic compounds, consisting of 2 aromatic rings joint together with a 3-carbon unit
floret: a small flower, one of a cluster as in grasses or *Compositae*
flush: a brief period of rapid shoot growth, with unfolding of the leaf primordia which had accumulated during the previous quiescent period
fluted (bole): with rounded grooves and folds
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
free: neither adhering nor united
fugaceous: withering or falling off rapidly or early
fulvous: yellow, tawny
funicle (funiculus): the little cord which attaches the ovule or seed to the placenta
fusiform: spindle-shaped; tapering towards each end from a swollen centre
germplasm: the genetic material that provides the physical basis of heredity; also a collection of genotypes of an organism
gibbous: more convex in one place than another
glabrate: destitute of pubescence and of any roughness
glabrescent: becoming glabrous or nearly so
glabrous: devoid of hairs
glandular: having or bearing secreting organs or glands
glaucous: pale bluish-green, or with a whitish bloom which rubs off
gley: a sticky clay layer formed below the surface of some waterlogged soils
globose: spherical or nearly so
glomerule: a condensed head of almost sessile flowers; a cluster of heads in a common involucre
glucoside: compound that is an acetal derivative of sugars and that on hydroloysis yields glucose
glume (plural glumes): the chaffy or membranous two-ranked members of the inflorescence of grasses and similar plants; lower glume and upper glume, two sterile bracts at the base of a grass spikelet
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
granulose (granular): composed of or covered with grain-like minute particles
graveyard test: a test to determine the durability of wood in contact with soil
green manure: green leafy material applied to and mostly worked into the soil to enrich the soil with nutrients and organic matter
gregarious: growing in associated groups or clusters
gum: a colloidal polysaccharide substance that is gelatinous when moist but hardens on drying; gum is exuded by plants or extracted from them
gynophore: a stalk supporting the gynoecium formed by elongation of the receptacle
habit: external appearance or way of growth of a plant
habitat: the kind of locality in which a plant grows
halophyte: a plant that grows naturally in soils having a high content of salts
hard-seededness: impermeability of the seed-coat, which avoids quick germination
hardboard: board manufactured from fibres of ligno-cellulosic material
hardwood: the wood of an angiospermous tree as distinguished from that of a coniferous tree
harvest-index: the total harvestable produce (usually the main product only) as a fraction of the total biomass (usually aerial biomass only) produced by the crop
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
hedgerow: a closely planted line of shrubs or small trees, often forming a boundary or fence
hedgerow intercropping: see alley cropping
helophyte: a perennial swamp plant that roots in

the flooded soil and carries its leaves, flowers and fruits above the water
hepatotoxic: causing injury to the liver
herb: any vascular plant which is not woody
herbaceous: with the texture, colour and properties of a herb; not woody
heteromorphic: varying in number or form
heterostylous: having styles of two or more distinct forms or of different lengths
heterotypic: described from more than one species; these differing in structure
hilum: the scar left on a seed indicating its point of attachment
hirsute: with rather coarse stiff hairs
hirtellous: minutely hirsute
hispid: covered with long rigid hairs or bristles
hispidulous: minutely hispid
homonym (botany): a name rejected because of an earlier application of the same name to another taxon
husk: the outer covering of certain fruits or seeds
hybrid: the first generation offspring of a cross between two individuals of different species
hybridization: the crossing of individuals of different species
hydrolysis: a chemical reaction of water in which a bond in the reactant other than water is split and hydrogen and hydroxyl are added
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
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
impressed: marked with slight depressions
inbreeding: breeding through a succession of parents belonging to the same stock
incised: cut deeply
incompatibility: in floral biology: not capable of cross- or self-fertilization; in plant propagation: not capable to make stock–scion combinations resulting in a lasting union
indehiscent: not opening when ripe
indeterminate: of inflorescences, a sequence in which the terminal flowers are the last to open, so that the floral axis may be prolonged indefinitely by the terminal meristem; of shoot growth: when the shoot apex forms and unfolds leaves during extension growth, so that shoot growth can continue indefinitely
indigenous: native to a particular area or region
indumentum: a covering, as of hairs, scales, etc.
inequilateral: unequal-sided
inferior: beneath, lower, below; an inferior ovary is one which is below the sepals, petals and stamens
inflorescence: the branch that bears the flowers, including all its bracts and branches
infructescence: a ripened inflorescence in the fruiting stage
inner bark: the secondary phloem; the living part of the tissue outside the cambium
inoculation: grafting, more properly budding, a single bud only being inserted; transferring e.g. mycorrhiza or rhizobia in the growing medium to promote growth
inoculum: material used for inoculation, e.g. rhizobia in soil to promote the growth of certain *Leguminosae*
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 (culm) between two nodes
in vitro: outside the living body and in an artificial environment
involucral: belonging to an involucre
involucre: a ring of bracts (involucral bracts) surrounding several flowers or their supports, as in the heads of *Compositae* or the umbels in *Umbelliferae*
isomer: a compound, radical or ion containing the same numbers of atoms of the same elements in the molecule as one or more others, and hence having the same molecular formula, but differing in the structural arrangement of the atoms and consequently in one or more properties
isozymes: multiple distinct molecular forms of an enzyme that differ in net electrical charge; important to the investigation of the molecular basis for cellular differentiation and morphogenesis, and increasingly used to clarify genotypic relationships
joint; jointed: an articulation (e.g. a node); articulated, falling apart at the joints
jugate: connected or yoked together; e.g. in leaves

1–n jugate: with 1–n pairs of leaflets
juvenile phase (stage): the period between germination and the first signs of flowering, during which vegetative processes preclude flower initiation even under the most favourable conditions
keel (carina): a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla; the principal vein of a sepal or glume
keeled (carinate): having a keel or carina
kernel: the nucellus of an ovule or of a seed, that is, the whole body within the coats
kiln dried: being seasoned in a kiln
kiln drying: see season
knee: an abrupt bend in a root, stem or tree-trunk
knee root: a tree root with an outgrowth
kraft pulp: = sulphate pulp
lac insect: a scale insect (*Laccifer lacca*, synonym *Kerria lacca*) that produces lac, a resinous gold-coloured substance used for lacqerware
lacerate: torn; irregularly cleft or cut
laciniate: slashed, cut into narrow lobes
lamellate: made up of thin plates
lamina: see blade
laminate(d): consisting of plates or layers
lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex
landrace: a locally developed kind of cultivar, without formal recognition, and usually much more variable than an official registered cultivar and from which usually several cultivars can be selected
lateral: on or at the side
laterite: a red soil that shows intensive weathering and chemical change and leaching away of bases and silica, leaving aluminium and iron oxides
lax: loose, distant
layer: a branch caused to root while still connected to the parent and used for propagation (layering)
leaching: of a soil, the removal of soluble and nutritive elements by a vertical, downward water movement
leaflet: one part of a compound leaf
lemma: the lower of the two glumes which surround each floret in the spikelet of grasses
lenticel: lenticular masses of loose cells protruding through fissures in the periderm on stems, fruits and roots; they usually arise beneath individual stomata and their main function is gaseous exchange
lenticellate: having lenticels
lenticular: shaped like a double-convex lens
lepidote: covered with small scales
liana: a woody climbing vine
lignin: a colloidal polymer of varying chemical structure used as secondary wall material in xylem vessels, tracheids and sclerenchyma fibres
lignotuber: a woody swelling, partly or completely underground, at the base of certain plants and containing numerous cortical buds, as in many eucalypts
ligulate: with or possessing a ligule
ligule: a membranous outgrowth on the upper surface of a grass leaf at the junction of the sheath and the blade which may be presented by a ridge or by a line of hairs; an elongated flattened strap-shaped structure
limb: the expanded part of a tubular corolla, as distinct from the tube or throat; the lamina of a leaf or of a petal; the branch of a tree
linear: long and narrow with parallel sides
lithosol: an azonal shallow soil consisting of imperfectly weathered rock fragments
lobe: any division of an organ or specially rounded division
lobed: divided, but not to the base
locular: divided by internal partitions into compartments as in anthers and ovaries
locule: the cavity of an ovary or anther
loculicidal: the cavity of a pericarp dehiscent by the back, the dorsal suture
log: a section cross cut from a tree or a branch of a tree. Round log: log of which bark, branches and protuberances have been removed. Squared log: a log sawn to an approximately rectangular cross-section
longitudinal: lengthwise
Lyctus: see powder-post beetle
macronutrients: chemical elements of which relatively large quantities are essential for the growth of a plant (such as N, P, Ca, Mg)
Malesia: the biogeographical region including Malaysia, Indonesia, the Philippines, Singapore, Brunei and Papua New Guinea
mangrove: a brackish-water coastal swamp of tropical and subtropical areas that is partly inundated by tidal flow
marcotting (air layering): a form of layering in which soil (rooting medium) is brought to the branch to be layered; the ball of soil in a polythene cover is wrapped around the girdled branch; after adventitious roots grow out above the girdle, the layer can be separated

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 crustaceae causing surface erosion
membranous: thin and semi-transparent, like a fine membrane
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
mildew: a superficial, usually whitish growth on living plants produced by fungi
modulus of elasticity: a measure of the stiffness of beams or long columns
modulus of rupture: a measure of the load-carrying capacity in bending until breaking occurs
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
monoculture: the cultivation during an extended period of time of a single product to the exclusion of other possible uses of the land
monoecious: with unisexual flowers, but male and female flowers borne on the same plant
monophyletic: of a group of species, one which includes the known or hypothesized common ancestor and all of its descendants
monotypic: consisting of a single element, e.g. of a genus consisting of only one species
morphogenetic: relating to the development of normal organic form
mucilage (mucilaginous): a gelatinous substance that is similar to gum but that swells in water without dissolving and forms a slimy mass
mucro: a sharp terminal point
mucronate: ending abruptly in a short stiff point
mucronulate: diminutive of mucronate
mulch: plant or non-living materials used to cover the soil surface with the object of protecting it from the impact of rainfall, controlling weeds, temperature and evaporation
multifid: cleft into many lobes or segments
multiseriate: arranged in several rows
muricate: rough, with short and hard tubercular excrescences
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
nematode: small elongated cylindrical worm-like micro-organism, free-living in soil or water, or parasitic in animals or plants
nerve: a strand of strengthening and/or conducting tissue running through a leaf, which starts from the midrib and diverges or branches throughout the blade
node: the point on the stem or branch at which a leaf or lateral is borne
nodulation: formation of root-nodules or (occasionally) stem-nodules
nodule: a small knot or rounded body, often in roots of leguminous plants, where bacteria of the genus Rhizobium are active in the fixation of nitrogen from the air
nurse trees: trees planted between the main trees to increase the rate of site canopy closure for better weed control and for better formed main trees
nut: a one-seeded indehiscent fruit with a hard dry pericarp or shell
nutlet: a little nut
ob-: prefix, indication inverse or opposite condition (obtriangular, obcordate, etc.)
oblanceolate: reverse of lanceolate
oblate: more or less spherical but flattened at the poles
obligate: necessary, essential; the opposite of facultative
oblique: slanting; of unequal sides
oblong: longer than broad, with the sides parallel or almost so
oblongoid: a solid object which is oblong in section
obovate: reverse of ovate
obovoid: a solid object which is obovate in section
obpyriform: pear-shaped but attached at the broad end
obtuse: blunt or rounded at the end
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
order (and its extensions, first, etc.): a sequence, as of branching: a first order branch branches to produce a second order branch, etc.
orifice: an opening by which spores, etc., escape; ostiole
orthotropic: having a more or less vertical direction of growth
outcross: cross-pollination, usually by natural means, with plants differing in genetic constitution
ovary: that part of the pistil, usually the enlarged base, which contains the ovules and eventually becomes the fruit
ovate: egg-shaped in outline or in section; a flat surface which is scarcely twice as long as broad with the widest portion below the middle
ovoid: a solid object which is egg-shaped (ovate in outline)
ovule: the immature seed 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
papillae: soft superficial glands or protuberances
papillate: having minute nipple-like protuberances
papillose: covered with minute nipple-like protuberances
pappus: the various tufts of hairs on achenes or fruits; the limb of the calyx of *Compositae* florets
parenchyma: tissue composed of more or less isodiametric cells, e.g. the pith and mesophyll
paripinnate: a pinnate leaf with all leaflets in pairs
particle board: board made from bonded particles of wood and/or other ligno-cellulosic material
partite (parted): cleft, but not quite to the base
patent: spreading out widely
pedicel: stalk of each individual flower of an inflorescence
pedicellate: furnished with a pedicel
peduncle: the stalk of an inflorescence or partial inflorescence
pedunculate: furnished with a peduncle
peltate: of a leaf, with the stalk attached to the lower surface, not at the edge
pendent, pendulous: drooping; hanging down from its support
penninerved: pinnately veined, parallel veins arise at an angle from a midvein (as in *Musa*)
pentamerous: having five parts in a flower whorl
perennial: a plant living for many years and usually flowering each year
perfect flower: a flower possessing both male and female organs
perianth: the floral leaves as a whole, including both sepals and petals if both are present
pericarp: the wall of the ripened ovary or fruit whose layers may be fused into one, or may be more or less divisible into exocarp, mesocarp and endocarp
persistent: remaining attached; not falling off, not deciduous; applies to organs that remain in place after they have fulfilled their natural functions
perular: of leaf bud: bearing scales
petal: a member of the inner series of perianth segments which are often brightly coloured
petiolar: borne on, or pertaining to a petiole
petiolate: having a petiole
petiole: the stalk of a leaf
petiolule: the stalk of a leaflet
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
photoblastic: of seeds that germinate in daylight only
photoperiod: length of day favouring optimum functioning of an organism
photosensitive: sensitive to the action of radiant energy such as light
phyllode: a petiole taking on the form and functions of a leaf
phyllodinous: relating to phyllodes
phyllotaxis: the arrangement of leaves or floral parts on an axis or stem
phyllotaxy: the arrangement of leaves or floral parts on their axis
pilose: hairy with rather long soft hairs
pinhole borer: generally an ambrosia beetle damaging wood by a worm-hole 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
pinnatifid: pinnately cleft
pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of one or more ovaries, styles and stigmas
pistillate: a unisexual flower with pistil, but no stamens
pistillode: a sterile, often reduced pistil
pith: the soft core occurring in the structural centre of a log; the tissue, sometimes soft, in the centre of the stem of a non-woody dicotyledon
plagiotropic: having an oblique or horizontal direction of growth
pleurogram: a characteristic fissure in the epidermal palissade layer in some leguminous seeds (*Mimosoideae*, *Caesalpinioideae*); it is a U-shaped or horseshoe-shaped single or double line found on both faces of the seed and sometimes continuous between them and an important constant character to identify genera
plumose: featherlike with fine hairs
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 dry fruit composed of a single carpel and dehiscing by sutures, like in legumes
podzol: a zonal soil having an organic mat and a thin organic-mineral layer above a gray leached layer resting on a dark alluvial horizon
pole (tree): a young tree with a diameter of 10-30 cm at breast height
pollarding: cutting back the crown of a tree to the trunk in order to harvest wood and browse, to produce regrowth beyong the reach of animals, and/or to reduce the shade cast by the crown
pollen: spores or grains borne by the anthers containing the male element (gametophyte)
pollination: the transfer of pollen from the dehiscing anther to the receptive stigma
polymorphic: polymorphous, with several or various forms; variable as to habit
polyphenol: a polyhydroxy phenol
polyploid: with more than two sets (genomes) of chromosomes in the somatic cells
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
precocious: exceptionally early in development; flowering and fruiting at an early age
prickle: a sharp, relatively stout outgrowth from the outer layers
primordium: a member or organ in its earliest condition
procumbent: lying along the ground
progeny: offspring
proliferous: multiplying quickly; bearing progeny as offshoot
prop roots: aerial roots
propagule: a part of a plant that becomes detached and grows into a new plant
prostrate: lying flat on the ground
protandrous: of flowers, shedding pollen before the stigma is receptive
protogynous: of flowers, the stigma being receptive before the pollen is shed
provenance: a collection of pollen, seed or propagules from a certain restricted locality
proximal: the part nearest the axis (as opposed to distal)
pruinose (pruinous): having a waxy powdery secretion on the surface, a bloom
pruning: cutting off the superfluous branches or shoots of a plant for better shaped or more fruitful growth
pseudoraceme: raceme-like inflorescence but not a true raceme
pseudostem: an axis with the appearance of a stem but made up of other organs, e.g. leaf sheaths in *Musa* and *Curcuma*
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
pulvinate: cushion-shaped
pulvinus: a minute gland or swollen petiole base.
punctate: marked with dots or translucent glands
punctiform: in the form of a point or dot
pungent: bearing a sharp point; causing a sharp or irritating sensation
pustule: a pimple or blister
pyrogenous: produced by fire and heat
quadrangular: four-cornered or four-edged
qualitative short-day plant: plant that needs short days to flower (often with quantitative response); if the daylength surpasses a certain value (the critical daylength) the plant does not flower

quantitative short-day plant: plant flowers sooner under short-day conditions, but short days are not absolutely necessary for flowering

raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards

racemose: raceme-like

rachilla: a diminutive or secondary axis that bears the flowers

rachis (plural rachides): the principal axis of an inflorescence or a compound leaf beyond the peduncle or petiole

radial: lengthwise, in a plane that passes through the pit; radiating, as from a centre

radicle: the first root of an embryo or germinating seed

ratoon: shoots in perennial crops such as the pineapple, left on the plants after harvest to produce the subsequent crop (ratoon crop)

ray: the radiating branch of an umbel; the outer floret of an inflorescence of the *Compositae* with straplike perianth which differs from those in the centre or disk

rays (in wood): ribbons of parenchymatous tissue which are seen on a cross-section of timber as lighter coloured lines radiating from the pith outwards, and extending right up to the bark

receptacle: 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: the replanting of a formerly forested area with forest trees

regosol: an azonal soil consisting chiefly of soft and imperfectly consolidated material

regular: of a radially symmetrical flower; actinomorphic

reniform: kidney-shaped

resin: solid to soft semisolid amorphous fusible flammable substance obtained as exudate or as an extract of plants

restorative: capable of restoring health, strength, consciousness

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

rheophyte: organism preferring or living in flowing water

rhizobia: bacteria of the genera *Rhizobium*, *Bradyrhizobium* and *Azorhizobium* capable of forming symbiotic nodules on the roots of leguminous plants and able to fix atmospheric nitrogen

rhizome: an underground stem which is distinguished from a root by the presence of nodes, buds, and leaves or scales

rhombic: shaped like a rhomb, an equilateral oblique-angled figure

rhomboid (botany): quadrangular, diamond-shaped with the lateral angles obtuse

riparian: frequently growing on the banks of streams or rivers

root-nodules: small dwellings on roots of leguminous and other plants, containing nitrogen-fixing bacteria or fungi

root sucker: a shoot originating from adventitious buds on the roots

rosette: a cluster of leaves or other organs in a circular form

rostrate: beaked

rotund: rounded in outline, somewhat orbicular, but a little inclined towards oblong

rudimentary: of organs, imperfectly developed and non-functional

rugose: wrinkled

rugulose: somewhat wrinkled

Runkel ratio: parameter used by the pulp and paper industry, derived from the fibre dimensions of the culm: two times the fibre wall thickness divided by the fibre lumen diameter

runner: a specialized stem that develops from a leaf axil at the crown of a plant, grows horizontally along the ground, and forms a new plant at one of the nodes, usually at or near the tip (as in strawberry)

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 glucoside with soap properties

saprophyte: a plant which derives its food from dead organic matter

saprophytic: living upon dead organic matter such as humus

sapwood: the outer layers of wood adjacent to the bark which in the living tree contain living cells and reserve materials

scaberulous: somewhat rough
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
scandent: climbing
scarification (seed): scarifying, to cut or soften the wall of a hard seed to hasten germination
scarify: to treat a hard-coated seed by mechanical abrasion or with acid to facilitate germination
Scarronne's architectural model: habit of growth determined by an orthotropic rhythmically active terminal meristem which produces an indeterminate trunk bearing tiers of branches, each branch-complex orthotropic and sympodially branched as a result of terminal flowering
scion: the plant being propagated vegetatively in grafting; the part of the plant above the graft union
sclerenchymatous: of tissue, composed of thick-walled cells
scrub: vegetation whose growth is stunted because of lack of water coupled with strong transpiration
scurfy: bearing small scales on the surface (lepidote; scaly)
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 nerve: see secondary venation
secondary venation: the collection of veins of a leaf blade branching off from 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 accomodating 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
segment: the division of a palmate or costapalmate leaf
selective logging: a system with which only certain a priori selected timber groups are harvested from a forest
self-compatible: capable of fertilization and setting seed after self-pollination
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
self-sterile: failure to complete fertilization and obtain seed after self-pollination
semi-: prefix, meaning half or incompletely, e.g. semi-inferior
semi-aquatic: a water-plant which roots in the soil, but produces aquatic leaves, otherwise living as land-plants
senescence: advancing in age
sepal: a member of the outer series of perianth segments
septate: divided by one or more partitions
septum (plural septa): a partition or cross-wall
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
seta (plural setae): a bristle-like body
setose: set with bristles or bristle-like elements
setulose: set with small bristles or bristle-like elements
shale: sedimentary rock formed by the consolidation of unaltered clay or silt
shear: a measure for 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
sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses
shellac: a purified lac resin prepared by heating and filtering lac from lac insects
shelter-belt: = wind-break
shoot: the ascending axis, when segmented into dissimilar members it becomes a stem
shrub: a woody plant which branches from the base, all branches being equivalent
simple (botany): not compound, as in leaves with a single blade
sinulate: with a deep wavy margin
sinuous: wavy
slash: a cut or stroke along the stem of a tree to reveal exudates and colours of bark and sapwood
sod (turf): the upper stratum of soil bound by grass and plant roots into a thick mat
softwood: the wood of a coniferous tree

soga-batik: fine batik using traditional patterns and commonly vegetable dyes; it is especially employed in central Java (Indonesia)
solitary: single stemmed, not clustering
spat(h)ulate: spoon-shaped
spathate: furnished with a spathe
spathe: a large bract enclosing a spadix, or two or more bracts enclosing a flower cluster
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
spicate: spike-like
spiciform: with the form of a spike
spike: a simple indeterminate inflorescence with sessile flowers along a single axis
spikelet: a secondary spike, one of the units of which the inflorescence is made in grasses, consisting of one or more florets on a thin axis, subtended by a common pair of glumes
spine: a short stiff straight sharp-pointed hard structure usually arising from the wood of a stem
spinescent: ending in a spine or sharp point
spinulescent: slightly spiny or having small spines
spinulose: with small spines
spiral: as though wound round an axis
spur (botany): a hollow and slender extension of some part of the flower, usually nectariferous; a small reproductive shoot
staining: discoloration or variation from natural colour due to fungi, chemical action or other causes
stake test: = graveyard test
stamen: one of the male reproductive organs of a flower; a unit of the androecium
staminate: a flower bearing stamens but no pistil
staminode: an abortive or rudimentary stamen without or with an imperfect anther
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, or of petals arranged in the form of a star
stem: the main ascending axis of a plant; in bamboos usually named culm, in other plant groups occasionally
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)
stick lac: lac in its natural state that encrusts small twigs and the bodies of lac insects
stigma: the portion of the pistil which receives the pollen
stigmatose: provided with stigmas or having them conspicuously
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
stolon: a trailing stem usually above the ground which is capable of producing roots and shoots at its nodes
stoloniferous: bearing a stolon or stolons
stoma (plural stomata): a breathing pore or aperture in the epidermis
straggling: extremely divergent, spreading very far apart
strain: a group of individuals of a common origin, usually a more narrowly defined group than a cultivar
striate: marked with fine longitudinal parallel lines, as grooves or ridges
strigose: with short stiff hairs lying close along the surface
stripling: seedling stripped of all but its terminal leaves and used as planting stock
strip planting: setting trees in two or more parallel lines in a long narrow area that has been wholly or partially cleared
strophiole: = caruncle
stump: seedling with trimmed roots and shoot and used as planting stock; also the part of a tree remaining attached to the root after the trunk is cut
style: the part of the pistil connecting the ovary with the stigma
sub-: prefix, meaning somewhat or slightly (e.g. subacute), or below (e.g. subterranean) or less than, imperfectly
subalpine: relating to high upland slopes immediately below the timber line
subfamily: a taxonomic rank between the family and the tribe denoting a part of a family
subglobose: nearly globular
subshrub: a small shrub which may have partially herbaceous stems
subspecies: a subdivision of a species, in rank between a variety and a species

subulate: awl-shaped, sharply pointed
succulent: juicy, fleshy
sucker: a shoot, usually originating from adventitious buds on the roots or basal stem parts, which does not fit in the architectural model, but is capable of repeating the model
sudorific: causing or inducing sweat
suffrutescent: obscurely shrubby
sulcate: grooved or furrowed
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
symbiosis: the intimate living together of two dissimilar organisms in a mutually benficial relationship, e.g. rhizobia and legumes
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
tail (botany): any long and slender prolongation
taproot: the primary descending root, forming a direct continuation of the radicle
taxon (plural taxa): a term applied to any taxonomic unit irrespective of its classification level, e.g. variety, species, genus, etc.
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 sepals and petals can be made
terete: cylindrical; circular in transverse section
terminal: borne at the end or apex
ternate: in threes
terpene: a group of hydrocarbons present in turpentine, liquid resin or essential oil
tertiary nerve: see tertiary venation
tertiary venation: generally the collection of the smallest veins of a leaf blade
testa: the outer coat of the seed
tetrafoliolate: with four leaflets
tetrahedral: having or made up of four sides
tetraploid: having four times ($4n$) the basic number of chromosomes or twice the diploid number ($2n$)
thinning: removing trees, stems or plants from immature or mature stands in order to stimulate the growth of the remaining trees, stems or plants
thorn: a woody sharp-pointed structure formed from a modified branch
thyrse: a compound inflorescence composed of a panicle (indeterminate axis) with the secondary and ultimate axes cymose (determinate)
thyrsoid: like a thyrse
tiller: a shoot from the axils of the lower leaves, e.g. in some grasses and palms (making such shoots: tillering)
tilth: surface soil prepared for planting or cultivation
tissue culture: a body of tissue growing in a culture medium outside the organism
tomentellous: minutely tomentose
tomentose: densely covered with short soft hairs
tomentulose: slightly tomentose
tomentum: pubescence
trailing: prostrate, but not rooting
transverse: of tertiary veins, connecting the secondary veins, not necessarily in a perpendicular way
trapezoid: like a trapezium, a figure of four unequal sides
tree: a perennial woody plant with a single evident trunk
triad: a body of 3 units
tribe (plural tribae): a taxonomic rank between the family and the genus
trichome: any hair, bristle or scale-like outgrowth of the epidermis
trifoliolate: with three leaflets
trigonous: three-angled, with plane faces
trilocular: having 3 chambers, each usually bearing an ovule or seed
tripartite: divided into 3 parts
triploid: having three times the basic number of chromosomes, usually written $3n$
tripping (flowers): to help in pollinating
truncate: cut off more or less squarely at the end
trunk: the main stem of a tree apart from its limbs and roots
tuber: the swollen portion of an underground stem or root which acts as a storage organ and propagule; it is usually of one year's duration, those of successive years not arising directly from the old ones nor bearing any constant relation to them
tubercle: a small tuber-like excrescence
tuberculate: covered with warty protuberances
tuberous: producing tubers or resembling a tuber
tufted: growing in tufts (caespitose)
tussock: a tuft of grass or grass-like plants

twining: winding spirally
umbel: an indeterminate, often flat-topped inflorescence whose divergent peduncles (rays) and pedicels arise from a common point; in a compound umbel each ray itself bears an umbellule (small umbel)
umbelliform: umbrella-shaped
unarmed: devoid of thorns, spines or prickles
undershrub: any low shrub; partially herbaceous shrub, the ends of the branches perishing during the winter
undulate: wavy, said for instance of a leaf margin if the waves run in a plane at right angles to the plane of the leaf blade
unilocular: one-celled
unisexual: of one sex, having stamens or pistils only
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
VAM: see: vesicular arbuscular mycorrhiza
variegated: irregularly coloured in patches, blotched
variety: botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar
vein: a strand of vascular tissue in a flat organ, such as a leaf
velutinous: see velvety
velvety: with a coating of fine soft hairs; the same as tomentose but denser so that the surface resembles (and feels like) velvet
venation: the arrangement of the veins in a leaf
veneer: a thin sheet of wood
ventral: faces central axis (adaxial), opposed to dorsal (abaxial)
vermiculite: lightweight highly water-absorbent material, usually resulting from expansion of the granules of mica at high temperature
vermifuge: a drug serving to destroy or expel parasitic worms of the intestine
vernalization: the treatment of seeds or bulbs before planting to hasten flowering
verrucose: warty
verruculose: very warty, much covered with warts
verticillate: in a whorl with several elements arising at the same node
vertisol: dark and heavy clay-rich soil type (40–80% montmorilloniet) with well-developed horizons and a pH of 6–7.5 which generally occurs in areas with a pronounced dry season
vesicle: a small bladder or cavity
vesicular: bladder-like
vesicular arbuscular mycorrhiza: a common endomycorrhizal association characterized by 2 types of fungal structures: small structures within root cells known as arbuscules, and storage organs between root cells known as vesicles
vestigial: small and imperfectly developed
vexillum: see standard
viability: ability to live, grow and develop
villose (villous): with long weak hairs
vine: a plant having a stem that is too slender to hold itself erect and therefore supports itself by climbing over an object
viscid: sticky
viscous: glutinous, or very sticky
viviparous: germinating or sprouting from seed or bud while attached to the parent plant
warp: distortion of a piece of sawn timber usually occurring during seasoning
warty: covered with firm roundish excrescences
waterlogged: flooded with water, generally for a period of at least a few weeks
whorl: arrangement with more than two organs of the same kind arising at the same level
wildling: a seedling taken from natural regeneration to serve as planting stock
wind-break: one to several rows of closely spaced, preferably low branching trees planted to protect adjacent areas from strong winds
wing: any membraneous expansion attached to an organ; a lateral petal of a papilionaceous corolla
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 and divisible into equal halves in one plane only

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Index of scientific plant names

Page numbers printed in bold refer to main treatment.

Index of vernacular plant names

Page numbers printed in bold refer to main treatment. For transcriptions of Vietnamese names, see at the end of the index.

Transcriptions of Vietnamese characters

[aa] = â	[ar] = ả	[ax] = ã	[ej] = ẹ	[oo] = ô	[ow] = ơ	[uj] = ụ	[uwx] = ữ
[aaf] = ầ	[as] = á	[ee] = ê	[er] = ẻ	[oof] = ồ	[owf] = ờ	[ur] = ủ	[ux] = ũ
[aaj] = ậ	[aw] = ă	[eef] = ề	[es] = é	[ooj] = ộ	[ooj] = ợ	[us] = ú	
[aar] = ẩ	[awf] = ằ	[eej] = ệ	[ex] = ẽ	[oor] = ổ	[owr] = ở	[uw] = ư	
[aas] = ấ	[awj] = ặ	[eer] = ể	[if] = ì	[oos] = ố	[ows] = ớ	[uwf] = ừ	
[aax] = ẫ	[awr] = ẳ	[ees] = ế	[is] = í	[oox] = ỗ	[owx] = ỡ	[uwj] = ự	
[af] = à	[aws] = ắ	[eex] = ễ	[of] = ò	[or] = ỏ	[ox] = õ	[uwr] = ử	
[aj] = ạ	[awx] = ẵ	[ef] = è	[oj] = ọ	[os] = ó	[uf] = ù	[uws] = ứ	

The Prosea Foundation
(Plant Resources of South-East Asia)

Name, location, legal status and structure

- Prosea is a Foundation under Indonesian law, with an international charter, domiciled in Bogor. It is an autonomous, non-profit, international agency, governed by a Board of Trustees. It seeks linkage with existing regional and international organizations;
- Prosea is an international programme focusing on the documentation of information on plant resources of South-East Asia;
- Prosea consists of a Network Office in Bogor (Indonesia) coordinating 6 Country Offices in South-East Asia, and a Publication Office in Wageningen (the Netherlands).

Participating institutions

- Forest Research Institute of Malaysia (FRIM), Karung Berkunci 201, Jalan FRIM Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Sasana Widya Sarwono, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology and Biological Resources (IEBR), Nghia Do, 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 and Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific and Technological Research (TISTR), 196 Phahonyothin Road, Chatuchak, Bangkok 10900, Thailand;
- Wageningen Agricultural University (WAU), Costerweg 50, 6701 BH Wageningen, the Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and dissemination of reports and the research results.

Implementation

The programme period has been tentatively divided into 3 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–2000): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.

Documentation

A documentation system has been developed for information storage and retrieval called Prosea Data Bank. It consists of 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 Backhuys Publishers, Leiden, the Netherlands (formerly by Pudoc, Wageningen, the Netherlands). The handbook in green cover (paperback) is distributed in two price-classes: a low-price paperback, distributed by Prosea South-East Asia for all developing countries; a medium-price paperback, distributed by Backhuys Publishers, Leiden, the Netherlands, for developed countries (becoming available two years after publication of the hardbound edition). The bibliographies are distributed by Prosea South-East Asia.

The handbook

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In brief, Prosea is

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- committed to conservation of biodiversity;
- committed to rural development through diversification of resources and application of farmers' knowledge.

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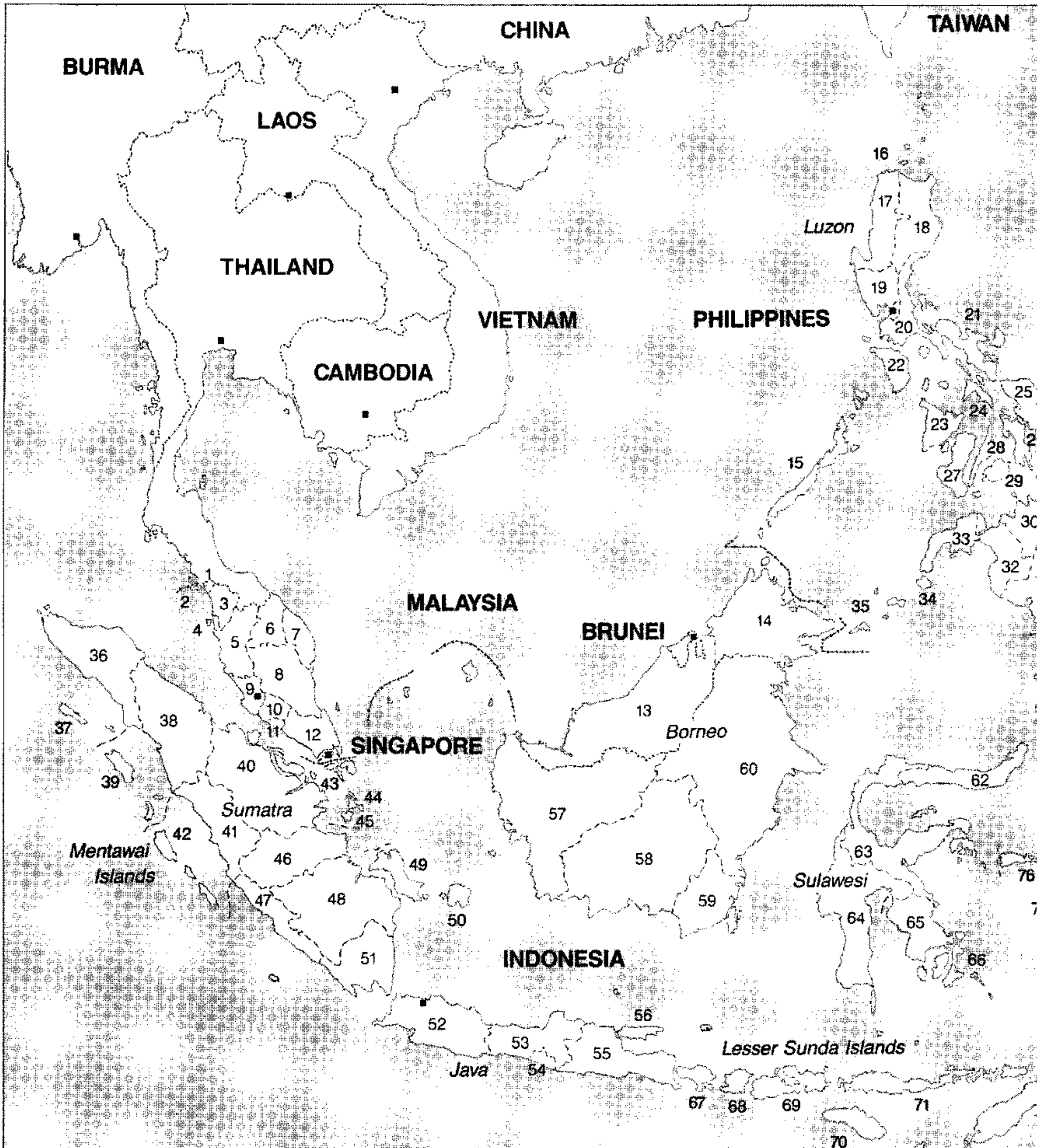
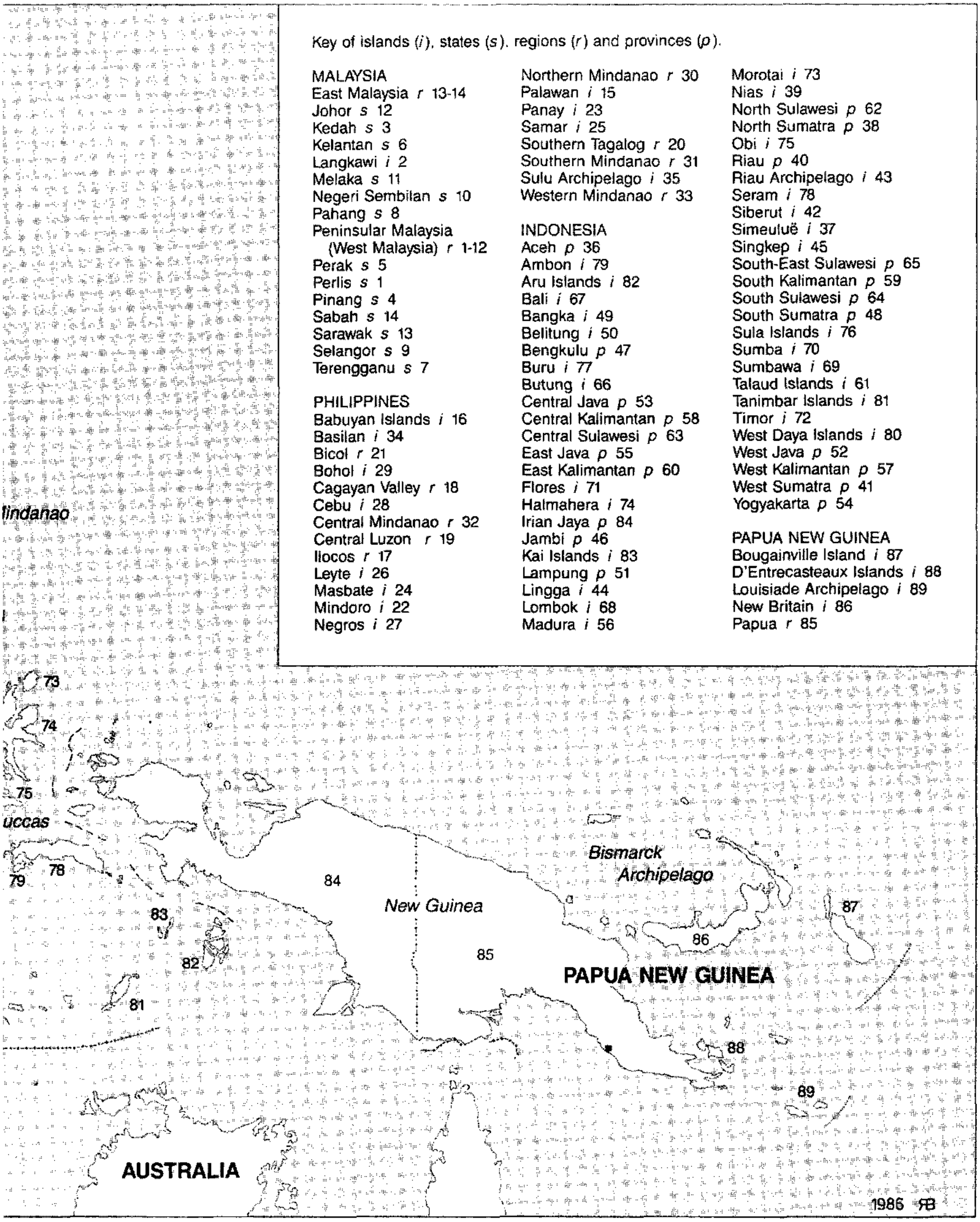


MAP OF SOUTH-EAST ASIA FOR PROSEA

Names of countries in capital letters and islands in lower case; numbers refer to the key.



Key of islands (*i*), states (*s*), regions (*r*) and provinces (*p*).

MALAYSIA
East Malaysia *r* 13-14
Johor *s* 12
Kedah *s* 3
Kelantan *s* 6
Langkawi *i* 2
Melaka *s* 11
Negeri Sembilan *s* 10
Pahang *s* 8
Peninsular Malaysia (West Malaysia) *r* 1-12
Perak *s* 5
Perlis *s* 1
Pinang *s* 4
Sabah *s* 14
Sarawak *s* 13
Selangor *s* 9
Terengganu *s* 7

PHILIPPINES
Babuyan Islands *i* 16
Basilan *i* 34
Bicol *r* 21
Bohol *i* 29
Cagayan Valley *r* 18
Cebu *i* 28
Central Mindanao *r* 32
Central Luzon *r* 19
Ilocos *r* 17
Leyte *i* 26
Masbate *i* 24
Mindoro *i* 22
Negros *i* 27
Northern Mindanao *r* 30
Palawan *i* 15
Panay *i* 23
Samar *i* 25
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East Kalimantan *p* 60
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Siberut *i* 42
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