

SEED LEAFLETS

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Norway's International
Climate and Forest Initiative
(NICFI)

Acacia auriculiformis Cunn. ex Benth.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Synonyms: *Acacia auriculaeformis* A. Cunn. ex Benth., *Racosperma auriculiforme* (A. Cunn. ex Benth.) Pedley.

Vernacular/common names: Northern black wattle (Australian trade name); coast wattle, ear pod wattle.

Distribution and habitat

Native to Australia, Papua New Guinea and Indonesia in hot humid and sub-humid lowlands with mean annual rainfall of 800-2500 mm and mean annual temperature of 20-30°C. Often found on river banks and in coastal areas.

It is cultivated widely in the tropics within an altitude range of 0-500 (-1000) masl, and even though frost does not occur in its natural range, it tolerates light frost. It is exceptionally tolerant to soil type in regard to fertility, salinity and pH. It can grow on acid mine spoils with pH 3 and on alkaline beach sands with pH 8-9. It does not tolerate shade or strong winds.

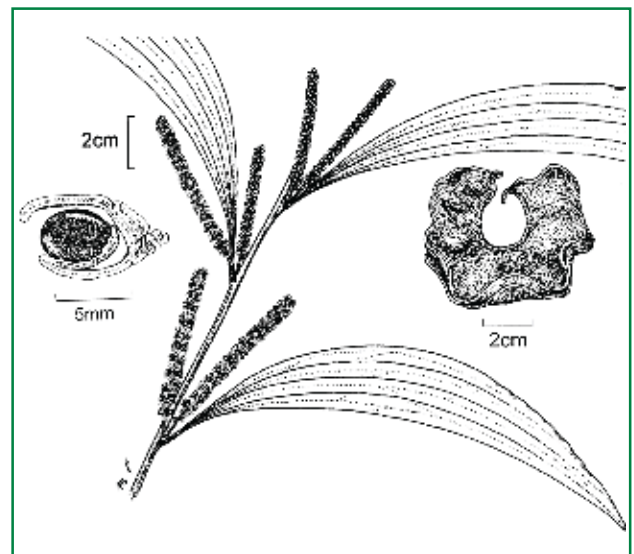
Isoenzyme analysis has revealed a marked genetic variation with 3 distinct groups corresponding to the geographic distribution in Papua New Guinea, Queensland and Northern Territory. Field trials show that provenances from Papua New Guinea have the highest production while those from Queensland have a high proportion of single stems. Those from the Northern Territory are inferior in both growth and form. The hybrid *A. auriculiformis* x *A. mangium* has shown desirable characteristics.

Uses

This species can grow under even the most difficult conditions in the tropics. The rapid early growth rate, ability to fix nitrogen, tolerance of infertile, acid, alkaline, saline or seasonally waterlogged soils and moderately dry seasons makes it very suitable for rehabilitation of degraded land. A valuable feature is the ability to compete with *Imperata cylindrica* reducing the grass to a sparse ground cover. The wood is excellent for firewood, charcoal, paper pulp and lighter construction work. Because of its spreading and competitive surface rooting habit it is not widely used in agroforestry systems but intercropping with peanut, rice, mung beans and kenaf has been successful.

Botanical description

A large shrub or medium-sized, evergreen tree, usually 8-20 m tall, on good sites up to 35 m. Bark grey or brown, longitudinally fissured. Leaves (phyllodes) 8-20 cm long, glabrous and curved, with 3 prominent nerves (four in *A. mangium*). Flowers bisexual, creamy yellow, scented, in up to 8.5 cm long spikes.



Seed with funicle, flowering branch and pod. Copyright: CSIRO, Forestry & Forest Products, Australian Tree Seed Centre.

Fruit and seed description

Fruit: flat, dehiscent, somewhat woody pod, 6.5 cm long, 1.5 cm wide, strongly curved and with undulate margins.

Seed: shiny black or brown, encircled by a long, red or yellow funicle. There are 55,000-75,000 seeds/kg.

Flowering and fruiting habit

The yellow flower spikes can be found on individual trees throughout the year but there is usually a distinct peak flowering season which may vary considerably with location.

Pollination is carried out by a wide range of insects. Seed is produced at an early age and normally in large quantities.

Phenology data:

Locality	Flowering	Fruiting
N. Territory	Apr-June	Aug-Oct
Queensland	Feb-May	Oct-Apr
Kuala Lumpur	Feb-May	Oct-Apr
Sabah	Feb-May	Oct-Apr
Java	Mar-June	
Thailand	Aug-Feb	
Vietnam	June-July	Nov-Mar

Harvest

Collection from the tree or from the ground. If collection is too early, it can be difficult to open the pods while late collection may result in loss of seeds.

Processing and handling

The pods are dried in the sun until they open. After extraction the funicle can be removed manually by rubbing the seed over a sieve.

Storage and viability

Seeds are orthodox and can be stored for several years in closed plastic bags. Moisture content for storage should be about 7%.

Dormancy and pretreatment

Pretreatment by scarification or immersion in boiling water for 1 min and left to soak for 24 hours.

Sowing and germination

Germination of 40-100% occurs after 6-15 days. Propagation by container plants, direct sowing or vegetatively by cuttings. Nursery techniques are described in Doran and Turnbull (1997).

Selected readings

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Forest tree form. Bensbach River, Balamuk, Western Provenance, Papua New Guinea. Photo: Maurice McDonald, CSIRO, Forestry & Forest Products, Australian Tree Seed Centre.

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Acacia mangium Willd.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Synonyms: *Rancosperma mangium* (Willd.) Pedley

Vernacular/common names: black wattle, hickory wattle, brown salwood (trade name).

Distribution and habitat

Native to northern Queensland in Australia, through Papua New Guinea into the Indonesian provinces of Irian Jaya and Maluku. A fast-growing, relatively short-lived (30-50 years) tree, adapted to a wide range of acidic (pH 4.5-6.5) soils in moist tropical lowlands.

It does not tolerate frost or shade. Grows better on fertile sites with good drainage but will tolerate soils of low fertility and impeded drainage. Young trees are susceptible to fire. Can become a weed under certain conditions.

Natural hybrids of *A. auriculiformis* and *A. mangium* have shown desirable characteristics.

Uses

A major plantation species in Asia where it is grown mainly for paper pulp. Other uses include fuelwood, construction and furniture wood, wattle timber, erosion control, shade and shelter. A valuable feature is the ability to compete with *Imperata cylindrica* reducing the grass to a sparse ground cover.

Botanical description

Evergreen tree, up to 30 m tall. The bole can be unbranched for more than half of the total tree height; it is sometimes fluted at the base and the diameter rarely exceeds 50 cm. Bark is rough and furrowed, either grey or brown. Small branches are winged. Leaves (phyllodes) large, up to 25 cm long, 3-10 cm broad, dark green with normally four main longitudinal nerves (three in *A. auriculiformis*); leaves on juvenile trees are compound. Flowers bisexual, white or creamy, in rather loose spikes up to 10 cm long, single or in pairs in the upper leaf corners.

Fruit and seed description

Fruit: dehiscent pod that is tightly coiled when ripe, slightly woody, 7-8 cm long, 3-5 mm wide.

Seed: black and shiny, elliptical, 3-5 x 2-3 mm, with a bright yellow or orange funicle folded beneath the seed. There are 66,000-120,000 seeds/kg.

Flowering and fruiting habit

Time of flowering differs throughout its natural and planted range. In Australia flowering occurs February-May, and seed matures October-December. In Indonesia mature fruits are available from July, in Papua New Guinea in late September.

As an exotic, the normal flowering cycle may be disrupted and flowering can occur throughout the year; however, a distinct peak is usually discernible. The peak is reported to be June-July in Peninsular Malaysia, January in Sabah, October-November in Taiwan and September in Thailand. In Tanzania mature fruits are harvested June-July. It flowers precociously, and viable seed can be harvested 24 months after planting. The species is generally outcrossing; and pollination is by insects.



1, Habit of young tree; 2, flowering twig; 3 pods. From: Plant resources of South-East Asia 5:2.

Harvest

Collection from the tree or from the ground.

Processing and handling

The pods should be processed as soon as possible after harvest. Pods and seeds should not be left long to dry in the sun, as temperatures over 43°C can reduce viability. Extraction with flailing thresher followed by winnowing as described in Doran et al. (1983) is suitable for this species. The funicle can be removed manually by rubbing the seed over a sieve.

Storage and viability

The seeds are orthodox and can retain viability for several years when stored in airtight containers in a dark, cool room. The recommended moisture content for storage is 5-7 %.

Dormancy and pretreatment

Mature seeds are pretreated by immersion in boiling water for 30 seconds followed by soaking in cold water for 24 hours; alternatively they can be manually scarified. Germination rate is high (75-90%) after suitable treatment.

Sowing and germination

Seeds can be sown in seedbeds, germination trays (wet towel method) or directly in containers. Awang and Taylor (1994) give a detailed description of nursery techniques. Vegetative propagation by cutting and tissue culture is very important for this species.

Selected readings

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Natural stand in Papua New Guinea. Photo: Maurice McDonald, CSIRO, Forestry & Forest Products, Australian Tree Seed Centre.

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Acacia mearnsii De Wild.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Synonyms: *A. mollissima* Willd., *A. decurrens* (Wendl.) Willd. var. *mollis* Lindl. *Rocosperma mearnsii*

Vernacular/common names: black wattle (standard trade name); acacia noir (Fr.); acacia negra (Sp.).

Distribution and habitat

A fast-growing, nitrogen-fixing tree adapted to a wide range of sites from the temperate and subtropical lowlands to tropical highlands.

It is native to Australia but grown world-wide. Optimal areas in the subtropics are above 400 m in altitude, 850-1200 mm rain/yr. and mean temperature above 16°C. In tropical areas it is best grown in highlands at 1500-2500 m altitude, 900-1600 mm rain/yr. and mean temperature of 12-18°C. Absolute minimum temperature of 5°C to avoid frost damage. Fairly tolerant to soil type but prefers moist, relatively deep light-textured and well-drained soils. Light-demanding and sensitive to fire.



1, Flowering branch; 2, pods. From: Plant resources of South-East Asia.

Uses

Produces high quality tannin, paper pulp, firewood and charcoal. Used for erosion control, windbreaks and soil improvement.

The use of tannin for production of waterproof wood adhesives is expanding. It is an efficient nitrogen-fixer with annual yields up to 250 kg/ha of fixed nitrogen, and it is also a good source of green manure. Unfortunately an aggressive coloniser that is becoming a weed in many places.

Botanical description

Tree or large shrub, 6-10 m tall, sometimes reaching 25 m and with a diameter up to 60 cm. The bark is brownish-black, hard and fissured. Young branches with hairs. No thorns. Leaves 8-12 cm long, fern like; 8-21 pinnae each with 16-70 pairs of small, olive green leaflets.

Inflorescence a globular head with 20-30 pale yellow-white flowers. The inflorescences are arranged in a much branched panicle.

Fruit and seed description

Fruit: pod with fine hairs, straight or almost so, often constricted between the seeds. Typically 7 seeds/fruit.

Seed: small, 3-5 mm long, black, smooth with a short cream-coloured aril. There are 65,000-90,000 seeds per kg.

Flowering and fruiting habit

Flowering begins when the trees are about 2 years old, but significant seed production does not start before the fifth or sixth year.

Flowering takes place from October to December in Australia, during September to October in Brazil and from late August to early October in South Africa. Mature seed is available for collection some 12-14 months after flowering.

Pollinated by insects, especially bees. *A. mearnsii* is regarded as an outcrossing species with partial self-compatibility. Estimates of out-crossing rates in this species are variable and range from 48 to 100%. It is common that many of the flowers are male only.

Harvest

The pods are dehiscent and seeds are dispersed when the pods open. When the seeds are mature, they change colour from white to black and the pod colour changes from green through yellow to brown. There is great variation within and between trees in regard to time of ripening.

Collection can take place when the pods have turned yellow. There are typically 2-3 weeks from the seeds are mature and until they are dispersed. Collection can be from the tree or from covers on the ground.

Processing and handling

Fresh pods have a high moisture content and gunny bags should be used for temporary storage. For the seed to afterripen, the pods are spread out on a cover in the shade until they turn brown. The pods are then left in the sun to dry until they open and the seed is released. To extract the seed, a flailing thresher is effective. After extraction the seed is dried directly in the sun, which may take several days.

Storage and viability

The seed is orthodox. When properly stored in airtight containers the seed can keep high viability for many years. Optimal moisture content for storage is 5-7 %.

Dormancy and pretreatment

The seeds have a hard seedcoat and requires pretreatment by immersion in boiling water for 1 min or 90°C for 3 min followed by soaking in cold water for 24 h.

Sowing and germination

The seeds can be sown directly in the field or in containers. Normally two seeds are sown and surplus seedlings transplanted to empty pots. Seedlings are ready for outplanting after about 4 months when they are 20 cm tall.

Inoculation with rhizobium bacteria may be necessary when it is grown outside of its natural range. For direct sowing in the field, the seed is sown in rows 1.8-2.7 m apart in well-cultivated and weed-free ground and later thinned until the spacing is appropriate.

Germination is typically 50-80%. Vegetative propagation is possible using 10-15cm cuttings with leaves. Mist spray, constant heat of 28°C, and mixtures of IBA and NAA appear essential to good rooting.

Selected readings

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Trees pollarded for shade in tea estates in India. Photo: Douglas Boland, CSIRO, Forestry & Forest Products.

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Acacia mellifera (Vahl) Benth.

Taxonomy and nomenclature

Family: Fabaceae (Leguminosae), Mimosioideae

Synonym: *Acacia detinens* Burch.; *Acacia senegal* ssp. *mellifera* (Vahl) Roberty; *Mimosa mellifera* Vahl.

Vernacular/Common names: Black thorn, hook thorn, wait-a-bit thorn (Engl.); kikwata (Swahili); bilel, lanen, laner (Somali); swartaak, swarthook (Afrikaans); kedad, kitir, kitr (Arabic).

Distribution and habitat

Acacia mellifera has two separate distribution areas in Africa: Its largest distribution is in the Sahelian east Africa extending into the Arabic peninsula; another distribution area is dry southern Africa in Namibia and Botswana.

The species commonly occurs in dry savannah sites in western, eastern and southern Africa with mean annual rainfall 250-650 mm; sometimes extending up to 1500 masl on rocky hillsides. It thrives on a variety of soil types from sandy to heavy clay including vertisols. It can grow in mixed stands with e.g. *Commiphora*, *Salvadora*, *Balanites aegyptiaca* and other acacias. It is a strong regenerator both by seed and root suckers and sometimes form large stands of 2-3 m high, dense, impenetrable thickets. Absence of grass fires tends to promote regeneration by *A. mellifera*.

Uses

Acacia mellifera is a multipurpose tree species of the dry and harsh environment. Wood is small and only applicable for small construction purposes e.g. native huts and fuel. Foliage and pods are eagerly browsed by camels and goats. Flowers are a good source of honey for bees. The plant has alleged medical properties as the bark is used for stomach-ache, sterility, pneumonia, malaria and syphilis.

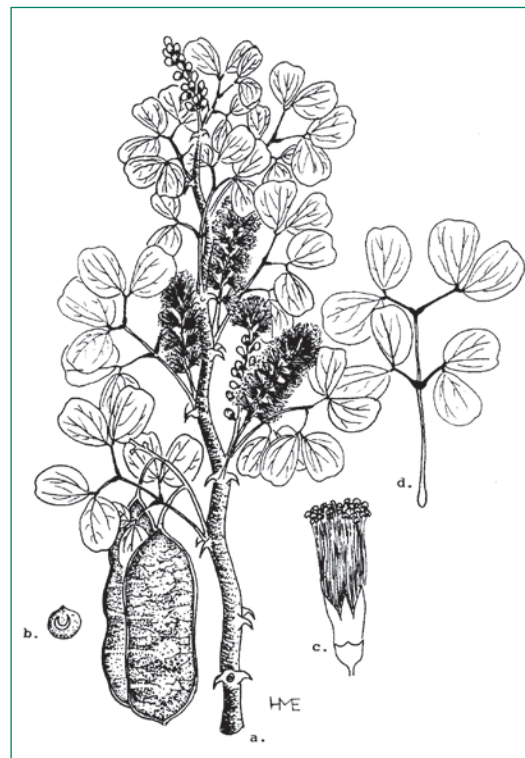
The plant has a shallow and aggressive root system, limiting its use in farms with crops.

Botanical description

Acacia mellifera is a low branched tree or shrub, rarely more than 5-6 m. The bark is smooth and light brown, turning blackish with age. Thorns in pairs, small, black, sharp and hooked.

Compound leaves with two pinnae, each with a single pair of leaflets. Leaflets elliptic 0.6-2 cm long and 0.6-1.2 cm wide, glabrous.

Flowerbuds reddish, flowers white or cream coloured in elongated spikes, up to 3.5 cm long. Individual flowers small with 1/2-1 1/2 mm pedicel, 1 mm calyx and 2 1/2-3 1/2 mm corolla.



A. mellifera flowering and fruiting branch. From: El Amin 1990.

Fruit and Seed description

Fruit: The fruit is a dehiscent pod containing 2-3-seeds. It is papery and reticulate, straw-coloured, flat, elongated, 2 1/2-5 1/2 cm long, 18-23 mm wide with pointed apex.

Seed: Seeds are hard-coated. The form is circular to lenticular, 7-9 mm long, 5-6 mm wide, compressed, 1.5-1.8 mm thick. Light brown-olive green, smooth. Pleurogram horse-shoe shaped. Funicle redbrown. 1,000 seed weight, 42-47g; there are approximately 20 000 seeds/kg

Flowering and fruiting habit

Reproduction may start after 3 years. Flowering takes place in the dry season, usually before leaf flush, - in bimodal climates two flowering events may take place. Development from flowering to fruit takes about 3-4 months.

Harvest

Harvest by picking up pods under the trees or beating or shaking fruit bearing branches. Harvest time is not critical unless seeds are strongly attached by bruchids or pods are removed by browsers.

Processing and handling

Pods will open upon drying and seeds can be released with gentle mechanical impact on the pods. Pods are light and papery. Most of them can be removed by hand. Small pieces of pod and other light debris can be removed by winnowing or other air blowing method.

Storage and viability

The seed exhibit orthodox storage behaviour, and dry seeds can be stored for several years even at ambient temperature. Bruchid infested seed can be damaged during storage but the insects rarely re-infest new seed in storage. Viability can be maintained for several years in hermetic storage at 10°C with 4.5-9% mc..

Dormancy and pretreatment

Seeds exhibit moderate physical dormancy, with about 10% fresh seed germinating w/o pretreatment. Bulk pretreatment by submerging seeds in boiling water and letting the seeds cool and imbibe in water overnight. Alternative is 5-15 minutes in concentrated sulphuric acid followed by careful rinsing.

Sowing and germination

Germination is epigeal. Seeds may be sown in pots or seed beds for later transplanting. Germination is usually quick with paracotyledons unfolding after 4-5 days



Branchlet with flowers. Photo: James Wolstencroft

Selected readings

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Acacia nilotica(L.) Del.

Taxonomy and nomenclature

Family: Fabaceae (Leguminosae), Mimosoideae

Synonym: *Acacia subalata*, *A. scorpioides*, *A. arabica*, *Mimosa arabica*, *M. nilotica*.

Vernacular/Common names: Tuwer (Somali), Nunga, Mgunga (Swahili), Babul (int. trade name).

Subspecies: 9 subspecies / varieties are recognised, the most important are subsp. *adstringens*; subsp. *kraussiana*; subsp. *nilotica*; subsp. *tomentosa*.

Distribution and habitat

Acacia nilotica is found throughout sub-Saharan Africa from west to east extending into southern Africa as far as Botswana and south-western Asia with common occurrence in Iran, Iraq, Pakistan and dry zone India. It has been introduced into cultivation in both Australia and southern America and Mexico.

Subsp. *nilotica* occurs grows in Sahel from Senegal over Sudan and the Arabian peninsula to India. Subsp. *kraussiana* is a more southern species.



Natural distribution range (countries) of *Acacia nilotica*.

The species occurs from 0-1340 masl with 200-1270 mm mean annual rainfall. It is light demanding, drought resistant and tolerate seasonal waterlogging. Its natural growth niche is particularly along rivers and streams, and near ponds. However, it also occurs abundantly away from water in dry areas.

Uses

Acacia nilotica is one of the most important multipurpose tree species of dryland Africa and South Asia. The wood is hard and used for general construction purposes and implements. It is fairly termite resistant. The wood yields an excellent fuelwood. Flowers are attracting bees and make a good base for apiculture. Pods are nutritious and make a high quality fodder for livestock especially during the dry season. The plant

has alleged medical properties as the bark is used for treatment of cough, cancers, tumours of the ear, intestine pains and the roots to treat impotence.

Botanical description

Acacia nilotica is a small tree growing to 12-15 meters with a broad rounded (rarely umbrella shaped) crown. On poorer soils it mainly grows as a shrub.

Bark dark brown, cracking, underbark rust red. Young branchlets light brown, hairy, covered with lenticels. Spines (thorns) in pairs, straight, thin, sharp, up to 10 cm long. Leaves bipinnately compound with 2-11 pairs of pinnae, 7-25 pairs of leaflets. Flowers in bright yellow globose heads, 1.2 – 1.5 cm in diameter.



Fruit and Seed description

Fruit: The fruit is an indehiscent pod, which shows large variation between different sub-species in terms of size, form and constriction between the seed. Subsp. *tomentosa* is deeply constricted between the seeds, while subsp. *nilotica* and subsp. *subalata* and *kraussiana* has a leathery appearance and not or very little constricted between the seeds. There are 8-12 seeds per pod, average approx. 11.

Seed: Seeds are extremely hard-coated. They are oblong, 6½-11 mm long, 12-14 mm wide and 3½-4 cm thick, dark brown to blackish brown. Pleurogram distinct, oblong, creamy white. Seed weight variable; 1000 seed weight 100 – 250 g, equivalent to 4000 to 10000 seeds per kg

Flowering and fruiting habit

Flowers are nectar-less. Most flowers are functionally male with a few hermaphrodites and are mainly bee-pollinated. Temperature affects flowering and fruiting. In the Sudan *A. nilotica* flowers irregularly but generally between June and September and seed fall takes place from March to May. In Australia trees flower from March to June and green pods are produced within four months but ripe pods fall from November to February.

Harvest

Harvest by picking up pods under the trees or beating or shaking fruit bearing branches. Harvest time is not critical unless seeds are strongly attached by bruchids or pods are removed by browsers.

Processing and handling

Seeds are extracted from dried pods by pounding, threshing or other type of mechanical disintegration of pods. Different sub-species exhibit great variance in terms of ease of extraction. Seeds are very hard and are rarely damaged by mechanical extraction.

After disintegration of pods, seeds are extracted by a combination of sifting and winnowing.

Alternatively pods can be fed to goats and seeds, most of which pass undamaged, and extracted from the dung.

Storage and viability

The seeds exhibit orthodox storage behaviour, and dry seeds can be stored for several years even at ambient temperature. Bruchid infested seed can be damaged during storage but the insects rarely re-infest new seed in storage.



Dormancy and pretreatment

Seeds exhibit very strong physical dormancy and very few seeds will germinate without pretreatment. Manual pre-treatment by e.g. hot wire burning, filing or nicking is most effective. Dipping into boiling water may be used for non-stored seed but has very small effect on dry seed. Bulk treatment with concentrated sulphuric acid for 10-20 minutes is most efficient. There is no other known dormancy type.

Sowing and germination

Germination is epigeal. Seeds may be sown in pots or seed beds for later transplanting. Germination is usually fast with paracotyledons unfolding after 4-5 days.

Selected readings

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Acacia senegal (L.) Willd.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Varieties: *Acacia senegal* var. *rostrata* Brenan, *A. senegal* var. *kerensis* Schweinf., *A. senegal* var. *leiorhachis* Brenan, *A. senegal* var. *senegal*.

Synonyms: *Acacia circummarginata* Chiov., *A. oxyosprion* Chiov., *A. rostrata* Sim., *A. rupestris* Stocks ex Boiss., *A. spinosa* Marloth & Engl., *A. verec* Guill. & Perr., *A. volkii* Suesseng., *Mimosa senegal* L., *M. senegalensis* Houtt.

Vernacular/common names: three-thorned acacia, gum arabic tree (Eng.); gommier blanc, verec (Fr.); gummibaum (Ger.); goma arábica (Sp.).

Distribution and habitat

Widespread in tropical Africa from Senegal in the west to Ethiopia and Somalia in the north-east, southwards to Natal; also extends into India.

It is most common in areas with 300-400 mm rain/year but can grow in areas with as little as 100 mm, and a dry period of 8-11 months. Altitude range of 100-1700 m. Very drought-resistant and tolerant of high daily temperatures but sensitive to frost. Prefers well-drained, sandy soils but can grow on slightly loamy sands.



1, Foliage and inflorescence of *A. senegal* var. *rostrata*; 2 and 3, Seed and pod from same. 4, Pod and seed of *A. senegal* var. *leiorhachis*. From: J.H. Ross 1979. A conspectus of the African *Acacia* species.

Uses

A pioneer, nitrogen-fixing tree that is mainly grown for production of gum arabic but also used for fuelwood, fodder, rope, dune stabilisation and soil improvement.

Leaves and pods are browsed by sheep, goats, camels, impala, and giraffe. The leaves contain 10%-13% digestible protein and 0.12%-0.15% phosphorus, while the pods contain 15% digestible protein and 0.12%-0.14% phosphorus. Dried seeds are also used for human consumption.

It is highly suitable in agroforestry systems in combination with watermelon, millet, forage grasses and others. In Sudan it is grown in "gum gardens" for gum production as well as to restore soil fertility.

Botanical description

Variable species. Deciduous tree or shrub up to 15 m tall but usually less; umbrella-shaped crown; bark variable. Short, black prickles, normally in threes, the central curved downwards.

Leaves small, 1-10 cm long, 3-8 pairs of pinnae, each with 7-25 pairs of leaflets. Flowers white and fragrant, in 3-12 cm long spikes, 2-3 together in the leaf axils.

Fruit and seed description

Fruit: yellow to brown, papery, dehiscent pod, 2-19 cm long, 1-3.5 cm wide, flat and thin with either rounded or pointed end. There are 1-8 seeds per pod. **Seed:** round and flat, 8-12 mm in diameter, olive brown. There are 10,000-30,000 seeds/kg.

Flowering and fruiting habit

In general, flowering begins just before or at the beginning of the rainy season when the leaves emerge and the seeds mature in the dry season. In areas with more than one variety there can be large variations in flowering and fruiting time. Pollination is probably by insects.

Harvest

Before they open, the pods are harvested by shaking the branches over a tarpaulin on the ground. To minimise insect attack the pods are often collected early when they are still green.

Processing and handling

After collection the pods are dried in the sun until they open and the seeds are extracted by beating the pods in a sack before cleaning.

Storage and viability

The seeds are orthodox and store well in a cool, dry, insect-free place. At 10°C and moisture content of 5-7%, viability can be maintained for several years.

Dormancy and pretreatment

Unlike other acacias, the seed coat of *A. senegal* is not impermeable to water even after storage, and scarification is normally not necessary. Germination is improved if the seeds are soaked in cold water for 12-24 hours before sowing.

Sowing and germination

As a typical pioneer species it is easy to propagate from seed and germination is fast and uniform.

The seeds are sown in polybags or in 30 cm long tubes, 2-4 seeds per tube, thinned to one seedling after 4-6 weeks. Frequent root pruning is necessary in container plants as the tap root is fast growing. Planting out can take place after 4-6 months. Weeding is necessary the first two years.

For intercropping, 10 x 10 m spacing is suitable. For gum production, plants can be raised in the nursery or in direct seeded plantations spaced at about 4 x 4 m.

Phytosanitary problems

The seed is very susceptible to insect attacks. The buffalo treehopper (*Stictocephala bupalus*) may destroy seed crops. Larval stage of *Coleoptera* (bruchids), *Lepidoptera*, and *Hymenoptera* damage the seed.

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Habit of fruiting tree of *A. senegal* var. *senegal*, growing at Arba Nosa ranch, Ethiopian highlands. Photo: Chris Fagg, OFI.

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Acacia seyal Del.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Synonyms: *A. stenocarpa* A. Rich.; *A. hockii* De Wild.

Vernacular/common names: thal, white thorn, whistling thorn (Eng.); soffá (Arabic); epineux, seyal (French); bulki (Fula); fullai (Somali); dushe kerafi (Hausa); mgunga (Swahili).

Two varieties are recognised, var. *seyal* and var. *fistula*.

Distribution and habitat

Widespread in the semi-arid zone of tropical Africa from Senegal eastwards to Somalia and the Red Sea, and from the Nile valley south to Zambia. The range of the two varieties is quite distinct, var. *seyal* extending north- and westwards from central Sudan, var. *fistula* south of latitude 10°S.

Normally found in areas with 500-1200 mm rain/yr. and a distinct dry season. The upper elevation limit is about 2000 m. Lowest temperature within its natural range is 5-10°C occasionally below 5°C at high altitudes but the pattern of distribution indicates a frost-sensitive species. Grows well on deep, heavy soils with high pH (6-8) and especially var. *fistula* is tolerant to waterlogging.

Uses

Nitrogen-fixing species that is excellent for silvo-pastoral systems. The bark provides valuable forage for cattle and game and leaves and pods are used for fodder. The dry matter net energy contents of both varieties are high, 6-8 MJ kg⁻¹ (foliage) and 4-7 MJ kg⁻¹ (fruits) and the digestible protein content is 8-12% in leaves and 13-15% in fruits.

Also used for gum production (gum talha) though not as valuable as gum arabic.

Especially var. *seyal* is an important source of fuelwood and charcoal, stands managed on a 10-15 year rotation yield 10-35 m³ fuelwood per ha.

Botanical description

Variable species. Tree up to 9 m tall, sometimes reaching 17 m, with a flattened, spreading crown. The slash is bright red, exuding yellowish gum. In var. *fistula* the powdery bark is normally white or greenish-yellow while var. *seyal* has reddish bark.

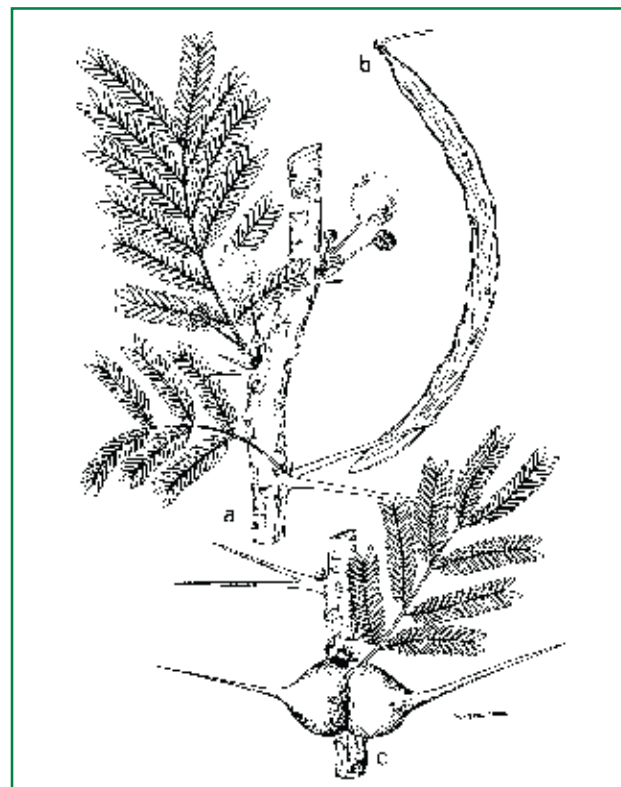
Both varieties have straight thorns in pairs, up to 8 cm long but only var. *fistula* bears whistling thorns (ant-galls) that are fused at the base.

Leaves are bipinnate with 2-12 pairs of pinnae each with 10-22 pairs of leaflets. Flowers bright yellow, in large round heads, 2-3 flower heads together in the leaf axils.

Fruit and seed description

Fruit: the dehiscent pods are light brown, slightly curved, 7-22 cm long, with fine longitudinal veins and slightly constricted between the seeds. There are 6-10 seeds/pod.

Seed: light brown, 6-9 mm long, 4-5 mm wide. There are 20,000-25,000 seeds/kg.



A. seyal var. *seyal*. a, flowering branchlet; b, pod. *A. seyal* var. *fistula*. c, sterile branchlet showing "ant-galls". Illustration from Ross 1977.

Flowering and fruiting habit

Flowering is concentrated in the middle of the dry season and ripe fruits are available about 4 months later.

Harvest

Full-sized pods are harvested from the tree before they open.

Processing and handling

The pods are dried in the sun until they open and the seeds are released.

Storage and viability

Seeds are orthodox and can be stored for several years if they are well dried and kept cool and free of insects. Moisture content for storage should be 4,5-9%.

Dormancy and pretreatment

There are various reports on the need for pretreatment, possibly due to differences in provenance. Most agree, however, that pretreatment accelerates the germination rate. The most common method is scarification.

Sowing and germination

Germination is rather slow, normally about 30% in 7 days. The seeds can be pregerminated on moist filter paper to allow rapid identification of viable, non-dormant seed. The germinated seeds are transferred to containers filled with a silt-rich medium. Seedlings require shade until the second leaf expands and watering at intervals of 1-3 days as necessary to keep the medium moist but not waterlogged. Direct seeding in prepared planting spots is practised with success in Sudan; at early stages of development *A. seyal* was capable of competing with weeds.

Nodulation occurs in natural populations. In artificial regeneration it has been achieved by pelleting seed with culture of bacterial isolates, sowing into an infected medium or germinating in unsterilised soil. Uninfected seedlings have been inoculated successfully by treatment with a suspension of a symbiont. *Rhizobium* strains from *A. mellifera* and *A. senegal* and *Bradyrhizobium* from the latter have proved to be effective symbionts.

Phytosanitary problems

Over 40 species of insects are reported associated with *A. seyal*. These include 10 species of bruchid beetles, which may damage large proportions of stored seeds.

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Acacia seyal with green bark. Ethiopia. Photo: Henrik Keiding, DFSC

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Acacia tortilis (Forssk.) Hayne

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae) Subspecies: *A. tortilis* subsp. *heteracantha* (Burch.) Brenan, *A. tortilis* subsp. *raddiana* (Savi) Brenan, *A. tortilis* subsp. *spirocarpa* (A. Rich.) Brenan, *A. tortilis* subsp. *tortilis*

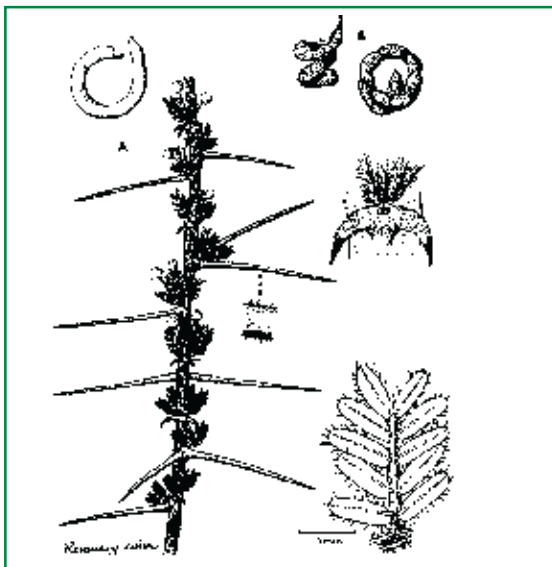
Synonyms: *Acacia fasciculata* Guill. & Perr., *A. heteracantha* Burch., *A. litakunensis* Burch., *A. maras* Engl., *A. raddiana* Savi, *A. spirocarpa* A. Rich., *A. spirocarpoides* Engl., *Mimosa tortilis* Forssk.

Vernacular/common names: Apple ring acacia, umbrella thorn.

Distribution and habitat

Widespread throughout the savannah and dry zones of Africa, from Senegal to Somalia and south to South Africa; in Asia in Israel, Jordan and southern Arabia to Iran. Subsp. *raddiana* has successfully been introduced to India from Israel.

A very drought-resistant species that grows in areas with as little as 40 mm rain/year and with temperatures reaching up to 50°C. In the countries that fringe the Sahara it is often the species that extends furthest into the desert. It is found growing from below sea level and up to 2000 m altitude and tolerates light night frost. It favours alkaline soils and avoids waterlogged sites, but apart from that it will grow on a wide range of sites.



A, subsp. *raddiana*; B, subsp. *spirocarpa*. From: *Acacias of Kenya*.

Uses

A slow-growing species but grows relatively fast on dry soils.

It is an important fodder tree in many arid areas. Pods and leaves have a good level of digestible protein (mean = 12%) and energy 6.1 MJ/kg dry matter, as well as being rich in minerals. Seeds are high in crude protein (38%) and phosphorus, an element usually scarce in grasslands.

The pods require milling to increase digestion in cattle. Over 90% of the flowers abort and drop from the trees, providing an additional important forage. The wood is excellent for fuelwood production and the tree resprouts vigorously when coppiced. Although used for a number of purposes, the timber is neither strong nor durable.

Botanical description

A very variable species. It can be multi-stemmed shrubs (ssp. *tortilis*), or trees up to 20 m tall with rounded (ssp. *raddiana*) or flat-topped (ssp. *heteracantha* and *spirocarpa*) crowns.

Bark is grey-brown-black, rough and fissured. The spines are in pairs, some short and hooked up to 5 mm long, mixed with long straight slender spines up to 10 cm long. The presence of these two types of thorns distinguishes *A. tortilis* from other African acacias.

Leaves are smooth to densely pubescent, 1-7 cm long, with 2-14 pinnae each with 6-22 pairs of leaflets. Flowers white or pale yellowish-white, fragrant, in round heads, solitary or in fascicles.

Fruit and seed description

Fruit: a contorted or spirally twisted pod, yellow-brown, 5-15 cm long, with longitudinal veins and slightly constricted between the seeds. There are 5-18 seeds/pod. Semi-dehiscent, i.e. the ripe pods open but remain on the tree without releasing the seed.

Seed: elliptic, slightly compressed, 6 x 35 mm, olive green to red brown, smooth. The surface is darker inside the horseshoe-shaped pleurogram. There are 10,000-50,000 seeds/kg depending on subspecies.

Flowering and fruiting habit

Flowering is prolific with up to 400 flowers/meter twig and seed setting is normally high. The time from flowering to fruit maturity can be three to four months or more, being timed towards the end of the dry season. Fruit

drop can be spread over a number of months. Some pods may be retained in the dense thorny crown for months after maturity.

Locality	Flowering
subspecies <i>spirocarpa</i>	
Zambia	Nov-Dec
Mozambique	Jan-Feb
Malawi	Jan-Feb
Zimbabwe	Mar-Apr
Namibia	Mar-Apr
East Africa	Jan-Mar and Aug-Dec
subspecies <i>raddiana</i>	
East Africa	Jan-Feb and Sep-Oct
West Africa	Sep-Nov
India	May-June
subspecies <i>tortilis</i>	
East Africa	Apr, Aug and Nov
subspecies <i>heteracantha</i>	
southern Africa	Nov-Feb

Harvest

The seeds are mature when the pods change colour from green to yellow/light brown. To avoid infestation by insects, the pods should be harvested from the tree by shaking them down from the canopy on to tarpaulins. Pods that have been lying on the ground for some time are often infested. It is possible to afterripen seed extracted from pods that still have patches of green.

Processing and handling

The pods are dried in the sun and extracted by pounding the pods in a mortar or a sack or with a flailing thresher. After threshing, the material should be sieved and cleaned by winnowing or in an air screen cleaner.

Storage and viability

The seeds are orthodox and stores well in airtight containers at 0-5°C at 5-7% moisture content. Tests have shown germination of 77-98% after 7-9 years' storage at 4°C and elevated CO₂ concentrations.

Dormancy and pre-treatment

The seeds are hard coated and must be pretreated to germinate well. Boiling water is poured over the seeds before they are soaked in water for 24 hours. Scarification with 50% concentrated sulphuric acid for 40-50 minutes followed by washing in cold running water and then drying in the shade overnight is an alternative method.

Seeds of various dimensions have varying scarification requirements.

Sowing and germination

The seeds are sown in seedbeds, followed by pricking into pots. Young plants need protection from browsing for at least 3 years. Trees should be planted at wide spacing. Early growth is slow.

Phytosanitary problems

Infestation of seeds by insects is a major problem.

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Habit of subsp. *spirocarpa* growing at 2000 metres on the scarp of the Cherangani Hills, northern Kenya. Photo: Chris Fagg, OFI.

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Adansonia digitata L.

Taxonomy and nomenclature

Family: Bombacaceae

Synonyms: *Adansonia bahobab* L., *A. integrifolia* Raf., *A. situla* (Lour.) Spreng., *A. somalensis* Chiov., *A. sphaerocarpa* A. Chev., *A. sulcata* A. Chev., *A. digitata* L. var *congolensis* A. Chev, *Baobabus digitata* (L.) Kuntze, *Ophelus sitularius* Lour.

Vernacular/common names: baobab tree, monkey bread tree, upside-down tree. Local names include: mbuyu (Swahili), mwamba (Kamba), olimisiera (Maasai), toega (Mooré), Sira (Bambara), mramba (Kipare), isimuhu (Zulu).

Distribution and habitat

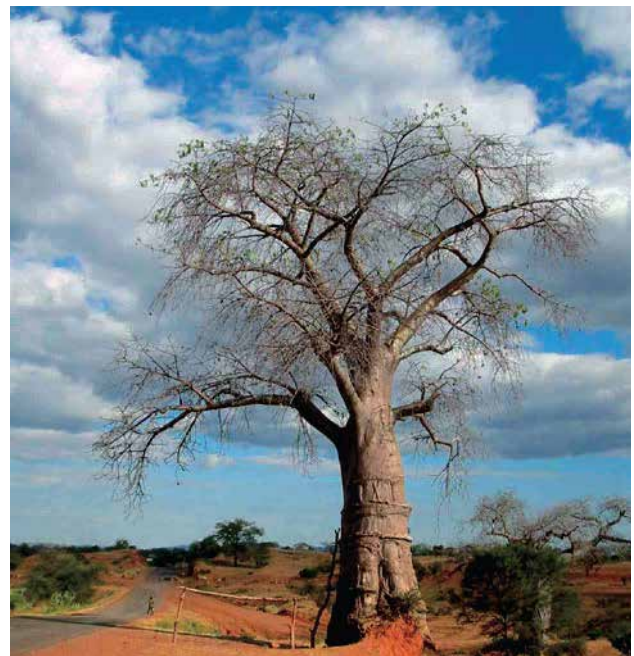
Distributed throughout Tropical and Sub-Saharan Africa, from Senegal to Sudan, eastern Africa, from Ethiopia to Mozambique and Natal. It is also found in Madagascar and has been introduced to Tropical America. It is usually located at low altitudes (up to 1000m), with mean annual rainfall of 100-1000mm, and a mean annual temperature of 20-30 C. However, it does not grow at high altitudes, or in moist tropical forests. It occurs on well drained soils of varying quality and is often left standing when land is cleared for cultivation. Bush burning in the dry season, grazing and seed diseases limit the number of trees. Damage to mature trees is often caused by elephants and mortality rates vary from 1 to 4% per year. Unfortunately, the population is declining and there is very low regeneration in its natural environment probably because of poor seed germination in some places and livestock, which readily eats the young trees. It is largely protected as a socio-cultural tree.

Uses

The baobab is an important indigenous fruit tree species, the white pulp is rich in vitamin C and used for making juice. The roasted seeds are very nutritious, rich in proteins and fats and this socio-economically important species is essential in the local diet. Fibres from the inner bark are long (90-120cm) and used to make rugs, mats, rope etc. The leaves, shoots and fruits are used as fodder. Most parts of the tree are used medicinally for a variety of illnesses. The wood is light (210-320kg/m³) and easily attacked by fungi. It has no commercial value as a timber, is unsuitable as fuelwood, but used for canoes and fishing floats.

Botanical description

Deciduous tree, usually not more than 20m tall, with a hugely swollen trunk of 3-10m (up to 28m on very old individuals) in diameter. It is one of the longest living trees in the world (3000 years). Bark is smooth, folded, reddish-brown or greyish brown. Primary branches stout. Leaves are compound with 3-9 leaflets, each 5-15cm long. Flowers are large, white, solitary in leaf axils.



Baobab tree. Road to Kariba border, Zambia.
Photo: C. Rønne

Fruit and seed description

Fruit: the mature indehiscent fruits, which hang on long stalks, are yellow-brown in colour, cylindrical in shape, slightly tapered at each end and up to 13 by 35cm. The fruit can be very variable and irregular in shape and has a hard woody shell covered in yellow-grey hairs. The pericarp is 8-10mm thick, enclosing the dry pulp. The fruits are persistent on the tree. Each fruit contains over 100 seeds, within its pulp.

Seed: the dark brown, angular, oval seeds are c. 1.3 by 0.9cm, and are contained within the fruit's whitish-pink, dry, acidic pulp. The seeds are smooth and laterally flattened. The seed coat is hard. There are typically 1700-2500 seeds per kg. Seeds have an oil content of c. 14%.

Flowering and fruiting habit

Flowering primarily occurs before the beginning of the rainy season. Some trees may be in flower at other times, except during the height of the dry season. The trees typically begin to flower when they are 8 to 23 years old. The pungently fragrant, white waxy flowers are large (up to 20cm in diameter) and showy. They open fully soon after sunset and stay open until morning, and are pollinated mainly by bats, but possibly also by wind and insects. Each flower wilts and falls within 24 hours of opening. The fruits mature 5-8 months after pollination and an average mature tree produces 200kg of fruit a year. When fruits fall to the ground termites enter and release the seeds. Monkeys, baboons, elephants, birds and rodents help to disperse the seeds.

Harvest

When the fruits seem dry and hollow they are mature. Fruits can be collected from the crown of standing trees by using a hook to cut the hanging fruits or by climbing into the crown. It is not recommended to collect from the ground. 3-8kg of fruit are required to obtain 1kg of seed.

Processing and handling

Dry fruits are collected and seeds are extracted by hitting the fruit on a hard surface in order to break it. The mixture of seeds and pulp is then soaked in water for up to 6 hours to remove the pulp by gentle squashing and floating in water. Floatation also separates dead seeds, with those that float being discarded; this is in general about a third of the total. The seeds can then be dried in the sun for 2 days.



Baobab seed. Photo: M. Sacandé

Storage and viability

The seed of this species displays orthodox seed storage behaviour. Dry seeds can be stored for up to 4 years at room temperature, without significant loss in viability. Seeds stored at c. 8% moisture content in a cool room (4°C) at CNSF for 15 years, germinated 94% at 25°C. The species has been stored at the MSB since 1991.

Dormancy and pretreatment

The seeds are known to remain dormant in the soil for several months. The limiting factor in germination is mainly the seed coats' impermeability to water. For optimum germination the seeds are scarified, e.g. with a hot wire, sulphuric acid (c. 1 hour), or soaked in boiling water for 5-7 min. and left to cool overnight. The seeds that swell should then be planted and the remaining seeds re-immersed, until they also swell. If properly pretreated, baobab seed normally has a high germination rate.

Sowing and germination

Seeds can be sown in beds or containers. Under optimum conditions they germinate in 15-40 days. Germination is epigeal, the seed coat cracking and the radicle protruding from the scar end. Seedlings should be protected from livestock (as the leaves are very palatable) and fire until they are well established.

When seedlings emerge it is best to shade them for 8 days, provide half shade for 4-7 days and then expose to full sun. Seedlings need to be 3-4 months old, reaching a height of 40-50cm, before transplanting.

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Albizia lebbek (L.) Benth.

Taxonomy and nomenclature

Family: Fabaceae - Mimosoideae

Synonyms: *Acacia lebbek* (L.) Willd., *Mimosa lebbek* L., *Mimosa sirissa* Roxb.

Vernacular/common names: East Indian walnut, Indian siris, woman's tongue, rattle pod, kokko (trade name).

Distribution and habitat

Indigenous to South-East Asia and Australia. It has been widely cultivated and is now pantropical. It grows well in areas with 600-2500 mm rain/year but tolerates as little as 300 mm. The altitudinal range is 0-1800 m and mean annual temperature 20-35°C.

Grows well on fertile, well-drained loamy soils but poorly on heavy clays. It tolerates acidity, alkalinity, heavy and eroded soils, and waterlogged soils. It is nitrogen-fixing, tolerant to drought and older trees can survive grass fires and intense night frost. While fire and frost will kill off aboveground growth of young trees, new growth will normally follow.

Uses

Albizia lebbek is one of the most promising fodder trees for semi-arid regions. It has leaves during a large part of the rainy season and digestibility of the twigs is considerably higher than that of most fodder trees. The concentration of crude protein is about 20% for green leaves, 13% for leaf litter and 10% for twigs. *In vitro* digestibility is about 45% for mature leaves, 70% for young leaves and 40% for twigs. Leaves, flowers and pods fall to the ground gradually during the dry season and can be browsed on the ground.

It is an excellent fuelwood and charcoal species and the wood is suitable for construction, furniture and veneer. The shallow root system makes it a good soil binder and recommendable for soil conservation and erosion control.

Botanical description

Deciduous tree, 15-20 m tall sometimes up to 30 m. Bark grey, corky, fissured and somewhat flaky. Leaves compound, bipinnate with 2-4 pairs of pinnae each with 2-11 leaflets. Flowers in large heads, 5-7.5 cm wide; each flower green or creamy white, fragrant, with many 1.5-2 cm long stamens.

Fruit and seed description

Fruit: pods are pale straw to light brown at maturity, 15-25 cm long, 3-5 cm wide, papery to leathery, flat and not raised or constricted between the seeds. The pods are indehiscent.

Seed: brown, flat, 8-10 x 6-7 mm. The 6-12 seeds are placed transversely in the pod. There are 7,000-12,000 seeds per kg.



1, Flowering branch; 2, flower; 3, fruit. From: Plant Resources of South-East Asia. No 5:3.

Flowering and fruiting habit

The growth pattern follows the seasonal changes. It stops growing early in the dry season, loses the leaves 2-3 months later and remains leafless for 1-2 months only. Towards the end of the dry season growth continues and flowering begins. Flowering and seed setting occur in the wet season and unless the trees have been frequently coppiced, they will produce large amounts of seed every year. Mature pods remain on the tree for 3-4 months.

Within its natural area of distribution flowering occurs September-October and pods mature in May-July in the beginning of the dry season. In India flowering is in March-May, fruits mature in August-October. In Sudan it flowers March-May and fruits May-August. In Tanzania ripe pods can be found July-December with a peak in August-October. Flowers are pollinated by insects.

Harvest

The pods are mature when they have turned light yellow and should be harvested when the last patches of green are disappearing. It is important that collection is not delayed as the mature pods can very quickly be infested by insects. It is possible that early collection followed by afterripening in the shade could minimise the damage.

Processing and handling

Even when the pods are collected early, many are infested by insects and temporary storage should be as short as possible as the insects develop during this phase. If the pods are collected when they are still green, the bags should be kept open during transport to ensure ventilation. Pods are dried directly in the sun until they rattle and become brittle. The seed is extracted by beating or in a flailing thresher which is very effective for this species. After extraction the seed is dried directly in the sun and pod segments and debris is removed in a seed cleaning machine.

Storage and viability

Seed storage is orthodox and viability is maintained for several years in hermetic storage at room temperature with low moisture content.

Dormancy and pretreatment

The seed is hard coated but pretreatment is not always necessary. If the seed coat is very thin, boiling water may be harmful. For other seed lots pretreatment with boiling water for 3-10 seconds is optimal. After immersion in boiling water the seeds are left to cool in the water for 24 hours.

Sowing and germination

Can be established by direct sowing, using container-grown stock or as bare-rooted seedlings or stump plants. When sown directly, it is necessary to weed the rows for several years. To reduce the field establishment period, seedlings can be raised in nursery beds for one year or more and transplanted as stumps with about 25 cm root and 10 cm shoot.

For production of bare rooted seedlings or stumps, seeds are sown in lines about 15 cm apart with the seeds spaced about 2 to 3 cm in lines and about 1 cm deep. About 40 g seed is required for sowing 1 m² of nursery bed. Germination starts within a few days and is complete in a month. Best seedling development is obtained in full sunlight.

Phytosanitary problems

The seeds can be heavily attacked by insects, but it is not known whether insect attacks proceed during storage.

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Tree habit. Photo: David Lea, CSIRO Forestry and Forest products.

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Alnus acuminata spp. *argutta* (Schlecht.) Farlow

Taxonomy and nomenclature

Family: Betulaceae

Synonyms: *Alnus jorullensis* H.B.K., *A. ferruginea* Kundh, *A. mirbelli* Spach, *A. spachii*

Vernacular/common names: Aliso, ilite (Mexico); palo de lama (Guatemala), jaíl (Costa Rica); cerezo (Colombia).

Distribution and habitat

Native to the high mountain regions of tropical America from Mexico to the north of Argentina, especially along rivers. Prefers 4 - 15°C but can survive temperatures below 0°C for shorter periods. Grows on slopes from 1500 to 3200 m in altitude, with annual rainfall of 1000-3000 mm and a dry season of 3-5 months. Can grow on poor soils but prefers deep, well drained silt or sandy silt of alluvial or volcanic origin. Tolerant to acid soils, pH 4.5-6.0.



Branch with female and male inflorescences. From: CATIE

Botanical description

Tree up to 25 m tall; trunk up to 150 cm in diameter, straight, with numerous yellow lenticels. Crown wide. Leaves alternate, simple with serrate margin. The flowers are unisexual, male and female flowers in separate inflorescences, called catkins, on the same tree. Male catkin 5-12 cm, hanging; female 2 cm, erect.

Wood cream-coloured, reddish when dry, without smell. Grain straight, texture fine, density 0.36-0.42 g/cm³. Not resistant to rot or insects. Easy to work and used for coffins, boxes for transporting vegetables, shoe lasts, matches, carpentry and furniture.

Fruit and seed description

Fruit: the fruiting catkin is cone-like, dehiscent, 1.5-2.0 cm long, 1.2-2.0 cm wide, with persistent, woody scales; green/yellowish at first, later brown. Fruit a one-seeded samara with winged bract. There are 80-100 seeds per catkin and 6,000-10,000 female catkins per tree.

Seed: elliptic, flattened, very small (0.65-1.30 mm long). Dispersed by wind. 800,000-4,500,000 seeds per kg.

Flowering and fruiting habit

Flowers early; in Costa Rica male flowers often in Jan-Feb, female Sep-Jan.

Harvest

The ripe catkins are collected when the colour has changed from green to yellow/brown and before they open. They are dried on paper in a shady place protected from wind and, if necessary, after-ripened in a cool and dry place.

In Costa Rica the harvest season is Aug-Nov, with a peak in Sep-Oct. Collection is only from trees older than 10 years. Younger trees bear viable seed, but smaller and with lower germination.

It is good practice to cut the catkin in two and observe the seed. If the embryos are white and the wings light brown, the fruits are ready to be collected. Catkins from previous years can persist on the tree; they are dark brown or black, contain no seeds and should be avoided.

Processing and handling

After harvest the catkins should be kept in perforated sacks or paper bags to allow ventilation. After 36 hours at room temperature followed by 2 hours in sun they will open. After extraction the seed can be cleaned with a sieve. If collection is done at the right time, flotation is not necessary.

Storage and viability

The seed is considered orthodox and can be stored in hermetically sealed glass bottles or plastic bags, preferably at 3-5°C. After one year in a ordinary refrigerator, germination is reduced with app. 2% every month. If stored at room temperature losses in germination between 5 and 10% after 9 months have been reported.

Dormancy and pretreatment

The seeds are pretreated by stratification in moist sand at 5°C for 10-20 days.

Sowing and germination

Broadcast sowing in beds, 15-20 g/m². Press the seeds gently into the substrate or cover with moss or a thin layer of soil and sand (1:1) and water twice daily. After 13 days the first leaves will appear and the secondary roots begin to develop nodules.

After germination it is important to remove the seedlings gradually away from the sun so that the shoots can lignify and the roots develop. Cuttings can be made from seedlings that are 3-5 cm tall and have 4-6 leaves. The cuttings should be watered and kept in the shade the first 2 weeks. If done correctly, up to 90% of the cuttings survive. Outplanting can normally take place 4-6 weeks later when the plants are 30-40 cm.

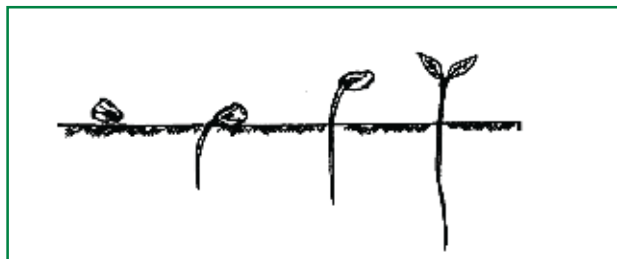
Phytopathological problems

During storage, the seeds can be infected with *Fusarium* and be damaged by species within the genus *Trichoderma*. In the nursery and plantations, fungi like *Rosellinia bunodes*, *Colletotrichum* and *Phomopsis* damage roots and shoots. *Phomopsis* can furthermore cause lesions in the foliage of older trees. The insects *Hypselonotus atratus* (Fam. Coreidae) and *Nodonota irazuensis* (Chrysomelidae) can cause defoliation in the nursery.

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Stages in the germination of *Alnus acuminata*. From: CATIE.

THIS NOTE WAS PREPARED BY CENTRO AGRONÓMICO TROPICAL DE INVESTIGACIÓN Y ENSEÑANZA AND TRANSLATED BY DFSC

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Azadirachta indica A. Juss.

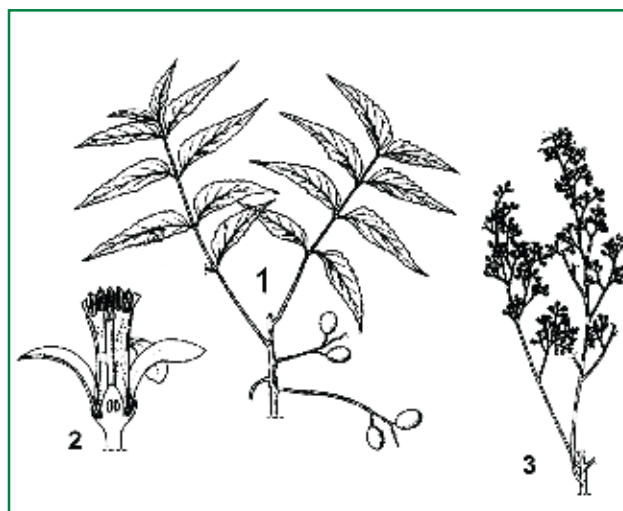
Taxonomy and nomenclature

Synonyms: *Antelaea azadirachta* (L.) Adelb., *Azedarach fraxinifolia* Moench, *Melia azadirachta* L., *M. fraxinifolia* Adelb., *M. indica* (A. Juss.) Brandis, *M. pinnata* Stokes

Vernacular/common names: neem, neem-tree, Indian lilac, white cedar (Eng.); margosa tree (Port.); nim (Urdu); indischer zedrac (Ger.); azad-darakht-i-hindi (Persian); tamaka, bowtamaka, tama, (Burmese); sadao india, sadao thai (Thai).

Distribution and habitat

Natural distribution is obscured by cultivation and naturalisation but it is believed to be native to Burma and NE India. Cultivated and spread into most semi-arid areas of India and Burma. Its status in Cambodia, Laos and Iran is not clear. Introduced into cultivation in many semi-arid and sub-humid areas of Asia and Africa, plus more recently into Australia, Latin America and southern United States. Wide temperature and rainfall regime. Most competitive in seasonal climate with long dry season and annual rainfall of 450-1150 mm. Most common at 0-700 m altitude but can grow up to 1500 m provided the temperature remains moderate. It does not tolerate cold or frost. Can grow on a wide range of soil types, but not tolerant to saline, waterlogged or cracking clay soils.



1, Fruiting branch; 2, section through flower; 3, part of inflorescence. From: Plant Resources of South-East Asia No.5:2.

Uses

Fodder, oil, soap, shade, soil conservation, ornamental, insecticide.

Botanical description

Medium sized tree, up to 15 m tall, rarely 25 m, with short, straight bole and long spreading branches, forming a dense, large, oval or rounded crown. Evergreen or, under extreme heat and drought, deciduous. Old bark turning dark grey, thick and furrowed. Leaves imparipinately compound with 7-17 pairs of leaflets, which are ovate or lanceolate, falcate with uneven base and dentate margins, 6-8 cm long, 1-3 cm wide. Inflorescence a 10-30 cm long panicle with many, small white to cream coloured flowers.

Neem is sometimes confused with the chinaberry, *Melia azedarach* L., but they are easily distinguished by the leaves. *Azadirachta* spp. have simple pinnate leaves, while those of *Melia* spp. are 2-to 3-pinnate.

Fruit and seed description

Fruit: ellipsoid drupe, 1.2-2 cm long, green/yellow when ripe, with a thin hard cuticle and juicy fruit pulp.

Seed: the pyrene contains one, rarely two, seeds. Seed weight varies with location and seed source. Available information indicates from 1700 seeds per kg in the Sahel to 3500-9000 seeds per kg in India.

Flowering and fruiting habit

Flowers hermaphroditic or male. Pollination by insects. The tree starts flowering and fruiting at about 5 years of age. Flowering generally occurs in the dry season and fruit ripening during the early part of the rainy season. Season and duration of reproductive phenoperiods vary according to location and climate. In bi-modal climates there are sometimes two flowering and fruiting seasons.

In India flowering occurs 2-5 weeks earlier in the southern than in the northern part of the country, with an approx. delay of reproductive season of 4.5 days for each 1° increase in latitude between 20° and 30° N. Duration of period from flowering to mature seeds is 10-12 weeks. Individual fruits have a development and ripening period of 1-2 months.

Harvest

The fruits are best collected from the tree since fallen fruits tend to have low viability. The optimum period for collection is when the colour of the fruit turns from green to yellowish-green. The easiest way of collection is to spread a tarpaulin under the trees and collect the fruits after they have been manually stripped of the branches or shed by shaking or beating the branches.

At about 10-12 years of age a medium-sized tree may yield 35-55 kg of fresh fruits per year or some 25 kg of dry depulped fruits.

Processing and handling

The fruit pulp must be removed before storage, either by hand or in a depulper. Under-developed and small fruits are initially discarded. The fully developed fruits are sorted according to maturity (colour). Fully mature fruits are depulped immediately to avoid fermentation. Green fruits are allowed to after-ripen in the shade 2-3 days before depulping. Depulping of green fruits is possible and does not affect viability but is more labour intensive.

Storage and viability

Neem seed has traditionally been considered recalcitrant, but there is great variation according to climate and provenance. Some African and Central American provenances (land races) have tolerated desiccation to a moisture content of 5-7% and consequent storage at 4°C up to 8 years with a 70% maintained viability. The provenances from Asia are often more recalcitrant. Confined storage is generally recommended. In this case the fruits are depulped, maintained at high moisture content (50%) by storage in moist sand or sawdust, and sown as soon as possible. Viability of moist seed typically ranges from 1-2 weeks to 2-3 months depending on storage conditions. The initial moisture content of the seed is about 40%.

Dormancy and pretreatment

No dormancy except from possible chemical inhibitors in the pulp, which are removed during depulping. Pretreatment is not required for fresh seeds. Manual scarification of the endocarp may enhance germination for seeds dried down to low moisture content.

Sowing and germination

The seeds are sown either in seedbed, in containers or directly in the field. In seedbeds, the seeds are sown in drills 15-25 cm apart with a spacing of the individual seeds of 2.5 cm. The seeds are pressed lightly into seedbed soil and covered with 1 cm sand or sandmixed soil. The seedlings are transplanted into a transplant bed or to containers when they are about 5 cm tall.

If sown in containers the seeds are sown one or two per container at a depth of about 1-1.5 cm. If both seeds germinate, one of the seedlings is transplanted. Direct sowing should be in properly prepared pits worked to min 15 cm depth and sowing depth as in containers. In drier zones the survival after direct sowing is often very low. Germination is epigeal and takes 1-2 weeks for fresh seeds.

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Ripe neem fruits. Photo: Lars Schmidt, DFSC.

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Balanites aegyptiaca (L.) Del.

Taxonomy and nomenclature

Family: Balanitaceae

Synonyms: *Ximenia aegyptiaca* L. (excl. *Balanites roxburghii* Planch), *Agialida senegalensis* van Tiegh., *Agialida bar teri* van Tiegh., *Agialida tom-buctensis* van Tiegh., *Balanites ziziphoides* Milbr. et Schlechter, *Balanites latifolia* (van Tiegh.) Chiov.

Vernacular/common names: desert date, soapberry tree, thorn tree, Jerico balsam, simple-thorned torchwood (Eng.); heglig (Arabic); corona di Jesus (Sp.).



Savannah, Ethiopia. Photo: Henrik Keiding, DFSC.

Distribution and habitat

Natural distribution is obscured by cultivation and naturalisation. It is believed indigenous to all dry lands south of the Sahara (Sahel), extending southwards to Malawi in the Rift Valley, and to the Arabian Peninsula. Introduced into cultivation in Latin America and India.

It has wide ecological distribution, but is mainly found on level alluvial sites with deep sandy loam and free access to water.

After the seedling stage it is intolerant to shade and prefers open woodland or savannah for natural regeneration. It is a lowland species growing up to 1000 m altitude in areas with mean annual temperature of 20-30°C and mean annual rainfall of 250-400 mm.

Uses

The fleshy pulp of both unripe and ripe fruits is edible and eaten dried or fresh. The fresh and dried leaves, fruits and sprouts are all eaten by livestock. An experiment in Burkina Faso showed that *B. aegyptiaca* contributed up to 38% of the dry-matter intake of goats in the dry season.

The wood is hard, durable and easy to work, but the small stem size and the tendency to fluting make sawmill processing difficult.

Botanical description

Multibranched, spiny shrub or tree up to 10 m tall. Crown spherical, in one or several distinct masses. Trunk short and often branching from near the base. Bark dark brown to grey, deeply fissured. Branches armed with stout yellow or green thorns up to 8 cm long. Leaves with two separate leaflets; leaflets obovate, asymmetric, 2.5-6 cm long, bright green, leathery, with fine hairs when young. Flowers in fascicles in the leaf axils, fragrant, yellowish-green.

Fruit and seed description

Fruit: a rather long, narrow drupe, 2.5-7 cm long, 1.5-4 cm in diameter. Young fruits green and tomentose, turning yellow and glabrous when mature. Pulp bitter-sweet and edible.

Seed: the pyrene (stone) is 1.5-3 cm long, light brown, fibrous and extremely hard. It makes up 50-60% of the fruit. There are 500-1500 dry seeds per kg.

Flowering and fruiting habit

Flowers are small, inconspicuous, hermaphroditic and pollinated by insects. The species has, especially in the equatorial zone, a pronounced diffuse flowering and fruiting habit; flowers and fruits occur during a prolonged season although a peak is always encountered. In areas with pronounced seasonal climate (northern and southern part of the distribution range) fruit maturation occurs before the rainy season.

In most of the Sahelian region the main flowering season is between October and March, the main fruiting season between December and April. In southern Africa (Zambia-Zimbabwe) flowering is in September - December, fruiting is between April and August. Flowering in Nigeria varies between November and April with ripe fruits becoming available in December and January and occasionally later, from March to July. Elsewhere, fruiting and foliage production occur at the height of the dry season.

Seeds are dispersed by ingestion by birds (e.g. hornbills) and larger animals (baboons, ruminants). The tree begins to flower and fruit at 5-7 years of age and maximum seed production is when the trees are 15-25 years old.

Harvest

Fruits are harvested when they turn yellow and the flesh becomes soft and sweet. In areas with abundant hornbills, fruits will not persist long on the tree. Discharged stones can be collected under the trees, but they are often prone to insect (seed borer) attack. Consequently, usually only a fraction of the fruits can be collected. Due to the prolonged fruiting season several collections may be necessary.

The fruits are collected by spreading a tarpaulin under the tree and shaking the branches until the fruits are released. Climbing is inconvenient because of the long branch thorns. A mature tree may yield up to 10,000 fruits per year which equals about 100-150 kg, or 55-80 kg of seed. Usually a smaller amount is harvestable due to the prolonged fruiting season and predation. Seeds may also be obtained from fruits that are being processed for other purposes.

Processing and handling

The outer fruit pulp must be removed as soon as possible to avoid fermentation. If extraction is not possible in the field, the fruits should be kept dry and spread in a thin layer during temporary field storage. The fruit pulp can be removed after soaking the fruits in water. Alternatively the fruits may be fed to livestock (cattle) and the stones picked from the droppings. The latter method will kill possible insects in the seeds. After extraction the stones are dried in the sun before storage.

Storage and viability

Seed storage behaviour is orthodox and moisture content for storage should be 6-10%. Cleaned, dried and free of insects, the seeds will remain viable for about 1 year at ambient temperature, 2 years at cool temperatures and several years in hermetic storage at 3°C.

Dormancy and pretreatment

Seeds that have passed the digestive tract of ruminants are said to germinate well without pretreatment. Fresh seeds need no pretreatment but seeds that have been stored will normally need manual scarification. Soaking in hot water for 12-18 hours, soaking in water for 24 hours at room temperature or boiling for 7-10 minutes and left to cool in the water are methods that have been reported to improve germination.

Sowing and germination

The seed should be sown vertically with the stalk end down. Germination occurs in 1-4 weeks and the seedlings are kept in the nursery for about 12 weeks

Phytosanitary problems

A major problem during storage is susceptibility to insect attack (seed borers). Short boiling (which may also serve as a pre-treatment before storage), insecticides or storage in CO₂ may kill present insects and further attack is prevented by storage in air-tight containers.

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Borassus aethiopum Mart.

Taxonomy and nomenclature

Family: Arecaceae

Synonyms: *Borassus flabellifer* L. var. *aethiopum* (Mart.) Warburg.

Vernacular/common names: African fan palm, ron palm, elephant palm. Local names: mtappa, mchapa (Swahili), sebe (Bambara), koanga (Mooré), murifate (Ilwana), mugumo (Duruma), mardafa (Somali), delieb (Arabic).

Related species of interest: *Borassus akeassii* sp. nov., whose petioles are green and less spiny, and whose fruits are greenish when ripe.

Distribution and habitat

Borassus aethiopum is indigenous to tropical Africa; being found in semi-arid and sub-humid zones from Senegal to eastern and southern parts of the continent. It is cultivated in India, Southeast Asia, Malaysia and also in Hawaii and Florida. It grows in great abundance on riverine flats and coastal plains, and also occurs in open secondary forest, dense forest borders and in savannah in drier areas where it is restricted to grassland with high ground water table, or along water courses (annual rainfall of 500-1000 mm). It thrives in temporary flooded areas, often forming dense stands. It is irregular, but widely distributed, typically found at altitudes of up to 400 m, but up to 1200 m in East Africa. *B. aethiopum* is common in populated areas where it is used as a multipurpose agroforestry tree. It is preserved for its traditional and economic values. The species is able to extract nutrients and thus grow on very nutrient-poor patches. This palm is slow growing and very long lived, to over 100 years old.

It is a fully protected species in Burkina Faso, where people are allowed to use only leaves and by-products like the sap, but not to cut down the plants. It is rare in Kenya, due to over-tapping for its sap.

Uses

Almost all parts of *B. aethiopum* are used, producing food, oils, timber, dyes, fibre, wine, and raw materials (leaves) for mats and baskets. The dark brown, coarsely fibrous wood is a highly prized timber. The wood is very resistant to termites and fungi, and is used in carpentry, construction and also for household articles. The roots serve for the treatment of stomach parasites, bronchitis, sore throats and asthma, as well

as being used for a mouthwash. The leaves are said to be an aphrodisiac and the sap is reported to have many uses. The seedlings are used in cooking. The fruits are eaten as a food supplement; both the fruit pulp and seeds are edible. The fruit is made into soft drinks, while the sap is fermented into palm wine used e.g. during traditional ceremonies. However, excessive tapping kills the plant.



Borassus aethiopum crown with hanging mature orange fruits. Photo: M Sacande.

Botanical description

Borassus aethiopum is a solitary, pleonanthic (does not die after flowering) palm. The tallest of the African palms, it can reach 30 m in height, but is typically 7-20 m. The straight trunk is dark grey, 40-50 cm in diameter; with a bulge up to 80 cm across above the middle (this bulge usually develops after ca. 25 years growth). The leaf bases leave a scar on the surface of the trunk. The leaves are dark bluish-green, palmate, markedly petiolate, and arranged in dense terminal tufts. Mature trees have between 10 and 40 living leaves, arranged in three spiral rows. The many-folded leaf blades are typically 1.5 to 3.6 m long. The petioles are up to 3 m long, 15 cm wide at the base and narrowing to 7.5 cm towards the top. The petioles are concave above and convex below, edged with curved teeth.

Flowers are unisexual. The male inflorescence is 0.8 to 1.8 m long, with 3-6 partial inflorescences that are ca. 50 cm long. The female inflorescence is usually unbranched, and 1.3 to 2.6 m long, with larger flowers of 2 x 3 mm. The flowers are tightly set in the axil of a bract. Flowers comprise 3 free external tepals and 3 internal tepals attached at the base.

Fruit and seed description

Fruit: The fruits are 8-18 by 6-16 cm, and each weigh 1-1.5 kg. They are smooth, and have persistent outer petals surrounding the base. They are often ovoid to slightly triangular; however, the shape depends on the number of seeds developed. A persistent, protective calyx covers approximately a quarter of the fruit. The fruits turn a dull orange-brown colour when ripe. The fibrous fruit pulp is yellow to white and slightly oily. Each fruit contains up to 3 ovoid compressed pyrenes.

Seed: The seed handling unit is the pyrene, which is hard coated and about 10 cm in diameter. Each pyrene weighs about 100 g. The morphological seeds are bilobed, pointed and basally attached, with an apical embryo, and a homogeneous, centrally hollow endosperm.

Flowering and fruiting habit

Reproduction is highly delayed and the reproductive period of the plant, before death, is short, about 20 years. Flowering usually occurs in the second part of the rainy season. *Borassus aethiopum* is dioecious; Females typically bear 50-100 fruits in a fruiting season. The seeds are naturally dispersed by mammals, such as chimpanzees.

Processing and handling

In West Africa, fruits are usually harvested from November till May. The pericarp is removed by hand-slashing to release the pyrenes.

Storage and viability

Seeds have a short viability and should be sown as soon as they are removed from the fruit pulp.



A fresh *B. aethiopum* fruit transversally cut-open displaying two normal seeds and an undeveloped seed. Photo: M. Sanon, Burkina Faso.

Sowing and germination

Seeds do not require pretreatment. They will germinate after about 4 weeks. The seedlings produce a very long taproot, which can be 1 m deep, while the leaf is only 1 cm high, therefore if possible they should be sown directly at the location where they will grow. If raised in nurseries they must be planted in very deep sowing beds (> 1m) to allow unrestricted root development.

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Ziziphus mauritiana Lam.

Taxonomy and nomenclature

Family: Rhamnaceae

Synonyms: *Rhamnus jujuba* L., *Ziziphus jujuba* Lam.

Vernacular/common names: ber, Chinese date, desert apple, Indian cherry, Indian jujube, Indian plum, jujube (English); kurkura (Amharic); sidr (Arabic); ber, ber boroi, boroi, kool (Bengali); eng-si, zee-pen (Burmese); manzanita (Filipino); jujubier, liane croc-chien (French); Indischer Jujubenstrauch (German); baer, ber (Hindi); bidara, dara, widara (Indonesian); putrea (Khmer); than (Lao); bidara, epal siam, jujub (Malay); toboro, tomboron moussana, tomborongo (Mandinka); bayer (Nepali); ajapriya, badara, kar-kandhu, kuvala, madhuraphala (Sanskrit); geb, gub (Somali); perita haitiana, Ponseré, yuyuba (Spanish); mkunazi (Swahili); elandai, yellande (Tamil); ma tan, ma thong, phutsan (Thai); geva (Tigrigna); c[aa]y t[as]o ta, tao, tao nhuc (Vietnamese); jujube (trade name).

Distribution and habitat

Native to South and Central Asia and China and naturalised in a large number of tropical and subtropical countries. It is a very hardy species that withstands salinity and drought as well as waterlogging. It is found growing up to 1500 m altitude but commercial cultivation usually only extends up to 1000 m altitude. It can survive temperatures as high as 50°C and down to 7°C but does not tolerate frost.

Uses

A multipurpose tree that provides both fruit, fodder and fuel. The fruits are usually eaten fresh, they have a high content of vitamin C and are very nutritious. They can also be dried, candied, pickled or used to make juice or ber butter. In Indonesia the young leaves are cooked as a vegetable. In parts of India and North Africa the leaves are used as fodder for sheep and goats. The timber is hard with a density of 535-1080 kg/m³ and is used for a number of purposes where a durable, close-grained wood is needed. It makes good charcoal with a heat content of almost 4.900 kcal/kg and is also used as firewood in many areas. The thorny tree makes excellent fencing that deters livestock as well as wild animals such as baboons. In India and Pakistan it is an important agroforestry and silvipasture species in arid and semi-arid areas. It is also planted for erosion control, soil and river-bank stabilisation and land reclamation.

Botanical description

Evergreen shrub or tree up to 15 m tall and up to 40 cm in diameter. The leaves are alternate and elliptic, 2.5-3.2 cm long and with three distinct veins. In the leaf-corners are two spines, one long and straight the other small and curved. Although most trees bear spines, spineless individuals are not uncommon. Flowers are small and bisexual, yellow or greenish, borne on short stalks, 2-3 together in the leaf-corners.

Fruit and seed description

The fruit is a drupe with a fleshy pulp and a single, hard stone. It is very variable in shape and size but most are round to oval. Fruits from wild trees can be as small as 1.8-2.5 cm while improved cultivars bear fruits as large as 5 cm in diameter. Both texture and taste of the pulp is similar to apples. The stone has irregular furrows and it normally contains two brown seeds with a papery seedcoat. Seed weight varies and there can be from 500 up to 3300 stones per kg.



Mature fruits of *Ziziphus mauritiana*. From: Morton (1987)

Flowering and fruiting habit

The trees can be evergreen or deciduous but except in dry areas, they remain leafless for only a short period. In India the trees flower in July to October and fruits are formed soon after. In February-March the fruits are mature and in some places a second crop is produced in the fall. In the wild, fruiting normally begins when the trees are 3-4 years old and usually a good crop is produced every year. The flowers are pollinated by ants and other insects, and in the wild state the trees do not set fruits by self-pollination. Most cultivars, however, can produce fruits without cross-pollination. The seeds are dispersed by birds and animals.

Harvest

The immature fruit is green in color, but as it ripens it goes through a yellow-green stage with mahogany-colored spots appearing on the skin as the fruit ripens further. The fully mature fruit is entirely red and the pulp becomes soft and wrinkled. The fruits are picked directly from the tree and only fully mature fruits should be collected. They should be transported in open bags to avoid fermentation.

Processing and handling

After collection the fruits are macerated in water to remove the pulp and the stones are rinsed in clean water. Empty stones can easily be separated by flotation in a 18% solution of ordinary cooking salt. Then the stones are spread out on a sheet and dried in the sun for one week.

Storage and viability

The seeds are orthodox and should be stored at low moisture content (7-10%) in air-tight containers. At room temperature the seed can be expected to store for at least one year. In cold store at 5°C the seed will retain high viability for several years.



Flowering and fruiting branch. Copyright: PROSEA Foundation

Dormancy and pretreatment

Germination often improves after the seed has been stored for some months. The hard stone restricts germination and cracking the shell or extraction of seeds fastens germination. This can be done using a vice but the seed inside is fragile and apart from being very time-consuming, removal of the shell can damage the seed. Without pretreatment the seeds normally germinate within six weeks whereas extracted seeds only need one week to germinate. Germination percentage is high both for treated and untreated seeds. Before sowing, the seeds are soaked in water for two days.

Sowing and germination

The seeds need light to germinate and it is not recommended to shade the seedbeds. They can be sown directly into containers or in germination trays or seedbeds and transplanted into containers when they have developed the first pair of permanent leaves. The seedlings may need as long as 15 months in the nursery before planting in the field. Great care must be taken when transplanting nursery stock to the field because of the long taproot. In general, stump planting is more successful than using bare-rooted stock. The stumps should consist of approximately 25 cm of root and 5-7.5 cm shoot. Alternatively the seeds can be sown directly in the field. Horticultural cultivars are normally grafted onto wild type seedling root stocks either in the nursery or in the field. Spacing should be 3x3 m for fodder production and wind-breaks. For orchard establishment the recommended spacing is 7x7 or 8x8 m.

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Boswellia serrata Roxb. ex Colebr.

Taxonomy and Nomenclature

Species Name: *Boswellia serrata* Roxb. ex Colebr.

Synonym: *Boswellia glabra* Roxb. *Boswellia balsamifera* Spreng

Family: Burseraceae

Two varieties: *Serrata* with serrate and pubescent leaves, and var. *glabra* with entire, glabrous leaves

Vernacular (Common name): Salai (Hindi), Indian frankincense tree, Indian olibanum tree (English), guggulu (Tamil), kuurdur (Arabic)

Distribution and habitat

Boswellia serrata is distributed throughout the Indian subcontinent (with the exception of Bengal, Western Ghat and north-east India), primarily in Central India between 16° to 31° N latitude and 73° to 86° E longitude. The climate is with hot summer and mild winter with maximum shade temperature from 40°-48°C, and minimum 0°-10°C. The normal rainfall ranges from 500-2000 mm. The habitat is tropical dry deciduous forest. The tree grows gregariously in areas with the rainfall of 1500-1800 mm, but quick drainage is more significant than higher rainfall. Therefore, it grows well in hill slopes, ridges of hills, where it may occur at the elevation up to about 1150 m.a.s.l. The species is a strong light demander. It can grow on a wide variety of geological formation and soils, such as gneiss, mica-schist, limestone, shales and quartzite's of dry ridges and stony hills, and on flat terrain. It thrives both in fertile and shallow and poor soil. The species can withstand the adverse effect of forest fire and drought.

Botanical description

Boswellia serrata is a deciduous tree with a light, spreading crown and somewhat drooping branches attaining generally a height of 9-15 m with a short bole of 3.0 to 4.5m and a diameter of up to 70 cm. The bark is dark-greenish grey, thick, smooth, exfoliating in thin papery flakes, resinous inside. Leaves are exstipulate, alternate, 30-45 cm long, crowded at the end of branches; imparipinnate with 17-31 leaflets. Leaflets are opposite to sub-opposite, variable in shape and size, 2.5-6.3 cm long and 1.2-3.0 cm wide, sessile, ovate or ovate-lanceolate with dented margins and pubescent surface (var *serrata*) or with entire, glabrous leaves (var. *glabra*). Flowers are bisexual, small in short racemes, cream-colored, crowded at the end of branches, but not terminal. Calyx



is persistent, pubescent outside, 5-7 toothed; petals are 5-7 in number, ovate, free.

Use

The timber is moderately strong, but soft and non-durable when fresh; the seasoned timber is fairly durable. It is used in furniture, water pipes, matches, boat masts, plywood and veneers. It is used as raw material in paper pulp and newsprint. Charcoal made from it is used in iron smelting. The bark of the tree exudes a fragrant transparent yellowish-green oleo-gum-resin known as 'salai guggal' or Indian olibanum. A mature tree may yield about 2-2.5 kg of oleo-gum-resin a year. A volatile oil, resin and gum are produced from this exudation. The volatile oil is used as substitute for turpentine and used for paint, varnishes, soaps and perfumery industry. Gum is an excellent adhesive used in incense sticks, distempers, calico-printing, and in textile industry. The resin is a good substitute for Canada balsam in colour and consistency. It is used for manufacturing soaps, paints, varnishes and printing inks. The salai guggal gum has antipyretic, diaphoretic and astringent properties and used by local people for diarrhea, piles, ulcers, arthritis, skin and gastric problems. The flowers and seeds are edible. The species is suitable for reclamation of shallow ferruginous soil or dry sandstone hills with a mean annual rainfall of 500-1250mm.



Fruit and seed description

Fruit: Fruits are simple, dry, dehiscent trigonous, 12-22 mm long capsules; fleshy, light green before maturation, but turn dry and brown after maturation, with three locules containing three seeds.

Seed: Seeds are solitary in each locule, compressed, hard, and winged along the margins. 13-25 seeds weigh one gram. 1000 pure seed weight is 40-77g.

Phenology, flowering and fruiting habit

The white flowers appear in stout racemes at the ends of branches from the end of January to April. The leaves turn yellowish to light brown before they fall in December; the new leaves appear in May-June. The tree remains leafless during the entire period of flowering and fruiting. The drupes ripen in May-June. Flowers are self-incompatible. It is an obligate out-crossing species and the number of filled, viable seeds depends on the pollinators and density of the population. The giant Asian honeybee (*Apis dorsata*) and Indian honeybee (*A. cerana var. indica*) are effective pollinators.

Seed collection

Fresh fruits are collected from the trees. Seeds should be collected 2 months after anthesis in 1st week of May, when the fruits turn light brown. The collection method is to spread a tarpaulin under the tree and collect the fruits by lopping the branches or plucking before their splitting.

Processing and handling

Fruits split open, when dried under shade. Seeds are extracted from the dry ripe fruits manually and wings are removed by rubbing between hands and then cleaning can be done either by winnowing or by a seed blower. Seeds should be immersed in water before they are sown to separate out the empty seeds, which float on the surface.

Dormancy and pretreatment

Seeds have no dormancy and do not need pre-treatment.

Storage and viability

Seeds of *Boswellia serrata* are of orthodox type and can tol-

erate desiccation to 3-6% moisture content. Under ambient conditions (room temperature 15-37°C) the seeds can be stored for up to two years, if stored at 3-6% moisture content. Viability can be extended for more than three years, if stored at low temperature (-20°C to 15°C).

Sowing and germination

Germination is hypogeal. Germination percentage may vary from 20-90% dependent on the number of filled seeds in a seedlot. Seedlings can be raised in polythene bags filled with a mixture of loamy soil and decomposed farm yard manure. Two to three seeds are sown in each polythene tube (15 cm x 10 cm) in the month of July-August. Germination takes place within two weeks. The species is rarely raised in seedbeds as the root system is delicate and sensitive to mechanical handling. Seedlings of 10-12 weeks old (15-20 cm) are planted in the fields with a spacing of 5m x 5m. The seedling are prone to die-off during prolonged drought in the summer months. While some seedlings die out completely, most of them re-sprout in the rainy season.

Hence, irrigation at 15 days intervals during dry season (November to June) and mechanical weeding in the early years of formation of plantation are therefore necessary. Seedlings may grow to 2.75m in 3 years. 8-10 years are generally required to extract gum.

Phytosanitary problems

The tree is attacked by fungi and insects. The important fungi are *Ceratostomella* spp. and *Graphium* spp causing blue stain or sap-stain in the logs and planks when freshly cut. Some of the borer and beetle attacking logs are: *Atractocerus reversus*, *Carphoborus boswelliae*, *Coptops aedificator*, *Megachile disjuncta*, *Platypus solidus*, *Plocaederus ferrugineus*, *Sinoxylon anale* and *Xeleborus similis*. The deterioration can be lessened by cutting the logs into planks. *Rhesala imparata* is a defoliator of the species.

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Bridelia micrantha (Hochst.) Baill.

Taxonomy and nomenclature

Family: Euphorbiaceae

Synonym: *Candelabria micrantha* Hochst.

Vernacular / common names: Bridelia, coast gold-leaf (English); mkarakala, mkarati, mtutu, mwiza (Swahili); munyansa, munyanya, mushiwe (Tongan); mlebezi, mnazi, msongamino (Nyanja).

Distribution and habitat

B. micrantha is reported native to most of sub-Saharan Africa except South Africa and Namibia. Natural distribution includes Angola, Burundi, Cameroon, Cote d'Ivoire, Democratic Republic of Congo, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Kenya, Liberia, Malawi, Mali, Mozambique, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia, Zanzibar, Zimbabwe.

B. micrantha occurs in savannah and secondary forest, in swamp forest, along forest edges, in riverine woodland and in gallery forest. It does well in a wide variety of climates. Altitude range 300-2200 m.; mean annual temperature: 18-28 °C, 800-2500 mm annual rainfall. The species grows on a variety of soils, from sandy to regular clay loams. It can withstand light frost but is not drought resistant.

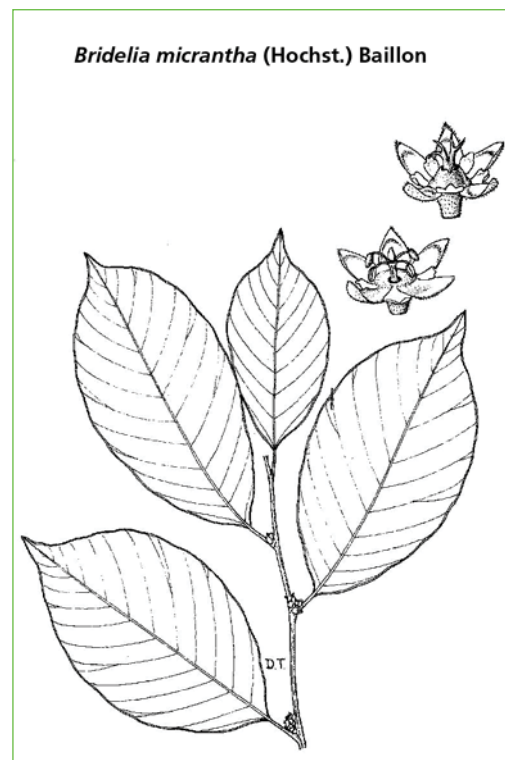
Uses

The species has a durable, termite resistant wood that is in high demand for poles, tool handles, bows, and timber for interior carpentry. It is regarded as one of the best fuel-wood trees and is used for both firewood and charcoal. The species has several applications in traditional medicine: the roots are crushed and used for treating stomach aches, tapeworms, diarrhoea, headaches, and sore joints. The leaf sap is used for sore eyes. The fruits are sweet, tasting like currants and are readily eaten by children. The species has wide applications in agroforestry especially for erosion control. The roots are effective soil binders. It is used in various types of intercropping as a shade tree e.g. in combination with banana and coffee.

Botanical description

Bridelia micrantha is a semi-deciduous to deciduous tree up to 20 m tall with a dense rounded crown and tall, bare stem; bark on young branches grey-brown and smooth, on older branches and stems dark brown and rough, cracking into squares; branches often spiny;

slash thin, fibrous, brown to dark red. Leaves alternate, simple; sub-coriaceous, deep glossy green above, paler and minutely appressed-puberulous beneath (hairs sometimes visible only with a lens); stipulate, stipules lanceolate-acuminate, 5-7 mm long; blade elliptic, oblong-elliptic or obovate, 4.5-18 x 1.5-7 cm, apex sub-obtuse to acuminate; base generally rounded; margins entire or slightly wavy; lateral nerves in 8-14 pairs, barely visible and reaching the margins without branching; petiole 3-10 mm long. Inflorescence with flowers in axillary clusters containing male and female flowers; male flowers on pedicles 1-2 mm long; sepals yellow-green, triangular, 1.5-2 mm long; petals obovate, shorter than the sepals; stamens 5; female flowers sessile, disk enveloping the ovary; styles 2, forked.



Leaves, male and female flowers of *B. micrantha* (source untraceable)

Fruit and Seed description

Fruit: Fruit black, subglobose to ellipsoid drupe about 8 mm long, 5-8 mm in diameter, each with 1 seed.

Seed: Seeds are very small with 19 000-19 500 seeds/kg.

Flowering and fruiting habit

Male and female flowers are separate but on same tree (monoecious). In southern Africa, flowering occurs from September to December and fruiting from January to April. Fruit and seed production is usually very high. The seeds are spread by birds, which feed on them and distribute them in their faeces.

Harvest

Seeds are harvested from the trees by shaking or cutting off seed bearing branches and collecting on a tarpaulin under the tree.

Processing and handling

Fruits should be processed as soon as possible after collection because seeds have short viability. The fruit pulp contains a growth inhibitor that must be removed, e.g. by rubbing on a wire mesh under running water.

Storage and viability

The seed has short viability (oily seed); do not store the seeds at all.

Dormancy and pretreatment

Pulp with germination inhibitor is removed in connection with seed processing. Germination can be accelerated by soaking the seeds in cold water for 24 hours after removing the fruit pulp.

Sowing and germination

Seeds are sown directly in polythene tubes or in seed beds for later transplanting. Germination is epigeal.



Bridelia micrantha (Hochst.) Baillon

Vegetative propagation

There is not much experience with vegetative propagation but the trees produce root suckers and coppice well after injury which indicates that there may be a potential for vegetative propagation.

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Calliandra calothyrsus Meissner

Taxonomy and nomenclature

Family: Fabaceae (Mimosoidae)

Synonyms: *Anneslia acapulcensis* Britton & Rose, *A. calothyrsus* (Meisn.) Donn.-Sm., *A. confusa* (Sprague & Riley) Britton & Rose, *A. similis* (Sprague & L. Riley) Britton & Rose, *Calliandra acapulcensis* (Britton & Rose) Standl., *C. confusa* Sprague & L. Riley, *C. similis* Sprague & Riley, *Feuillea calothyrsa* Kuntze.

Vernacular/common names: cabello de ángel, pelo de ángel (Sp.); calliandra, red calliandra (Eng.); kalliandra merah (Indonesia).

Distribution and habitat

Native to Central America from the western Pacific coast of Mexico to central Panama. It occurs in both primary and disturbed forest at altitudes between 0-1850 m in areas with 700-4000 mm rain/year. It can grow on a range of soils but is especially tolerant to acidic soils. It is not tolerant to frost and requires a mean annual temperature of 22-28°C.

Uses

The fast growth and tolerance to acidic soils where other tree species perform poorly has made it a popular species in small-scale agroforestry throughout the humid tropics. It is nitrogen-fixing and improves soil structure and fertility. It is used as an understorey component on coconut plantations, a shade tree in coffee and tea plantations and a nurse tree in timber plantations.

The ability to resprout after repeated cutting makes it valued for fodder production, especially in areas where the use of other multipurpose trees is limited by environmental and disease constraints. For example, it can replace *Leucaena leucocephala* in areas where growing *Leucaena* is prevented by psyllids. The leaves, flowers and twigs are edible and contain 20-25% crude protein and although the nutritive value is less than e.g. that of *Leucaena* it is a good supplement to the diet of most animals.

It is also widely used as fuelwood by small-scale farmers as well as grown in large plantations. In Indonesia it has been successfully used to rehabilitate *Imperata* grasslands. It is an important source of forage for honey-bees and the trees are a suitable host for the insects that secrete shellac, a compound used for lacquers and dyes.

Botanical description

Small tree or shrub with either one or more stems, up to 12 m tall and 20 cm in diameter. The leaves are compound, up to 20 cm long and divided into many small leaflets. At night the leaves fold against the stem. Flowers in up to 17 cm long, upright inflorescences that are placed just under the end of branches. The flowers have small, green petals and sepals and 5.5-6.5 cm long anthers that are white at the base and bright red at the ends.



1. Flowering branch, 2. peduncle with pods. Copyright: PROSEA Foundation

Fruit and seed description

Fruit: the fruit is a pod, up to 18 cm long, pale to dark brown and normally without hairs. There are 8-12 seeds per pod.

Seed: seeds are flat, oval, up to 8 mm in diameter and with irregular dark spots on the surface. There are 14.000-20.000 seeds per kg.

Flowering and fruiting habit

The flowering season varies throughout the natural range and where there is sufficient moisture available, flowering can extend throughout the whole year. However, a period of peak flowering normally occurs after the main wet season but before the onset of the dry season. This is observed both within and outside of its natural range indicating that it is mainly rainfall that initiates flower production. In Central America peak flowering occurs between October and January.

The flowers mature over several months, beginning with the flowers at the base of the inflorescence. They open for one night only, by the next day the anthers wilt and unfertilized flowers drop. Nectar-feeding, and to a lesser extent fruit-eating, bats are the main pollinators. Many insects also feed on the nectar but without pollinating the flowers. The species is predominantly outcrossing but the degree of tolerance to selfing varies between provenances.

C. calothyrsus flowers abundantly but relatively few seeds are produced and especially outside the area of natural distribution poor seed production is a major limitation to its use. Irrigation and fertilisation have been reported to improve seed production. When the pods split open the seeds are forcefully ejected and dispersed up to 10 m from the mother tree.

Harvest

When the pods become dark-brown the seeds inside are mature. Only ripe pods and their mature seeds should be collected. The pods are picked from the tree just before they open and the seeds are dispersed. Alternatively, hessian bags or nets can be placed on the ground under the trees. When the pods are ripe they open and the seeds will drop onto the ground where they are swept up at daily intervals. This method is mainly used in seed production areas where there are no other species present. It is less time-consuming and it ensures that only mature seeds are collected but may be difficult to use if the trees are grown in farmland or in dense vegetation. At the time of collection the mature seeds have a moisture content of 12-15%.

Processing and handling

If pods are collected, they are left in the sun to dry until they open. It is best to leave the pods to open slowly and not use force to open them. Inside the pods the seeds dry at a slow rate and too rapid drying can kill the seeds. Once the pods are open the seeds are cleaned manually or in a seed cleaner.

After extraction the seeds are dried in the sun to 6-10% moisture content. In very hot climates the seeds should not be exposed to direct sunlight for long periods of time. In wet conditions the seeds can be placed in net bags and dried in the hot streams of air over a stove. The bags must be at a safe distance from the heat source.

Storage and viability

The seeds are orthodox and should be stored at moisture content below 10% in air-tight containers. At room temperature (25°C) the seeds will retain high viability for about 12 months. If the seed needs to be stored for longer time, cold store is necessary. At 4°C the seed can be expected to retain 70-90% viability for up to five years.

Dormancy and pretreatment

Fresh seeds can germinate without any pretreatment. Dry seeds, e.g. seeds that have been stored, have a hard seedcoat and scarification improves germination significantly. Submerging the seeds in 70-80°C water and then leaving the seeds to cool in the water is the most common method and will normally give the best germination. However, in some instances hot water can kill the seeds and it is recommended to test the technique before using it on the entire seedlot. If for a given seedlot hot water turns out to be damaging, soaking in cold water for 24 hours is recommended.

For containerised stock, two seeds are sown at a depth equal to their length in a 10 x 20 cm container. Surplus seedlings are removed when the first adult leaves have developed. Germination is fast, it is normally completed in 4-10 days. After 6-12 weeks when the seedlings are 15-50 cm tall they are ready for planting in the field. For the production of bare root seedlings the plants need at least 2-5 months in the nursery. The seeds can also be sown directly in the field in the beginning of the wet season. Low cost vegetative propagation using leafy stem cuttings has been described by Dick *et al.* (1996).



Shade trees: tea plantations in Sri Lanka. Copyright: Alan Pottinger

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THIS NOTE WAS MADE IN COLLABORATION WITH THE INDONESIA FOREST SEED PROJECT

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Casuarina equisetifolia L.

Taxonomy and nomenclature

Family: Casuarinaceae

Synonyms: *Casuarina littoralis* Salisb., *C. litorea* L., *C. littorea* Oken., *C. muricata* Roxb., *C. sumatрана* Jungh.

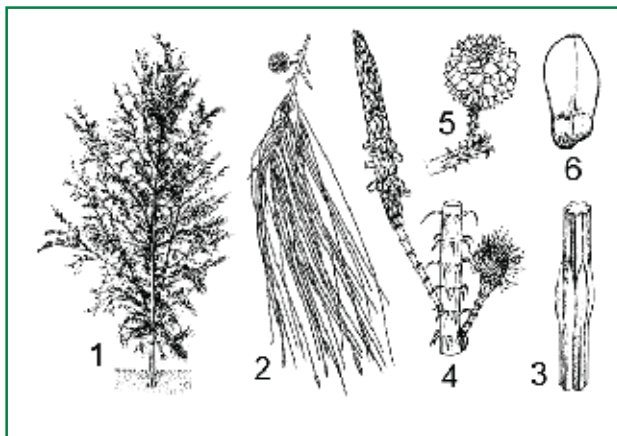
Vernacular/common names: beefwood, coast she-oak, horsetail casuarina, ironwood (Eng.); pin d'Australie (Fr.); pino australiano (Sp.). Two subspecies are recognised, *equisetifolia* and *incana*.

Distribution and habitat

Occurs naturally on subtropical and tropical coastlines from northern Australia throughout Malaysia, southern Myanmar, the Kra Isthmus of Thailand, Melanesia and Polynesia. Introduced world-wide in the tropical and subtropical zone.

Altitude range 0-1500 masl, mean annual rainfall 350-5000 mm, dry season duration 6-8 months, mean annual temperature 15-30°C, mean maximum temperature of hottest months 20-47°C and of coldest 7-20°C.

Prefers light, sandy soils; relatively fast-growing on poor soils and tolerates some salinity and salt-laden winds. Grows well in soils with pH 5.0-9.5. Does not tolerate waterlogging, is shade intolerant and sensitive to fire. Nitrogen-fixing (*Frankia* symbiosis). The life span is 40-50 years.



1, Habit of young tree; 2, flowering twig; 3, part of branchlet; 4, male and female inflorescence; 5, infructescence; 6, fruit. From: Plant Resources of South-East Asia 5:3

Uses

A true multipurpose species, providing a range of products and services for industrial and local users. Has been called “the best firewood in the world” and also produces high-quality charcoal. The wood is very difficult to work and cannot be used as sawn timber.

Because of its tolerance to salt it is used for erosion control in coastal areas. Other uses and services are paper pulp, timber, shade or shelter, ornamental, land reclamation and soil improvement. With the ability to fix nitrogen it has potential use in agroforestry.

Botanical description

An evergreen tree 6-35 m tall, subsp. *incana* typically smaller. Crown is finely branched. Bark light grey-brown, rough and furrowed on older trees. Encircling bands of lenticels are prominent on the young bark. Branchlets are drooping and needle-like; The tiny reduced leaves are arranged 7-8 together in whorls.

Flowers unisexual, male and female flowers can be on same or on different trees. Male flowers in simple terminal, elongated spikes, female flowers borne on lateral woody branches. The female, cone-like infructescence is round, 10-24 mm long, 9-13 mm in diameter.

Fruit and seed description

Fruit a grey or yellow-brown winged nut (samara), 6-8 mm long, with a single seed. One kg of green cones yields 20-60 g of seed. There are 370,000-700,000 seeds per kg.

Flowering and fruiting habit

Wind pollinated. Where there is a distinct wet or dry season, flowering and fruiting are regular, occurring once or twice per year. In areas with no distinct dry or wet season, flowering and fruiting tends to be irregular and may occur throughout the year.

Female cones mature 18-20 weeks after anthesis and open shortly after this, releasing the small fruits. The fruits on one tree do not all mature at the same time, presenting a problem for seed collection.

Harvest

The seeds are mature when the cones turn yellow and begin to open. The seed coat should be partly brown and the endosperm firm.

Processing and handling

The fruits are dried in the sun before the seed is extracted.

Storage and viability

Storage behaviour is orthodox. Viability can be maintained for several years in hermetic storage at 3° C with 5-9 % moisture content.

Dormancy and pretreatment

Seeds require no pretreatment.

Sowing and germination

Propagation by seed or cuttings. In the nursery, seed can be germinated in beds or trays containing sand or a mixture of sand and peat moss. Germination is normally complete after 2 weeks.

The seedlings are transferred to containers when they are 10-15 cm tall and reach plantable size (50-70 cm) in 5-8 months. Care should be exercised to avoid excessive watering as this may cause damping off. A 50% shade is suitable until seedlings are ready for out-planting. Seedlings 10-15 cm tall in germination beds can also be transplanted to open beds with 10 x 10 cm spacing to obtain bare-rooted planting stock. Soil containing mycorrhiza and *Frankia* (the nitrogen-fixing fungi in Casuarinas) from established stands should be added to the potting medium. The N₂-fixing potential can be greatly enhanced through the use of selected clones inoculated with effective *Frankia* strains.

In Thailand and India cuttings are made from small branchlets (2 mm in diameter and 10-15 cm long) and rooting is enhanced with hormones IBA or IAA. In southern China cuttings are taken from branchlets (1 mm in diameter and 5 cm long) and soaked in a solution of NAA before being placed in polythene tubes.

Plantations can be established using container seedlings, bare-root seedlings or rooted cuttings. A planting density of 2500 stems/ha is commonly used but some farmers plant up to 10,000 stems/ha when fuelwood or small poles are the required products. Pruning up to 2 m is necessary in plantations. Vegetative propagation by cuttings is very easy for this species.

Phytosanitary problems

Ants may predate the seeds and care should be taken to protect the seed after sowing.

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Naturally occurring trees at Wah Wee Beach, West Arnhem Land, Northern Territory, Australia. Photo: Maurice McDonald, CSIRO Forestry and Forest Products.

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Cedrela odorata L.

Taxonomy and nomenclature

Family: Meliaceae

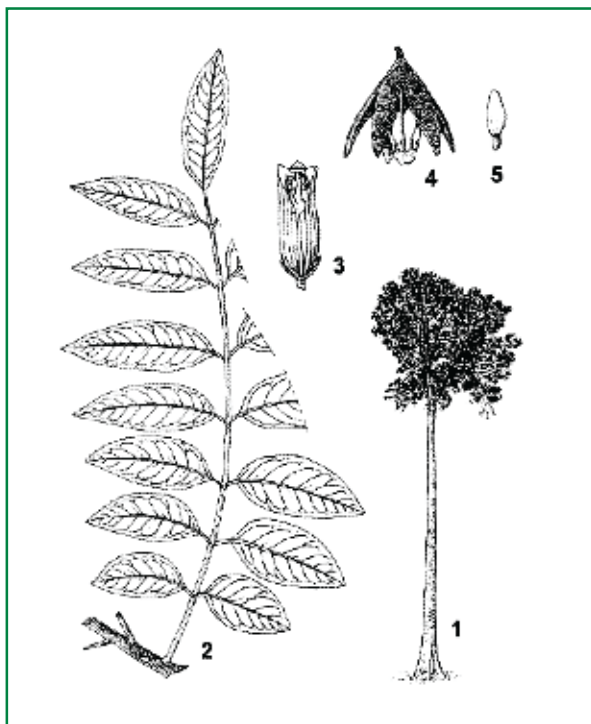
Synonyms : *Cedrela dugesii* S. Watson, *C. guianensis* A. Juss., *C. mexicana* M. Roem., *C. occidentalis* C. DC., *C. sintenisii* C. DC.

Vernacular/common names: cedar, cedarwood, cigar box cedar, Spanish cedar (Eng.); acajou rouge (Fr.); cedro, cedro amarillo (Costa Rica); culche (Mexico); cedro real (Nicaragua); cedro colorado (El Salvador); yom-hom (Thailand).

Distribution

Native to the neotropics from Mexico through Central America to Argentina including the Caribbean. Introduced into cultivation in Uganda, Tanzania, Madagascar and South Africa, and several South-East Asian and Pacific countries.

It is found from sea level to 2500 m altitude in humid seasonal tropics with annual rainfall of 1500-3000 (-4000) mm, mean annual temperature of 22-27°C and a dry season of 2-4 months. Prefers fertile, free draining, weakly acidic soils.



1, Tree habit; 2, leaf; 3, sectioned flower; 4, dehiscent fruit; 5, seed. From: Plant Resources of South-East Asia 5:2.

Uses

The timber is famous for its use in making cigar boxes and it is also used for musical instruments, light construction, veneer, plywood a.o. The insect repellent smell makes it suitable for wardrobes. In cocoa and coffee plantations it is planted for shade and as a windbreak.

Botanical description

Deciduous tree up to 40 m tall, sometimes with small buttresses. Young bark smooth and grey, deeply fissured with age. Leaves paripinnate, with 8-12 pairs of leaflets. Leaflets oval to lanceolate, 6-15 cm long, 3-5 cm wide, glabrous to densely pubescent. Flowers small, unisexual but with well developed vestiges of the opposite sex.

Fruit and seed description

Fruit: pendulous, dehiscent capsule, shiny brown, 5-7 cm long with 5 loculi, each with 2 rows of 3-5 seeds, hanging from the columella by their wing. Each fruit contains 25-40 seeds. The capsule opens from the apex.

Seed: flat, winged, 20-25 mm long, 5-8 mm wide (incl. wing), oblong, smooth, chestnut to red. Wing lateral, dark brown. Embryo straight, radicle facing the wing. The seeds lack endosperm. There are 40,000-60,000 dry, dewinged seeds/kg.

Flowering and fruiting habit

Monoecious species. Annual flowering is regular from about 10 years of age. Flowering normally occurs at the beginning of the rainy season but there can be large differences from one region to another. Fruit maturation takes about 6 months.

In Costa Rica flowering is Mar-June and fruiting is in July. Ripe seed is available in March-April in Nicaragua and March-June in the Philippines.

Areas with bimodal climates may have two fruiting seasons; in Tanzania, fruits can be harvested in April and November. The leaves are shed prior to fruit maturation.

Harvest

The seeds are mature when the capsule and seed wing change colour to dark coffee brown, and the seed coat hardens. Collection can start when the first capsules have opened.

The capsules are best collected from the tree. If collection is done from the ground, only those that have fallen the same day should be collected.

Processing and handling

After harvest the fruits should be transported to the processing unit without delay.

The fruits can be pre-dried on open trays in well ventilated, shaded areas for a few days and then transferred to full sunlight for 2 days or until the seeds are released. Another practice is to expose the fruits to sunlight for 4-6 hours daily for 6 days. It is important that the seeds are not dried too quickly or else they may lose viability.

Seeds are dewinged mechanically, e.g. in a cement mixer and then cleaned by winnowing. 3 litres of fresh fruits weigh about 1 kg. 50 lt of fruits yield about 1.4 lt of seed. Seed weight makes up some 4-6% of the fruit weight.

Storage and viability

Seeds are orthodox. Viability is short at ambient conditions but can be extended to at least 3-4 years when stored in airtight plastic bags at 2-5°C and a moisture content of 6-8%. Well-dried seeds (6-8% mc) stored in paper bags show no decrease in germination after 3 months, irrespective of the temperature during storage. For long term storage -13°C is recommended.

Dormancy and pretreatment

There is no dormancy but germination of dry stored seed may be faster by soaking in warm water for 12-24 hours before sowing.

Sowing and germination

Sowing is done directly in containers or broadcast in seedbeds and covered with a thin layer of soil. Where there is adequate moisture, shade is not necessary and increases the risk of damping-off. Germination is epigeal. Optimal temperature for germination is 25-30°C, but seeds can germinate at 15°C.

Collection and transplanting of wildlings is also used. In the Philippines, collected wildlings had a survival rate of 94% and after some months had a shorter taproot and more lateral roots than the original seedlings growing under the mother tree.

In Indonesia, 20 cm tall stumps with a diameter of 1-2 cm, planted at a depth of 10 cm showed nearly 100% survival.

Phytosanitary problems

Seedlings are susceptible to damping-off caused by e.g. *Rhizoctonia*, *Pythium* and *Fusarium* spp.

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Natural regeneration of *C. odorata* in coffee plantation, Costa Rica. Photo: David Boshier, OFI.

THIS NOTE WAS PREPARED IN COLLABORATION WITH CENTRO AGRONÓMICO TROPICAL DE INVESTIGACIÓN Y ENSEÑANZA

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Ceiba pentandra (L.) Gaertn.

Taxonomy and nomenclature

Family: Bombacaceae

Synonyms: *Bombax pentandrum* L., *Ceiba casearia* Medik., *Eriodendron anafractuosum* DC.

Vernacular/common names: kapok, cotton silk tree (Eng.); kapokier (Fr.); kapokbaum (Germ.); ceiba, ceibo (Sp.);

Distribution and habitat

Natural occurrence from 16°N in the United States, through Central America to 16°S in South America. Common on coastal plains up to 500 m altitude, with annual precipitation of 1000-2500 mm and temperatures from 20 to 27 °C. A light demanding pioneer, found in moist evergreen and deciduous forests; also in dry forests and in gallery forests.

Cultivated widely in the tropics between 16°N and 16°S. Can grow on a variety of soils, from sand to clay soils provided they are well drained. Prefers alluvial soils, slightly acidic to neutral. Tolerates drought and for shorter periods temperatures below zero; sensitive to fire. At the time of fruit setting, temperatures below 15°C can be detrimental.



Fruiting branch and flowering branchlet. From: Plant Resources of South-East Asia

Uses

The fibre makes an excellent material for a number of purposes, the foliage is used for fodder and oil is extracted from the seeds and used industrially. The tree is an important source of honey and also suitable for soil erosion control and watershed protection. In agroforestry it is grown with coffee, cacao, and in Java as support for pepper trees. In India it is used in taungya systems.

The wood is very light with specific gravity of 0.24 g/cm³. When dry, the colour varies between grey and yellow, with white parts. The grain is interlocked, the texture coarse, lacking luster and shape. The porosity is diffuse and the pores large. It has a high natural durability, is easy to work and preserve. Used for boxes and crates, plywood and pulp and paper products.

Botanical description

Tall tree, 25-70 m with a diameter of 100-300 cm. The trunk is cylindrical to slightly convex. Crown spherical to round, with bright green, open foliage; branches verticillate and abundant, sloping upwards; the bark is smooth to slightly fissured, pale grey with horizontal rings, protruding lenticels and sharp prickles that are irregularly distributed on the upper part of the trunk.

The leaves are digitally compound, alternate and clustered at the end of the branches. Petioles 5-25 cm long, partly red towards the base, slender and glabrous. 5-9 leaflets, 5-20 cm long, 1.5-5 cm wide, lanceolate to oblanceolate, apex acuminate, base cuneate, margin entire, dark green on upper side, pale green on lower side, glabrous.

Flowers in pendulous fascicles, clustered at the tip of the twigs; hermaphroditic, whitish, large. The calyx is bell-shaped, 1 cm long, with 5 to 10 short lobes; corolla 3-3.5 cm long, with 5 lobes, white to rose coloured, covered with silky hairs; stamens 5, united into a column at the base, longer than the petals; pistil with superior ovary, style long and curved near the apex, stigma enlarged.

Fruit and seed description

Fruit: a leathery, ellipsoid, pendulous capsule, 10-30 cm long, 3-6 cm wide, rarely dehiscent on the tree. Capsules split open into 5 valves, revealing a mass of grey woolly hairs in which the 120-175 seeds are embedded.

Seed: black or dark brown, covered with wool. Oil content 20-25%. There are 10,000-45,000 seeds/kg depending on provenance.

Flowering and fruiting habit

The flowers are pollinated by birds, bats and bees. Flowering takes place Dec-Jan in Honduras, Nov-Jan in El Salvador. Fruiting Mar-Apr in Honduras, Jan-Apr in El Salvador. The trees will normally begin to produce fruits when they are 4-5 years old.

Harvest

When the fruits have turned dark brown, they can be collected from the ground or cut from the tree using hooked knives. 600-900 fruits per tree has been reported.

Processing and handling

The fruits are left on sieves or in boxes to dry in the sun 3-4 hours every day for 2-3 days until they open. Extraction and cleaning is done manually by shaking the fruits in a bag.

Storage and viability

The seeds are probably orthodox. They contain large amounts of oil that tend to go rancid quickly and the viability diminishes rapidly. When the seeds are stored at 10-12 % moisture content in hermetically closed plastic bags at 15°C, they retain viability for 5-6 months.

Dormancy and pretreatment

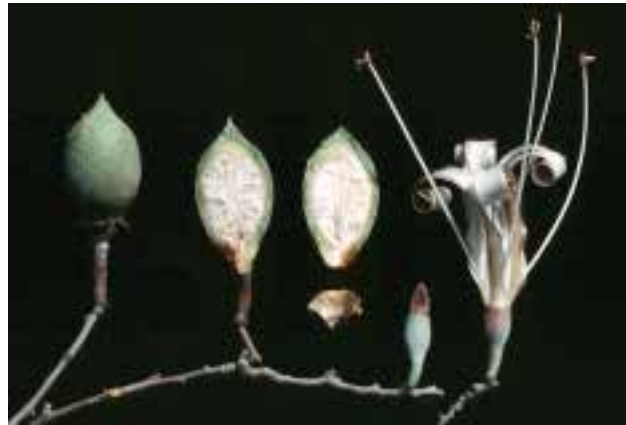
Immersion in boiling water for 1 min and then left in the cooling water for 24 hours has been reported to improve germination.

Sowing and germination

The seeds are sown in seed beds or in sand boxes in a greenhouse. Fresh seeds normally germinate 90-95%. When the first pair of leaves appears and the seedlings are 12-15 cm, the roots are pruned and the seedlings transferred to polybags. The plants are ready for planting in the field 4-6 months after sowing when they are 30-35 cm tall. Easy to propagate vegetatively by cuttings.

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Young fruits and flower. Photo: Duncan Mcqueen, OFI

THIS NOTE WAS PREPARED IN COLLABORATION WITH CENTRO AGRONÓMICO TROPICAL DE INVESTIGACIÓN Y ENSEÑANZA

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Commiphora africana (A. Rich.) Engelm.

Taxonomy and nomenclature

Family: Burseraceae

Synonym: *C. pilosa* Engl.; *C. calcicola* Engl. *Hendelotia africana* A. Rich.

Vernacular/common names: African myrrh, poison-grub commiphora (English); mbambara, mponda, mturituri, mtwitwi (Swahili); angka, gafal (Arabic); harige kanniedood (Afrikaans); dabba'un'un, hammersagara (Somali).

Distribution and habitat

Commiphora africana has a widespread native distribution throughout dry zones in Africa south of the Sahara, with rainfall between 300 and 800 mm. It occurs naturally in Angola, Botswana, Burkina Faso, Chad, Eritrea, Ethiopia, Kenya, Mali, Mauritania, Mozambique, Namibia, Niger, Senegal, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe

It is a typical species of the dry savannah (*Acacia-Commiphora* bushland). It is primarily a plane and lowland species growing up to 800 masl; occasionally, however, found up to 1600 masl. Occurs in areas with 300-800 mm mean annual rainfall. In the savannah it occurs on a variety of soil types often rocky sites, lateritic crusts and sand. Although it is found on clay, it does not do well on stiff types like vertisols.

Uses

An important multipurpose tree species in an otherwise poor environment. The species mostly used as a fodder species especially for camels and goats, at the end of the dry season when the tree busts into leaf before most other trees and before new grass sprouts. The species is most important for nomadic pastoralists in the Sahel. Wood is termite resistant and has all-round use as utility construction timber and for household implements. Fruits, bark and roots have alleged medical properties and are used in local medicine. Fruits are used for treatment of typhoid fever and as a remedy for stomach problems while bark powder is mixed with porridge and taken as cure for malaria.

In sedentary agroforestry systems the species may be used as fodder species as well as for live fences and hedges.

Botanical description

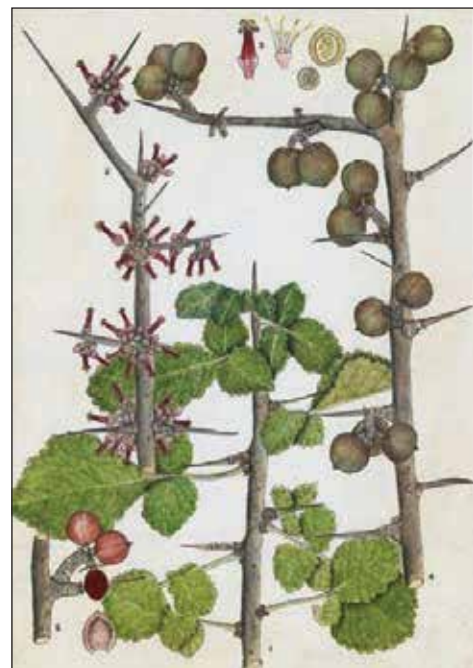
Commiphora africana is a deciduous shrub or small tree, rarely exceeding 5-10 m. It is low branching with a short trunk and rounded crown. Branches grow upwards, then spreading horizontally. Branches possess long spines from modified branchlets. Bark grey-green, peeling off in papery roles or scales revealing green under-bark. Leaves trifoliate with 1½-2 cm long petiole. Leaflets crenate, hairy under the margin and below; base cuneate. Terminal leaflet up to 4 long and 2½ cm wide; the two side leaflets smaller.

Flowers in axillary clusters of 4-10. Individual flowers are small, about 5-6 mm long, red with 4 free petals forming a corolla tube.

Fruit and Seed description

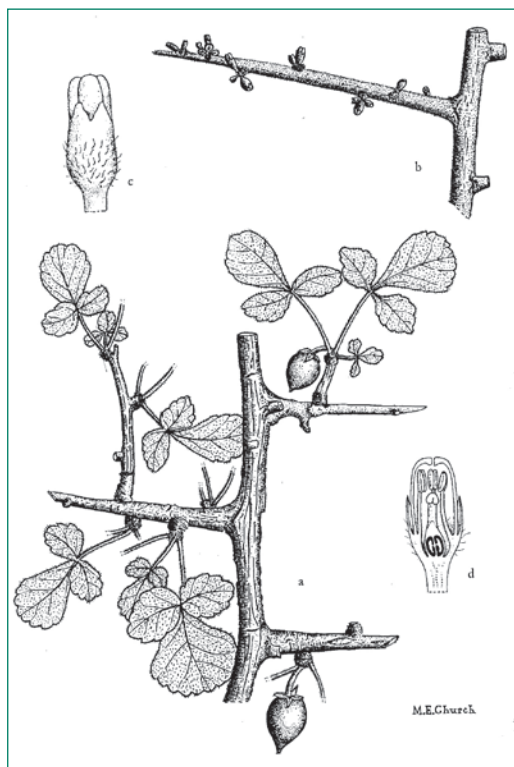
Fruit: Fruit an ellipsoid drupe, reddish, 8-10 mm long, 6-8 mm across, with short peduncle. The fruits split open when dry and expose a hard, furrowed stone embedded in a red, resinous flesh.

Seed: The seed handling unit is the pyrene / stone with enclosed morphological seed. The stone is about 4-5 mm long with a rough surface. There are about 8000 seeds per kg.



Flowering and fruiting habit

Flowering occurs at the beginning of the dry season usually before the leaf flush. Flowering and fruiting are irregular and do not occur every year. Pollination by insects. The seeds are dispersed by animals and birds.



Shots, leaves, flowers and fruits of *Commiphora africana*. From Dale and Greenway 1961.

Harvest

Fruits must be harvested from the tree when they start to split open. Fruit crop often sparse and currently removed by birds. Long handled tools are used to cut down fruits as tree spines makes climbing highly unpleasant.

Processing and handling

The stones are extracted by removing the exo- and mesocarp. The fruit is relatively dry and dry extraction is easiest, e.g. by rubbing seeds between rough surfaces.

Storage and viability

The seeds are orthodox, can presumably be stored for several years at room temperature. Cold storage prolongs longevity.

Dormancy and pretreatment

Imbibition is restricted because of the hard endocarp. Various methods to accelerate imbibition by surface treatment (e.g. acid) may work but is not reported in literature.

Sowing and germination

Germination is hypogeal.

Propagation

Means of propagation: Stakes, large cuttings or seeds. It is easy to propagate with cuttings

Selected readings

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Cordia africana Lam.

Taxonomy and nomenclature

Family: Boraginaceae

Synonym: *C. holstii.*, *Cordia abyssinica* R.Br

Vernacular/common names: East African cordia, large-leafed cordia, Sudan teak (English) Maku-mari, Muringa (Kikuyu); Samotet (Nan), Gambil (Arabic), Makobokobo (Swahili).

Distribution and habitat

C. africana is native to eastern and southern Africa including Angola, Democratic Republic of Congo, Djibouti, Eritrea, Ethiopia, Ghana, Guinea, Kenya, Malawi, Mozambique, Saudi Arabia, South Africa, Sudan, Tanzania, Uganda, Yemen, Zimbabwe, Altitude range 550-2,600 masl, mean annual rainfall 700-2 000 mm.

The species occur at medium to low altitudes, in woodland, savannah and bush, in warm and moist areas, often along riverbanks. It is frost tender. It will grow in drier conditions but thrives in good rainfall areas and is scattered in occurrence. It occurs in afro-montane rainforest and undifferentiated afro-montane forest (mixed Podocarpus forest), usually along margins and in clearings. It is an early colonizer in forest regrowth. It is often left when forests are cleared for cultivation, as the tree is an excellent shade tree for crops. Also found in riverine forest and secondary bushland, transgressing into humid types of woodland. In West Africa, this species seems to be restricted to montane and submontane habitats; it has limited distribution in the lowland habitats of the Democratic Republic of Congo.

Uses

Mature fruits have a sweet, mucilaginous, edible pulp. Leaves provide fodder for the dry season. The species provides good bee forage, as the flowers yield plenty of nectar. Beehives are often placed in the trees.

Fuel: Trees are a good source of firewood. The heartwood is pinkish-brown, reasonably durable, relatively termite resistant; it works easily and polishes well but is often twisted and difficult to saw. It is used for high-quality furniture, doors, windows, cabinet making, drums, beehives, joinery, interior construction, mortars, panelling and veneering.

Medicine: The fresh, juicy bark is used to bind a broken bone; this splint is changed occasionally with a fresh one until the bone is healed.

C. africana is planted as a shade tree in coffee plantations; it is usually left in the fields, as it provides excellent shade for crops. Leaf fall in the dry season is heavy, and the leaves make good mulch. Trees are planted in amenity areas.



Flowering branch, From Dale and Greenway 1963

Botanical Description

C. africana is a small to medium-sized evergreen tree, 4-15 (30) m high, heavily branched with a spreading, umbrella-shaped or rounded crown. Bole typically curved or crooked. Bark greyish-brown to dark brown, smooth in young trees, but soon becoming rough and longitudinally fissured with age; young branchlets with sparse long hairs. Leaves alternate, simple, ovate to subcircular, 7.5-17.5 (max. 30) cm long, 3.5-10.2 (max. 30) cm broad; thinly leathery; dark green above, paler green and velvety below; with

prominent parallel tertiary net-nerves (about 7 pairs of lateral nerves); apex broadly tapering or rounded; base rounded to shallowly lobed; margin entire; petiole slender, 2.5-7.6 cm long. Buds oval, stalkless, pleated open into flowers that are bisexual, white, sweet scented, shortly pedicelate or sessile, massed in compact panicles covering the crown, with a white mass of attractive flowers; calyx less than 1 cm long, strongly ribbed, back of lobes covered with short, soft, brown hairs; corolla lobes crinkled, white, long-exserted, funnel-shaped, about 2.5 cm long; cymes many flowered.

Fruit and Seed description

Fruit: a drupe, smooth, spherical, oval tipped, fleshy, 1.3-1.5 cm long; green when young, yellow to orange when mature; with a sweet, mucilaginous pulp and short remains of the calyx at the base; contains 2-4 seeds.

Seed: Seed is the pyrene/ stone / endocarp enclosing the morphological seed. Seeds lack endosperm. There are about 18,000 seeds/kg.

Flowering and fruiting habit

Flowering starts when trees are 3-5 years old. In Sudan, flowering occurs in October to December and fruiting from January to April; in Kenya, flowering is from April to June. It is repeated at intervals over several weeks and is evidently triggered off by rain showers. After pollination by insects, fruit development takes a period of almost 6 months. Fruit is eaten and probably dispersed by birds.

Harvest

Fruits are collected by shaking or pruning fruit bearing branches onto a tarpaulin.

Processing and handling

The fruits should be depulped immediately after collection by rubbing over a wire mesh under running water. Sometimes it may be recommendable to mix the fruits with fine sand to accelerate extraction of the sticky pulp from the seeds. The pulp and the stones are separated by floating water. After extraction the stones can be dried in the sun 6-8 % moisture content.

Storage and viability

Seeds have orthodox (desiccation tolerant) storage behaviour. Seeds can be stored for at least 1 year in hermetic storage at 3°C with no loss in viability.

Dormancy and pretreatment

Seeds are soaked in cold water for 6 hours and germinate within 40-60 days under ideal conditions; expected germination rate of mature healthy seed lots is 50-80 %.

Sowing and germination

Seedlings require 4-6 months in a nursery before planting out.

Selected readings

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Cordia alliodora (Ruiz & Pavón) Oken.

Taxonomy and nomenclature

Family: Boraginaceae

Synonyms: *Cerdana alliodora* Ruiz & Pav., *Cordia alliodora* var. *boliviana* Chodat & Vische, *C. alliodora* var. *glabra* DC., *C. andina* Chodat, *C. cerdana* (Ruiz & Pav.) Roem. & Schult, *C. gerascanthus* auct. non L., *C. goudoti* Chodat, *C. macrantha* Chodat, *C. velutina* Mart., *Lithocardium alliodorum* (Ruiz & Pav) Kuntze, *Varronia tuberosa* Sesse & Moc.

Common names: Spanish elm, cordia (Eng.); laurel (Sp.); salmwood (trade name)

Distribution and habitat

Widely distributed in tropical America from Mexico to Argentina and in the Caribbean islands. It can be found up to 2000 m altitude but is more abundant at lower altitudes. Prefers humid tropical forests with annual precipitation of 2000 mm or more and mean temperature above 23 °C, but is also common in dry areas with less than 1000 mm/yr. Best growth is achieved on well drained soils.

Botanical description

Deciduous tree, 20 - 45 m high and 30 - 75 cm in diameter; bole straight. Bark greyish, 8-15 mm thick, rough, with fissures forming squares. Leaves simple, alternate. Leaf elliptic-oblong, 10-20 cm x 2-7 cm.

Inflorescence a terminal panicle. Flowers small, 8-12 mm, white. The corolla is persistent and serves as an agent of wind dispersal when dry.

Uses

The wood is valuable, used for carpentry, furniture, cabinets, flooring, panelling and has potential for being used in paper production.

Also used in agroforestry where it is grown with coffee and cocoa. Flowers and fruits are used in medicine and the leaves in ointments and tonics.

Fruit and seed description

Fruit: brown at maturity, 1 cm long, 6 mm wide. Floral parts persistent.

Seed: white, 7 mm long, 5 mm wide. Seed weight is variable. In Costa Rica 80,000-15,000 seeds/kg is typical while it is 20,000-60,000 seed/kg in Colombia.

Flowering and fruiting habit

The flowers have a nectariferous disk and are pollinated by butterflies like the other species in this genus; self-pollination is rare. Flowering begins when the tree is only 2-3 year old and viable seed is produced from its 5th year. A large canopy tree can produce as much as 10 mill flowers and 1 mill seeds in a year.

In Mexico, Central America and the Caribbean, flowering generally starts about December and may extend through to April, whereas at the southern end of its range, flowering starts in January. In places like Colombia, where the climate is less seasonal, flowering all year is common.



1, Flowering branch; 2, vertical section through flower; 3, fruit. From: Plant Resources of South-East Asia. No. 1. 1. Auxiliary plants.

Harvest

Timing the collection is critical to ensure high germination in this species. The fruits are mature when they are of the same light brown colour as the persistent corolla. Tests have shown that when they turn darker brown, viability is reduced. The optimal time for harvest is when the fruit changes colour from yellow to brown. As a rule of thumb, collection from the tree should wait until two weeks after the last flowers have opened.

To test seed maturity the seed is removed from the calyx and squeezed at the point of the shrivelled style to remove the embryo. The seed is mature when the embryo is hard, like a grain of rice, but immature if the embryo is still soft and translucent. Seed collected too soon before natural fruit fall have low germination.

The tree can be climbed with ladders or spurs. Small branches with mature fruits are cut and caught on a sack or tarpaulin before they hit the ground. One tree can produce up to 8 kg fruit, but the normal yield is 0.5-3 kg.

Processing and handling

Immediately after harvest the fruits are transported in jute sacks to a well ventilated storeroom where they are spread out on tarpaulins. The moisture content at harvest varies from 10 to 40%. The fruits are dried in shade, or at most 3-4 hours a day in the sun, until they reach a moisture content of 7-10%. Shade drying typically takes four to six days. The fruit is separated from the floral parts by shaking and finally washed.

Storage and viability

The seed is orthodox, but if not stored properly it loses viability fast. It is especially important to use bags that are completely airtight, either heavy plastic or aluminium.

In Costa Rica experience is that after two weeks at room temperature the germination is down to 40%. Best storage is at 5°C and moisture content 7-10%. An experiment from Colombia showed that seed stored at 5°C and 8.5% moisture content retained 76% germination after 14 months.

Dormancy and pretreatment

Pretreatment is not necessary.

Sowing and germination

Germination begins two weeks after sowing and is finished after 6 weeks. Germination is typically 50-60%. The seeds can be sown in bags or in sandbeds and transplanted to bags after germination.

In Costa Rica seeds are sown in boxes with sterilised sand, and 22 days after germination the seedlings are transplanted to shady beds at 25 x 25 cm distance. After 5-6 months the plants are planted out. Propagation by pseudo-grafting is often used in Costa Rica.

In Columbia sowing in a mixture of dark soil, sand and rice husks in the ratio 2:1:1 resulted in a germination of 80% after 10-20 days. Seeds can be broadcast or sown in 1-1.5 cm deep furrows.

Phytosanitary problems

Seed are predated prior to dispersal by bruchid beetles (*Amblycerus* spp.), with as much as 50% of seed killed, although levels of attack vary between trees and years. The larvae eat the developing seed embryo and attacked seed are distinguished by the round hole left in the calyx by the emerging adult beetle.

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A wet zone population in a 14-year-old provenance trial, Tumaco, Colombia. Photo: David Boshier, OFI

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Dalbergia melanoxylon Guill. & Perr.

Taxonomy and nomenclature

Family: Leguminosae

Synonyms: *Amerimnon melanoxylon* (Guill. & Perr.) Kuntze, *A. stocksii* (Benth.) Kuntze, *D. stocksii* Benth.

Vernacular/common names: African blackwood, African ebony¹ and zebrawood. Its local names: abanus, mpingo (Swahili), mwengo (Meru), Kissikiinde (Mooré), opok (Luhya), mugembe (Kinyamwezi), babanous, kelto (Arabic).

Distribution and habitat

The species is widespread in tropical Africa, from Senegal and Cote d'Ivoire in the West, to Kenya and Ethiopia in the East, and extending South to South Africa. It is found in at least 26 sub-Saharan countries, and is often grown outside its native area, e.g. in India and Sri Lanka. It occurs in the Sudanian savannah on humid rocky soils near swamps or temporary rivers. It is also found in deciduous woodland, in coastal bushland and wooded grassland, where the soils are sufficiently moist. Minimum annual rainfall > 400 mm. On dry sites it grows on poorly drained soils. It grows from low altitudes of up to 1400 m. Its range of distribution has been reduced due to timber exploitation. It is listed as a threatened species in e.g. Burkina Faso. Its natural regeneration is erratic, and it is slow growing.

Uses

Dalbergia melanoxylon wood has characteristically thin external yellowish white sapwood and internal purple heartwood. The hard, heavy wood is fine-grained, resistant to insect attack and is one of the most valuable timbers in Africa. The timber (mpingo) is widely used in carpentry, construction, musical instruments, walking sticks, furniture, tool handles and art work. It is mainly the intensive exploitation of its wood, which makes it endangered in Kenya. The foliage is used as forage and fodder for animal and pods are eaten by livestock. The species has various local medicinal uses (bark, roots and leaves) as well as many magic-religious uses.

Botanical description

Dalbergia melanoxylon is a small spiny deciduous tree or shrub. Most individuals are 5-7 meter high, multi-stemmed, branched with a low, irregularly shaped crown. Trees can occasionally grow to 20 meters. Young branchlets whitish grey with dense white lenticles; older bark pale grey, becoming fissured or flaked with age; the slash is orange-pink. The 0.5-5 cm long, straight thorns are the hardened tips of short branches. The stipules are leaf-like, about 5 mm long, and fall very early. Leaves are alternate, imparipinnate, 5-20 cm long with 4-6 pairs of alternate or subopposite leaflets, plus the terminal one. Leaflets variable in shape and size; they are mostly obovate, with a broadly cuneate to subcordate base, and a truncate or emarginated apex, 1-5 by 0.7-3 cm with a 4-7 mm long petiole.

The white, sweetly scented asymmetrical flowers are 5 mm long, with a slightly pubescent calyx, and usually 9 stamens. The 3-12 cm long, laxly branched and many flowered panicles appear with the new leaves.



Dalbergia melanoxylon, 1. flowering branchlet, 2. fruiting panicle, 3. flower, 4. staminal sheath, 5. immature fruit. From: Kenya Trees and Shrubs, Dale and Greenway 1961.

¹ Note: Ebony is a trade name of *Diospyros* spp., but occasionally used for other species with dark or blackish wood.

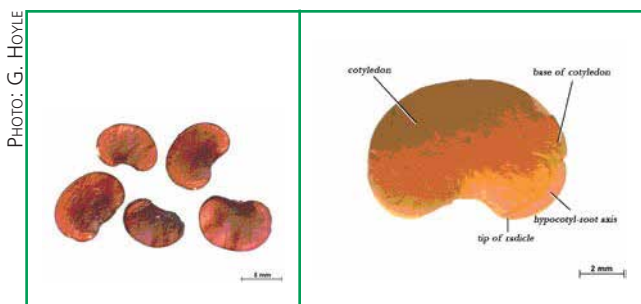
Flowering and fruiting habit

Flowering occurs in the second part of the dry season or with the first rains when the leaves open; in southern Africa, for example, this is in October to December. Flowers are hermaphroditic and pollinated by insects. Fruit development from pollination to maturity takes about 6-8 months. In southern Africa the fruits are mature between January and March, in Tanzania fruit are collected between May and June.

Fruit and seed description

Fruit: Elliptic-oblong or irregularly oblong, flattened, indehiscent pods, grey when mature, 3-7 by 0.8-1.4 cm. Each pod usually contains one seed, but can contain up to 4 seeds. More-seeded fruits are constricted between the seeds.

Seed: The seeds are reniform (kidney shaped), laterally compressed, smooth and 7.5-9.5 long, 4.8-6.3 mm wide and 0.5-0.7 mm thick. The mean fresh seed mass varies between 0.06 and 0.17 g (TSW = 60 to 170 g). The seeds are very fragile when dry and difficult to separate from the pod. Mature seeds are brown / black and can easily be selected from the immature white ones. The seeds have a thin seed coat, small hilum and very short raphe. The endosperm is non-ruminate, and the embryo is yellow.



D. melanoxylon seeds.

Harvest

The pods remain on the trees for some time after maturity; however, the seeds are prone to insect infestation and therefore should be harvested as soon as they are ripe. Pods are collected by shaking the branches to detach the pods.

Processing and handling

Pods should be sun dried after harvest. Cut tests or X-ray can assess the degree of insect infestation. Seed extraction is very tedious; therefore, pods are typically broken and pieces containing one to several seeds are sown. This procedure implies that empty segments of pod may be obtained. However, it is not possible to

visually determine whether a pod is empty, but full seed extraction is not recommended because of the fragility of the seeds.

Storage and viability

Seed storage behaviour is »orthodox«. Viability can be maintained for several years in hermetic storage at 3°C with 9-12% moisture content. Seeds stored in a cool room at 4-5°C maintained viability of 84% germination after three years. Seeds of this species have been stored at the MSB since 1990 with recent X-ray analysis indicating about 90% viability.

Dormancy and pretreatment

Seeds exhibit no or only slight physical dormancy. Soaking seeds in water at room temperature for 24 h or removing the covering pod before sowing improves their germination.

Sowing and germination

Germination is epigeal. Under optimum conditions seeds germinate in 8-20 days. Growth is fairly slow, with the plant reaching 4 m after c. 7 years.

Selected readings

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Dalbergia sissoo Roxb. ex DC

Taxonomy and nomenclature

Family: Fabaceae (Papilionoideae)

Synonyms: *Amerimnon sissoo* (Roxb. ex DC.) Kuntze

Vernacular/common names: shisham, sissoo, sisu, tahli, Indian Rosewood.

Distribution and habitat

The area of natural distribution is the foothills of the Himalayas from eastern Afghanistan through Pakistan and India to Nepal. It is a primary coloniser of new alluvial soils along riverbanks and forms forest, either pure or mixed with other species. It often occurs in association with *Acacia catechu* (khair-sissoo forest).

It is primarily found below 900 m altitude but ranges naturally up to 1500 m. It tolerates temperatures from below 0°C to nearly 50°C. In its natural range the annual rainfall varies from 750 to 4500 mm concentrated in 4-5 months followed by a long dry season. It can survive with only 400 mm rain/year but best growth is achieved with 1000-1700 mm rain.

It does not tolerate heavy clays, shallow soils or waterlogging. It is sensitive to fire and even light fires will damage the trees. The natural populations of *D. sissoo* have been selectively logged for several hundred years which has led to a seriously depleted gene pool.



Foliage, flowers and fruits. Copyright: United States Department of Agriculture Forest Service Collection Hunt Institute for Botanical Documentation, Carnegie Mellon University, Pittsburgh, PA.

Uses

Sissoo is one of the most useful multipurpose trees of South Asia.

It is mainly grown for the timber which is among the finest for cabinets, furniture and veneer. The heartwood is golden to dark brown, with density of 0.7-0.8 g/cm³ (at 12% mc), extremely durable and resistant to termites.

The wood is excellent for fuelwood and charcoal. The calorific value of the sapwood is about 4900 kcal/kg, heartwood about 5200 kcal/kg. The sapwood is also used for pulp.

Leaves, young shoots and green pods are an important source of fodder. The leaves contain up to 24% crude protein (dry weight basis) and dry matter digestibility is about 56%. The fodder value is highest in April and May when other sources of green fodder are scarce.

The species is nitrogen fixing and used in agroforestry systems with many crops. Although sissoo trees can negatively effect crop production due to competition for nutrients, moisture and light, studies have shown that the net value of intercropping sissoo and wheat is higher than wheat monocropping.

It provides shade and shelter and is used as such in mango, tea and coffee plantations. Its habit of developing root suckers and runners makes it useful for erosion control.

Apart from the above, sissoo provides other minor products (e.g. honey) of high economic importance. The ease of propagation by self-seeding, coppice, root suckers and stumps and the many environmental and socio-economic benefits makes it one of the most valued tree species by farmers in the region.

Botanical description

Medium to large deciduous tree, much-branched and slender, normally with crooked bole. It can grow up to 30 m tall but is usually smaller. Bark is pale grey fairly rough with shallow fissures and peeling off readily.

Leaves normally about 15 cm long and compound; 3-5 leaflets increasing in size upwards, the terminal one up to 6 cm long.

Flowers bisexual, small, pale yellow, in 10-15 cm long panicles that are conspicuously hairy when young. Fruits hanging in dense clusters at the ends of the shoots.

Fruit and seed description

Fruit: the fruit is a light brown indehiscent pod, 5-9 cm long, 10-12 mm wide, thin and glabrous and with conspicuous veins. There are 1-5 seeds / pod.

Seed: kidney-shaped, 8-10 mm long, 4-5.5 mm wide, pale brown to almost black, flat and with thin testa. There are 40000-55000 seeds per kg.

Flowering and fruiting habit

Within the area of natural distribution the leaves are shed in November-December and new leaves appear in January-February. The first flowers appear together with the new leaves and in March-April the flowers open. By the end of April, young green pods appear and in October when the dry season sets in the fruits begin to ripen.

The flowers are pollinated by bees, thrips and other insects.

Seed production starts when the trees are 3-4 years old and normally a good crop is produced every year with yields of 1-3 kg per tree.

Although results have been conflicting, the most recent results point to the species being partial selfing and partial outcrossing, a type of breeding system often found in pioneer species. The rate of outcrossing has been estimated to 60-90%, it varies between populations and for the single population over time.

Harvest

Ripe fruits can be harvested from December to March. The fruits should be collected from the tree by climbing or by shaking the fruits onto a tarpaulin on the ground. It is not advisable to collect from the ground as the seeds are often infected. 1.25 kg pods contain about 1 kg seed.

Processing and handling

After collection the pods are dried in the sun and when dry, broken in segments each containing one seed. The segments are then cleaned by winnowing to remove empty pieces of pods.

Storage and viability

The seeds are orthodox and when properly dried and stored in airtight containers they will retain high viability for several years even at room temperature, longer if stored at 5°C.

The seeds can be infested by the pea beetle, *Bruchus pisorum*. Infestation is initiated in the field but breeding can continue during storage.

Dormancy and pretreatment

The seeds are not hardcoated and scarification is not necessary. Soaking for 24-48 hours in cold water before sowing improves germination.

Sowing and germination

The seeds (pod segments) are sown in March-April in lines in raised seed-beds and watered two times every day. Germination starts after about one week and is completed in about three weeks. The germination rate is typically 60-80%. When the seedlings are about 5 cm tall they are transplanted into containers. For production of stumps, 12-16 months are required in the nursery.

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27-year-old planting of *Dalbergia sissoo* in northern India. Photo: H. Keiding, DFSC.

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Dovyalis abyssinica (A. Rich) Warb

Taxonomy and nomenclature

Family: Flacourtiaceae

Synonym: *Aberia abyssinica* Clos

Vernacular/Common names

Mukambua, Ngambua (fruit) (Kamba), Mukambura, Ngambura (fruit), (Kikuyu), Akutho, Songola (Luo), Olmarogi, Olmorogi (Maasai).

Distribution and habitat

Dovyalis abyssinica is a shrubby tree occurring naturally from Ethiopia, Erithrea and Somalia in the north through Kenya and Tanzania to Malawi in the south. In Kenya it is found on Mt. Kulal, Nyambene Hills, Taita Hills, the central highlands, and Loita Hills highlands in Rift valley province. It is found up to 2,700 masl. It grows in upland rainforest, dry evergreen forest, on riverbanks and sometimes in more open woodland. Sometimes it is found as a remnant tree or shrub in coffee plantations. It is common on red soils.

Uses

The fruit is edible (eaten raw), but very acidic. It is used for making jam, and added to porridge as a flavouring. Roots and stem are good for making soup. The roots also have medical properties with alleged effect on gonorrhoea, bilharzias, stomach-ache and fever. The leaves provide fodder for livestock, primarily goats and sheep. Flowers attract bees and the plant is often used as a live fence.

Botanical description

Dovyalis abyssinica is a spiny evergreen shrub or tree, up to 5m height, with a rounded crown. The bark is ash grey, almost always supporting lichens. Branches armed with stout spines, up to 1½ cm long. The branchlets are covered with numerous dotted pores (lenticels). Leaves are oval to obovate, up to 5-7 cm long and 3 cm wide with a rounded tip, edges unevenly rounded. Shiny, dark green, with reddish stalks and veins. Flowers are unisexual, yellow-green or greenish without petals, 5-7 mm long. Female flowers single or in 2-3 flowered fascicles. Male flowers in clusters, with 40-60 stamens.



Photo: Paul Juma

Dovyalis abyssinica leaves and inflorescence (female flowers)

Fruit and Seed description

Fruit: The fruit is a round globose berry, about 2 cm diameter with persistent calyx, green and hairy when young turning smooth and orange-yellow at maturity. Pulp edible sweet-sour. 4-5 seeds.



Photo: J.K. Kamba

Dovyalis abyssinica fruits

Seed: Light brown, laterally flat, disc-shaped, flat about 0.5 cm diameter, rough surface and soft seed coat. There are 30,000-40,000 seeds in a kilogramme; seed weight depends on provenance and the climatic conditions during the ripening period.



Dovyalis abyssinica seed

Flowering and fruiting habit

The tree is dioecious. The flowering season occurs during the beginning of the long rainy season between March and April while fruits mature between August and September. Pollination is by insects e.g. bees. Fruit development from pollination to maturity takes about 4 months.

Harvest

The mature yellow-orange fruits are collected by hand picking or shaking branches to release fruits.

Processing and handling

Ripe fruits can be squeezed by hand, otherwise fruits are rubbed gently on fine wire mesh/screen, then washed in running water to remove mucilage. Seeds are dried under controlled conditions.

Storage and viability

The seed exhibit orthodox to intermediate storage behaviour. Freshly extracted seeds often have a moisture content of up to 40-50 %. Seeds should be dried to moisture content of <10%. Initial drying under shade and regularly turning to avoid overheating. Dry seed

can be stored in airtight containers (plastic or glass jars, or aluminium packets) in a cool dry place for short to medium term storage. For long-term storage, e.g. conservation, seeds can be stored at sub-zero temperature for many years with no significant loss of viability.

Dormancy and pretreatment

Fruit pulp presumably has chemical inhibitors and thorough washing is recommended during processing in order to remove possible remnant inhibitors. The seed has a soft seed coat and therefore needs no pre-sowing treatment.

Sowing and germination

The seeds can be sown in seed beds or containers. Under optimal conditions they attain germination in 9-30 days. A test with fresh seed with moisture content of 53% showed 92% germination.

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Dovyalis caffra (J.D. Hook & Harvey) Warb.

Taxonomy and nomenclature

Family: Flacourtiaceae

Synonyms: *Aberia caffra* Harvey & Sond.)

Vernacular/common names: kei apple, dingaan' s/ wild apricot.

Distribution and habitat

Native to southern Africa where it grows in open bush and wooded grassland, often in *Acacia* woodland and frequently associated with termite mounds. Introduced to other African countries, Australia, southern USA, Middle East and in Europe to the Mediterranean countries.

It is found at 800-1200 m altitude but in Kenya it grows at 2450 masl. Thrives in deep, well-drained, loamy or sandy soil to which compost has been added.

Uses

Mainly grown for fencing and for the edible fruits which are rich in vitamin C. They can be eaten fresh or used for jelly and jam. The fermented pulp has herbicidal properties. When it is grown for fencing, the branches must be intertwined early and trimmed regularly.

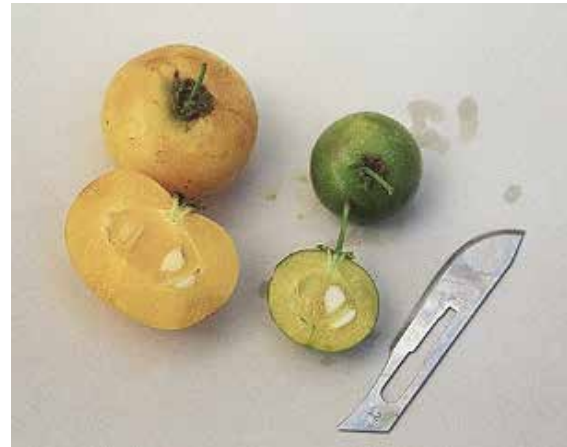


Foliage. Photo: Kirsten Thomsen, DFSC.

Botanical description

A shrub or small tree, usually 3-5 m tall, sometimes reaching 8 m. The bark is grey and smooth, later flaking into square sections; branches are armed with stout spines up to 6 cm long.

Leaves are normally arranged in clusters on dwarf branches, 2-5.5 cm long with entire margins that are slightly rolled under. Flowers creamy-green, small, in dense clusters, seen more as a mass of stamens.



Ripe (left) and immature fruits. Photo: Kirsten Thomsen, DFSC.

Fruit and seed description

Fruit: almost round, fleshy berry up to 4 cm in diameter, orange when ripe. There are 5-10 seeds/fruit.

Seed: small, rounded or crescent-shaped. There are 25,000 – 45,000 seeds/kg.

Flowering and fruiting habit

Monoecious species, pollinated by insects. Seed production begins when the tree is about 3 years old. In southern Africa flowering and fruiting occur November-January. In Tanzania fruits are ripe in February-March.

Harvest

Collection takes place when the fruits have changed colour from green to yellow/orange and have become soft. They are collected from the ground after shaking the branches. Moisture content at the time of harvest is high, about 35%.

Processing and handling

After soaking the fruits for 2-3 days, the pulp is removed by squashing and then rubbing the fruits through a wire mesh.

It is recommended to use gloves as the soaking water gets very acidic. The fruits are dried in the shade in a place with good ventilation and the remaining pulp is removed by winnowing. After drying, the seed (pyrene) should have a moisture content of 6-10%.

Storage and viability

Because of the often poor storability and high moisture content at harvest the seed has been considered recalcitrant. The seed tolerates desiccation, however, and in a trial in Kenya, fresh seed dried down to as low as 4% mc germinated nearly 97% (Omondi, W., K. Thomsen & S. Diklev, 2000). If the seed is properly dried and stored at 6-10% moisture content in air-tight containers at 3° C, it can remain viable for several years (Albrecht, J., 1993)

Dormancy and pretreatment

The seed is not dormant and no pretreatment is necessary.

Sowing and germination

Seeds are sown in flat seedling trays and covered with a fine layer of sand and kept moist. Germination normally takes 18-20 days. The seedlings transplant well. Vegetative propagation from cuttings is also used, but cut tips should be treated with root-stimulating hormones before planting out.

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THIS NOTE WAS PREPARED IN COLLABORATION WITH KENYA FORESTRY SEED CENTRE

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Faidherbia albida (Del.) A. Chev.

Taxonomy and nomenclature

Family: Fabaceae (Mimosoideae)

Synonyms: *Acacia albida* Del., *Acacia albida* var. *senegalensis* Benth., *Acacia gyrocarpa* Hochst. ex A. Rich., *Acacia mossambicensis* Bolle, *Acacia saccharata* Benth., *Prosopis kirkii* Oliv.

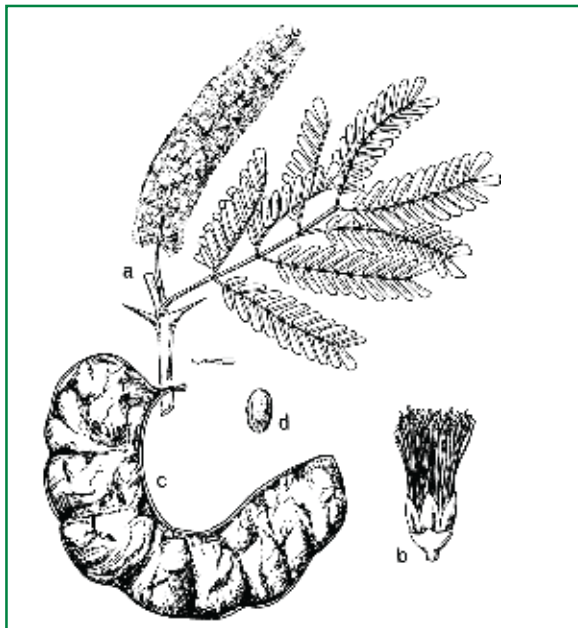
Vernacular/common names: apple-ring acacia, winter thorn (Eng.); cad, kad (Fr.).

Distribution and habitat

Widespread in dry tropical Africa into the Middle East and Arabia. Introduced into India, Pakistan, Nepal and, in the Western Hemisphere, Peru.

It can grow in a wide range of climates and habitats. The altitudinal range is from 270 m below sea level in Israel up to 2500 m in Sudan.

Provided there is access to under ground water it can grow independent of rainfall, such as in the Namib Desert. In west African savannahs, optimal conditions are 500-800 mm annual rainfall while in East Africa it grows well with as little as 8 mm and as much as 1800 mm rain/year. It does not tolerate frost. It will grow on a wide range of soil types depending on the provenance, but requires a relatively high water table for establishment and prefers flat sites.



A, flowering branch; b, flower; c, pod; d, seed. From: Ross, 1977. A conspectus of the African *Acacia* species.

Uses

The unusual phenology and the ability to fix nitrogen makes *F. albida* excellent in agroforestry systems. The mulch created by falling leaf litter and the canopy shade at planting time favors crop production beneath its canopy.

It is also of high value as a fodder tree. Leaves, pods and seeds contain 200, 150 and 260 g total protein/kg of dry matter and total protein digestibility can reach 73%. Tannins limit digestibility, but incorporating pods into low quality fodder enhances ingestion without reducing digestibility. Milling the pods increases digestion of seeds. Other uses include firewood, charcoal, construction timber, medicine (bark), soil fixation and conservation.

Botanical description

Large tree to 30 m in height, 1m in diameter; normally only one stem. Bark on young shoots nearly white, grey/brown on older parts, with fissures revealing the green cortex. Spines in pairs, up to 3.2 cm long, never inflated.

Leaves up to 10 cm long, 3-10 pairs of pinnae each with 6-23 pairs of leaflets. Conspicuous glands at the junction of each pair of pinnae. Inflorescence a spike, 3-16 cm long. Flowers yellowish/white.

Fruit and seed description

Fruit: indehiscent pod, bright orange to reddish brown, smooth, distinctively coiled or twisted. The shape of the pods can vary considerably between trees in one population. There are 10-30 seeds/fruit.

Seed: 10-12 mm long, shiny brown. There are 7,000-20,000 seeds/kg, the seeds are smaller in west Africa than those from the east and south

Flowering and fruiting habit

An unusual feature of *A. albida* is the tendency to shed the leaves at the onset of the rainy season and remain leafless until the beginning of the dry season when new leaves appear and flowering commences.

In some areas flowering may occur twice in a year. Not all trees flower every year. In East Africa seeds mature in July-October.

Harvest

The seeds are ripe when the pod changes colour from green to yellow, and they should be collected as soon as possible to avoid insect infestation. If the pods are harvested when green, the seed can be afterripened with success. Harvest is done by shaking the tree and catching the pods in a tarpaulin. Collection from the ground should be avoided.

Processing and handling

After harvest, the pods are left to dry in the sun before they are packed in hessian bags.

Seed extraction is best done with a flailing tresher but pistle and mortar can also be used. One kg of pods yields about 5.9 lt of seed. After extraction the seed is dried in the sun. For cleaning, an air screen cleaner is effective.

Storage and viability

The seed is orthodox and stores well. Infestation by insects is a problem, but only a minor one if the seeds are packed with CO₂ and stored at low temperatures.

Dormancy and pretreatment

The seed has physical dormancy. Scarification by nicking or burning gives the highest germination but good results can also be obtained by using a seedgun. The most common treatment is boiling the seeds in water for 3-5 minutes followed by 24 hours soaking in cold water. However, the effect of boiling water is variable and for some seedlots it has little effect.

Sowing and germination

The seeds are sown in pots or in 10 x 30 cm plastic bags and watered moderately. The roots must not be allowed to develop too much. Direct seeding is not recommended because of weed problems.

After 10-14 weeks the seedlings are ready for outplanting. This is done early in the rainy season. Seed from a broad range of provenances is available from members of the African *Acacia* trials network (OFI, CIRAD-Fôret, FAO).

Phytosanitary problems

The seeds are very susceptible to attack by bruchid beetles but with proper storage this can be limited.

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Crops of sweet potato grown under the canopy of *F. albida* at Gelemso in Ethiopia. Photo: Chris Fagg, OFI.

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Gardenia volkensii K. Shum ssp. *spathulifolia* (Stapf & Hutch.) Verdc.

Taxonomy and nomenclature

Family: Rubiaceae

Synonyms: *Gardenia spatulifolia* Stapf & Hutch.

Vernacular/local names: Gardenia (English), Mchimwemwe (Swahili, Digo), Mkimwemwe (Giriama), Mukumuti (Kamba), Shiuna (Luhya), Oltakurukuriet, Oltgururiet (Maasai).

Distribution and habitat

Widely distributed in east, central and southern Africa, from Somalia in the north to Transvaal and Namibia in the south. It occurs under a wide range of climates from semi-humid to semi-arid. In Kenya it is found from the coast to the Lake Victoria basin and also in northern Kenya in open woodland, often many concentrated in one area. The species has been widely planted as an ornamental park tree and garden plant throughout the tropics. It occurs on a wide variety of soils, ranging from sand to clay, as well as in rocky areas. The tree prefers well-drained soils and does not withstand waterlogging; often associated with termite mounds.

Uses

The bright and beautiful large flowers of *Gardenia volkensii* make it a highly appreciated ornamental plant. The plant has various medical properties; infusion of the fruits and roots is used to accelerate vomiting to remove unwanted food from the stomach. The wood is suitable for carving ornaments. Branches of gardenia are used by pastoralists to close the entrances to animal enclosures. The plant is also used for fencing cattle enclosures. The hard fruit shells (pericarp) are used as bottles by children.

Botanical description

A small branchy, deciduous tree, rarely reaching more than 8 m with relatively dense crown and a short thick and often fluted trunk. Bark is pale grey, smooth on young branches. In older parts, bark is flaking in small, fairly thick sections, resulting in a molted appearance. Leaves are glabrous, in pairs from end of 3-whorled branchlets, broadly spatulate, up to 2½-4 (-5) cm long. Flowers are large, up to 10 cm long, white and fragrant, borne singly. Corolla large, 8-9 merous, showy white, turning yellow after a few days, then brown before dropping, tube up to 10cm long or more.

Fruit and Seed description

Fruit: The fruit is a globose indehiscent berry-capsule, about 10 cm in diameter, warty and grey with 8-10 prominent longitudinal ribs.

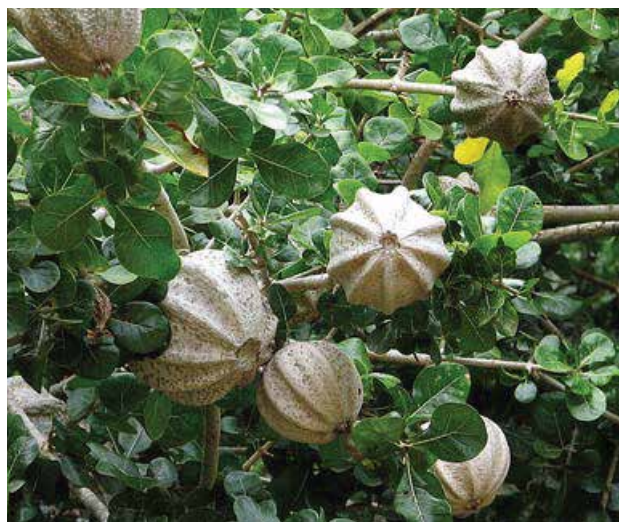


Gardenia volkensii flower

Gardenia fruit and leaves

Seed: The light brown, disc-shaped flat seeds are about 0.5cm long and are contained within the fruits' whitish-grey acidic pulp. The seeds are smooth and laterally flattened. The seed coat is hard.

There are 35,000-50,000 seeds in a kilogramme. The number of seeds per kilogramme depends on the provenance and the climatic conditions; under suitable climatic conditions, the seed weight tends to be larger than under harsh climatic conditions.



Gardenia volkensii fruit and leaves



Gardenia volkensii seeds

Flowering and fruit development

In Kenya the flowering season is between November and December while fruits mature between April to June. In Zimbabwe flowering is from August to December. The flowering and fruiting season varies from place to place. The fruits remain on the tree for a long time after maturity.

Seed collection method

The mature grey fruits are collected from the crown by hand picking or cutting fruit stalks.

Processing and handling

The hard fruits are first allowed to ferment in water before cutting them in half to release the seeds. Seeds are cleaned by enclosing them in a cloth with running water to remove the pulp. They are further cleaned by hand sorting and dried in the sun to the required moisture content (<10%).

Storage and viability

Seeds can be stored in airtight containers (plastic, kilner jars, and aluminium packets) in cool dry place for 2 to 5 years. For storage lasting to over 5 years e.g. conservation, seeds can be stored at sub-zero temper-

ature for many years with no significant loss of viability. Seeds can remain dormant for a long period.

Seed sowing and germination

The seed has a hard seed coat and therefore the limiting factor in germination is mainly the seed coat's impermeability to water. For optimum germination the seeds are pretreated by nipping with a nail cutter or a knife. Seeds are sown by broadcasting them thinly and evenly on a seedbed containing sand/soil and light mulch spread over the seedbed to keep it moist. Watering is done in the morning and evening until they germinate. They germinate within 10-20 days. Mulch is removed immediately after germination starts. The expected germination rate is 80-90%. The young seedlings are pricked out when they have 3-4 leaflets. They can be transplanted when they are 30cm tall roughly within 6 months after sowing.

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Gliricidia sepium (Jacq.) Steud.

Taxonomy and nomenclature

Family: Fabaceae (Papilionoideae)

Synonyms: *Gliricidia lambii* Fernald, *G. maculata* var. *multijuga* Micheli, *Lonchocarpus roseus* (Miller) DC., *L. sepium* (Jacq.) DC., *Millettia luzonensis* A. Gray, *Robinia rosea* Miller, *R. sepium* Jacq., *R. variegata* Schlttdl.

Vernacular/common names: mother of cocoa, Mexican lilac, gliricidia (Eng.); madre de cacao, madreado, madero negro (Sp.); quick stick (Jamaica).

Related species of interest: the genus comprises two other species, *G. maculata* and *G. brenningii* but only *G. sepium* is grown outside its native range in tropical America. *G. sepium* is distinguished from the other two species by having erect inflorescences, pink flowers and leaflets with pointed tips.

Artificial hybrids between *G. maculata* and *G. sepium* have been created but it is uncertain whether hybrids occur under natural conditions. The hybrids created in the trial showed little potential for planting.

Distribution and habitat

The true native distribution is obscured by early cultivation, but circumstantial evidence suggests that it is limited to the seasonally dry deciduous forests of the Pacific coastal lowlands and some dry inland valleys of Central America and Mexico. For several centuries it has been introduced outside tropical America and is now distributed all over the tropics. In many places where it grows as an exotic, the introduction originates from a narrow genetic base and several local land races suffer from inbreeding.

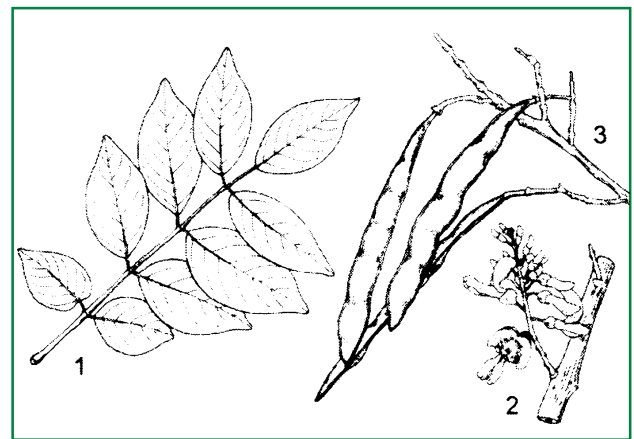
It is a pioneer species that readily colonises open ground and is used for reclaiming *Imperata* grasslands. It can grow in a wide range of habitats and soil types ranging from pure sand to deep alluvial lake bed deposits, with rainfall from 600-3500 mm/year and from sea level up to 1200 m altitude. It is rarely found at higher altitudes as prolonged frost will kill the trees and even occasional frost can cause leaf drop and dieback. Although it grows well in areas with high rainfall, a dry season of 8-13 weeks is necessary for seed production. As an aggressive coloniser it has the potential to become a weed but is rarely so perhaps because it in most places is coppiced regularly and not permitted to set seed.

Uses

Gliricidia is the quintessential multipurpose tree. It is probably the most common living fence species in the tropics. The ability to resprout vigorously and repeatedly after cutting allows a high production of animal fodder, fuelwood and poles. Under optimal conditions the annual biomass yield may be as high as 12 t dry weight per ha.

The nitrogen-fixing properties and leaves that can be used for mulch and green manure make it highly suitable in agroforestry systems. The name 'mother of cocoa' is due to the species being used as shade tree for cocoa, coffee and tea. The tolerance to cutting allows manipulation of the canopy to vary the intensity of shading at different times of the year.

The wood is hard and durable with a density of 0.5-0.8g/cm³. It burns slowly, with little smoke and no sparks and has a calorific value of 4900 kcal/kg.



1, Leaf; 2, flowering branch; 3, fruiting branch. (Hanum and van der Maesen, 1997)

Botanical description

Single to multi-stemmed tree, rarely shrubby, 2-15 m tall. Stems erect, 5-30 cm diameter at base, with or without branches from near the base. Bark greyish-brown with minute furrows on older stems. Leaves pinnately compound, 19-30 cm long, normally with 13-21 leaflets. Leaflets opposite, 4-8 cm long, normally with pointed tips, rarely rounded. The size of the leaflets increases towards the tip of the leaf.

Flowers light-pink to pinkish, rarely white, in 2.5-15 cm long, erect inflorescences.

Fruit and seed description

Fruit: 10-17 cm long pod, light to dark reddish-brown, with short stalk and slightly constricted between the seeds. The valves are woody at maturity and the pod is explosively dehiscent. There are 3-10 seeds per pod.

Seed: round, 8.5-11.5 mm in diameter, uniformly brown. The number of seeds per kg varies between 4,500 and 11,000, typically about 8,000.

Flowering and fruiting habit

The species is strongly outcrossing and although mating between related individuals occurs, it does not tolerate a high level of inbreeding. Studies have shown that the percentage of ovules that develop into seeds is correlated to how closely related the parent trees are. The closer the parent relationship is, the smaller is the seed:ovule ratio.

Within the native range the flowers are pollinated by nectar-seeking bees, especially the large black bee, *Xylocopa fimbriata*. The low seed setting that is seen in some parts outside the native range may be caused by lack of pollinators.

In areas with pronounced dry season, the trees are deciduous, shedding their leaves during the dry season and flowering and fruiting while leafless. In Central America flowering occurs in December-March in the beginning of the dry season and seeds mature one or two months later. In non-seasonal, humid areas the trees may be evergreen and flowering sporadic. In these areas seed setting is often low.

Harvest

The pods are normally harvested just before they open when they are dry but it is possible to collect the pods up to two weeks before opening. The green pods must then be after-ripened in the shade in a well-ventilated place.

Processing and handling

The ripe pods are dried in the sun until they open. As the pods almost explode when they open, the drying patio must be covered with nets or alternately the pods can be dried in mesh bags.

Storage and viability

The seed is orthodox and at low moisture content (6-10%) at 4°C it can be stored for over 10 years without loss of viability.

Dormancy and pretreatment

The seed has no dormancy and pretreatment is not necessary.

Sowing and germination

Seeds are sown in containers and the seedlings are ready for planting out after 2-3 months when they are about 30 cm tall. Direct sowing is possible with 2-3 seeds per site at a depth of 1-2 cm. Site preparation

must be carried out before sowing and followed by weeding until the trees are established.

Vegetative propagation by cuttings is easy. Both large and small cuttings can be used but it is important that the cuttings are taken from branches that are straight and healthy and without side branches. Trees that are established from cuttings have shallow root systems and short bole and are less resistant to strong winds.

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Live fences. Cochabamba, Bolivia. *Gliricidia sepium* is often used for live fences managed by regular pollarding. Photo: D. Jøker, DFSC.

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Gmelina arborea Roxb.

Taxonomy and nomenclature

Family: Verbenaceae

Synonyms: None

Vernacular/common names: jati putih (Indonesia); gamari, gumadi (India); gamhar (Bangladesh); yamane (Myanmar); white teak (Eng.).

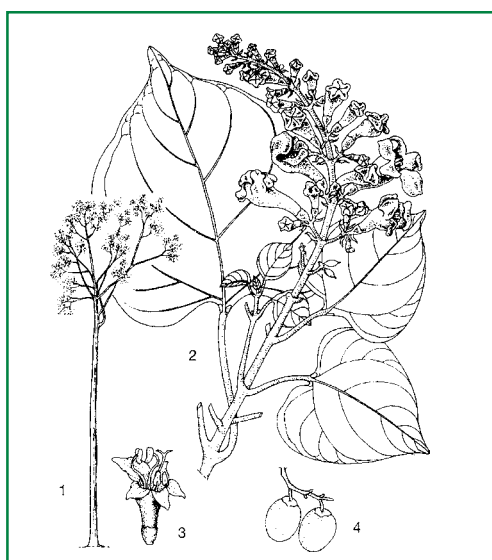
Distribution and habitat

The area of natural distribution includes Nepal, India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Thailand, Laos, Cambodia, Vietnam and Southern China. In the natural forest, the species is usually found scattered and in association with other species. It is found in evergreen forests in Myanmar and Bangladesh and in relatively dry mixed deciduous forest types in Central India.

It has been introduced as a plantation species in many countries, and large plantations are found in South-East Asia, West Africa and South America.

Uses

The wood is used mainly for light construction and for pulp. Several parts of the tree are used for medicine and the leaves are used for cattle fodder.



1, Tree habit; 2, flowering twig; 3, flower; 4, fruits. (Soerianegara and Lemmens, 1993)

Botanical description

A medium-sized tree up to 30 (-40) m tall; bole with average diameter 50 cm but sometimes reaching 140 cm. The bark is smooth or scaly, pale brown to grey.

The twigs are glabrous or pubescent. Flowers of bright yellow colour, arranged in large, terminal panicles (30-350 flowers in each). Leaves are opposite and usually more or less heart-shaped, 10-25 cm x 5-18 cm. The flower is large, up to 4 cm long, perfect, with an irregular 5-lobed tubular corolla.

Fruit and seed description

Fruit: the fruit is a succulent drupe, 20-35 mm long, with a shiny, leathery skin and a sweet, pulpy mesocarp. The stone (endocarp) is 10-25 mm long, with one round and one pointed end. The stone normally contains four seed chambers, in rare cases five. **Seed:** one or more of the chambers contain seed but there are rarely more than two filled seeds per fruit. The size of the seed increases with stone size, e.g. from 6 to 9 mm in length.

The weight of 1000 stones is approximately 400 g.

Flowering and fruiting habit

Gmelina flowers and fruits every year. In the natural distribution area with a seasonal climate, flowering starts in the dry season when trees are leafless. In seasonal climates outside the natural distribution there is no distinct flowering and fruiting period, and flowers and fruits can be seen more or less throughout the year. The fruit matures 1½ month after flowering. The species is predominantly outcrossing and the flowers are pollinated by large bees.

Harvest

Fruits are picked from the ground. The mature fruits may fall from the tree while they are still green. Green fruits turn yellow within a week and after about two weeks from falling, they turn brown and after about three weeks black. It is best to collect the fruits when they are still green or yellow, as germination capacity of brown and especially black fruits is low.

As all fruits do not fall and mature at the same time, fruits should be collected frequently, e.g. twice every week during the collection period, that may stretch over several months. Clearing of shrubs and weeds from the forest floor is recommended to ease seed collection. Production of fruits varies with age of stand, ecological conditions and stand conditions. There are reports of seed production from 30 kg cleaned stones/ha/year to around 170 kg/ha/year.

Processing and handling

Transport of fruits to the processing site should be in open baskets or nets, not in plastic bags. In order to avoid fermentation, fruits should be brought to the cleaning area within 24 hours. This is especially important for fully ripe – i.e. yellow and brown – fruits. As much care as possible should be taken to avoid damage to the fruits, since fermentation is more likely to start among damaged fruits.

At the processing site, the fruits should be sorted into those that are ready for immediate processing (yellow and brown colour) and green and green-yellow fruits, which will benefit from after-ripening. After-ripening is done in the shade by spreading the fruits in a 10-15 cm thick layer until they have turned yellow. This may take up to one week.

Depulping of small quantities of fruits can be done manually by mashing the fruits until the pulp is loose from the stone, and rinsing with water. For larger quantities of fruits depulping is normally done in a coffee-depulper. Soaking the fruits in water for 24 hours before depulping will facilitate the process. After depulping, the fruits are spread out on a wire-mesh tray and rinsed with water to remove juice and pulp.

Normally traces of pulp will remain on the stones after depulping and further cleaning or polishing of the stones is required. This can be done either manually by rubbing the stones with sand and water or mechanically (also with sand) in a concrete mixer.

Finally the stones are washed and dried well in the sun.

Seed storage

Fruits, which have been dried down to a moisture content of 5-8 % and kept below this moisture content in cold storage (4-5 °C), can be stored for several years without reduction in viability. It is however difficult to sun dry the stones below 10 % moisture content, so additional drying in an oven (35-50 °C) may be required for long term storage. If seeds are sown within a year from processing, sun drying and storage in airtight containers is sufficient.

Rodents may cause severe losses in stored stones. Storing in metal containers prevents such losses.

Dormancy and pretreatment

The seeds have no dormancy, and no pretreatment is required. Soaking of the seed in cold water for 24-48 hours before sowing is recommended.

Sowing and germination

The seeds (stones) are sown in a seedbed of soil or sand, covered by a thin layer of sand or soil. The germination of *Gmelina* seed is epigeal with the radicle emerging first and the cotyledons shortly after. Depending on the position of the first germinating seed,

the stone may be left in the ground or be pushed up, and the conditions for possible remaining seed to germinate may thus be more or less favourable.

Seeds normally germinate quickly and at high levels. Often the germination will be above 100% as more than one seed will germinate from each stone. The optimal temperature for germination is about 30° C, lower temperature will reduce germination. The seedbed should be exposed to full sunlight as partly or full shade will reduce germination. After germination, the seedlings can be transplanted to containers.

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18-year-old *Gmelina arborea* of good quality. Nimbia, Nigeria. Photo: Henrik Keiding, DFSC

THIS NOTE WAS PRODUCED IN COLLABORATION WITH INDONESIA FOREST SEED PROJECT

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Grevillea robusta Cunn. ex R. Br.

Taxonomy and nomenclature

Family: Proteaceae

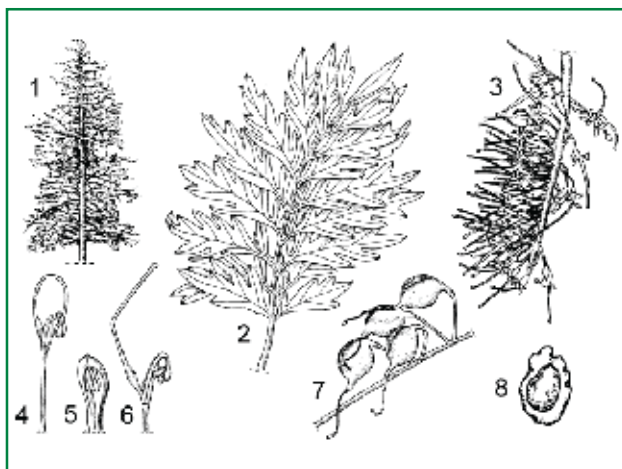
Vernacular/common names: Southern silky oak (Australian standard trade name), silk(y) oak (English), mgrivea (Swahili), son indian (Thai)

Distribution and habitat

Native to eastern Australia. Introduced into warm, temperate, subtropical highland regions around the world and widely planted in India, Sri Lanka and many countries in Africa. Within the area of natural distribution it is found in warm, humid to sub-humid zones, 100-800 m altitude, 1000-1500 mm rain/year. Tolerates annual rainfall of 600-2700 mm and altitudes to 2500 m, but prefers altitudes below 1200 m and with less than 2000 mm rain/year. Average temperature for coldest month not below 0°C and at no time lower than -10°C. Prefers light, well-drained soils, mildly acid to neutral. Light demanding.

Uses

Timber, firewood, industrial, leaf mulch, fodder and shade tree in coffee plantations. Excellent agroforestry species as it interferes little with crops. Best growth is obtained when it is planted in rows or intermixed with crops; not suitable for monoculture. The sapwood is pale, the heart-wood yellow-brown and silky.



1, Habit; 2, leaf; 3, inflorescence; 4, young flower (stigma retained in bud); 5, tepal with anthers attached; 6, mature flower (extended style + stigma); 7, fruits; 8, seed. From: Plant Resources of South-East Asia 5:3.

Botanical description

Tree 20-30 m tall, 50-80 cm in diameter. Bole unbuttressed, erect, somewhat tapering. Crown pyramidal, tufted with open canopy. Bark grey, furrowed, with lenticels. Leaves alternate, 10-34 x 8-12 cm, pinnately compound, fern-like, pale green above, white-hairy below. Facultatively deciduous. Flowers in 7-13 cm long, erect racemes, bright yellow-orange, 2 cm long. The style is long, recurved at first, later straight.

Fruit and seed description

Fruit: boat-shaped, dehiscent, 2-seeded capsule up to 2 cm long, tipped with the long, persistent style

Seed: brown, flat, ovate-oblong, about 1 x 0,5 cm with a shiny centre surrounded by light brown papery wing. There are 50-120,000 seeds per kg.

Flowering and fruiting habit

Flower and fruit setting occurs after the rainy season. Pollination by birds and bats. The period from fertilisation to fruit maturity is two months.

Prolific seeder, often 2 kg seed/tree; heaviest crop from 20-40 year-old trees.

Harvest

The fruits are collected when the colour changes from green to yellow and the first hint of brown appears. The seeds do not mature at the same time, in each inflorescence there are many stages of maturity.

Collection is difficult because of the short time (often only 2-3 days) between seed maturity and dispersal. The seeds must be mature when they are harvested. Collection of seeds from the ground is possible but very time consuming and it should only be done in dry weather as the wings stick to the ground if wet.

Fruit and seed processing and handling

The fruits are cleaned by gentle winnowing or sieving and air-dried in trays in the sun until they open. If the capsules do not open, drying in the shade will often help.

Seeds are cleaned using a screen, a laboratory gravity table or an air separator. The wings should be removed to reduce bulkiness, reduce fungal attacks and facilitate sowing. After extraction the seeds are dried in the sun.

Dormancy and pretreatment

The seeds have no dormancy but germination is delayed and uneven. Soaking in cold water for 24 hours may improve germination.

Storage and viability

If the seeds are dried to app. 8% moisture content and packed in air-tight polythene bags, they store well even at room temperature. The following results were obtained at the Australian Tree Seed Centre:

Storage time	Temperature		
	23°C	3-5°C	-15°C
Initial (1987)	77,0 %	77,0 %	77,0 %
1 year	73,0 %	76,7 %	70,3 %
4 years	81,3 %	75,0 %	70,7 %
6 years	58,7 %	64,7 %	68,0 %
8 years	54,0 %	75,3 %	65,3 %

s.e.d. = 3,92 %

Source: Australian Tree Resources News No. 4, 1998

Sowing and germination

Seeds can be sown in shady seedbeds with sandy loam and sand 1:1. The seedbeds should be protected from heavy rain with plastic sheets, not watered too much and ensured good drainage to avoid problems with fungi. Germination occurs after 2-4 weeks. When the seedlings are 7 days old, they are pricked out in polytubes. The seeds can also be sown directly in polytubes.

Shade is required for 2-3 weeks after transplanting. Regular root-pruning is recommended. For industrial plantations, bare-rooted stocks are often preferred. Outplanting is done 6-8 months after sowing when plants are 20-30 cm. Weeding is necessary for the first 1-2 years after planting.

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Shade trees in tea plantation, Sri Lanka Photo: Stephen Midgley, CSIRO Forestry and Forest Products.

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Jatropha curcas L.

Taxonomy and nomenclature

Family: Euphorbiaceae

Synonyms: *Curcas purgans* Medic.

Vernacular/common names: physic nut, purging nut (English); pourghère, pignon d'Inde (French); Pur-gier-nuß, Brechnuß (German); piñoncillo (Mexico); coquillo, tempate (Costa Rica); tártago (Puerto Rico); mundubi-assu (Brazil); piñol (Peru); pinón (Guatemala); kanananaeranda, parvata-randa (Sanskrit); bagbhe-renda, jangliarandi, safed arand (Hindi); kadam (Nepal); sabudam (Thailand); túbang-bákod (the Philippines); jarak budeg (Indonesia); bagani (Côte d'Ivoire); kpoti (Togo); tabanani (Senegal); mupuluka (Angola); butuje (Nigeria); makaen (Tanzania); purgeerboontjie (South Africa); dand barrí, habel meluk (Arab); yu-lu-tzu (Chinese); purge-ernoot (Dutch); fagiola d'India (Italian); purgueira (Portuguese);

Distribution and habitat

It is still uncertain where the centre of origin is, but it is believed to be Mexico and Central America. It has been introduced to Africa and Asia and is now cultivated world-wide. This highly drought-resistant species is adapted to arid and semi-arid conditions. The current distribution shows that introduction has been most successful in the drier regions of the tropics with annual rainfall of 300-1000 mm. It occurs mainly at lower altitudes (0-500 m) in areas with average annual temperatures well above 20°C but can grow at higher altitudes and tolerates slight frost. It grows on well-drained soils with good aeration and is well adapted to marginal soils with low nutrient content.

Uses

The species is widely grown in the tropics as living fences because it is easily propagated by cuttings and not browsed by cattle. The seeds contain 30-35% oil which is used as an insecticide, for soap production and numerous other purposes. The seed oil can also be used as a substitute for diesel oil in engines and in recent years special interest has been shown in the cultivation of physic nut in energy plantations. Press cake made from the plant is valuable as organic manure. It has a nitrogen content similar to chicken manure (3.2-3.8%). The seeds are not edible mainly due to a high content of toxic proteins but all parts of the plant are used in traditional medicine. However, some provenances have been reported to produce edi-

ble seed and in Mexico the seeds from a non-toxic variety are eaten after roasting. Being drought tolerant, it can be used to reclaim eroded areas. Unfortunately it is host for the cassava virus that can be transmitted to the crops and it should never be used for fences around cassava fields.

With the combination of oil production and erosion control and the ability to grow in marginal areas with poor soil and low rainfall, this species has great potential in rural development as a source of household income and at the same time creating environmental benefits. Examples from Mali show that villages that plant 15 km of *Jatropha* hedges can harvest about 12 tons of seed which may generate 1800 US\$ of cash income when the oil is extracted and the products sold (1998 figures).



Jatropha curcas tree in village, Matabeleland Province, Zimbabwe. Photo: Jacob Jepsen.

Botanical description

Small tree or large shrub, up to 8 m tall and with diameter up to 20 cm. Trunk is straight, branching low above the ground; bark is thin and yellowish. Leaves are 6 x 15 cm and lobed. Flowers small and greenish, unisexual with male and female flowers at the same tree.

Fruit and seed description

Fruit: a grey-brown capsule, up to 4 cm long; it is normally divided into 3 cells, each containing one seed.

Seed: seeds are black, about two cm long and one cm thick. There are (1000) 2000-2400 seeds per kg.

Flowering and fruiting habit

The trees are deciduous, shedding the leaves in the dry season. Flowering occurs during the wet season and two flowering peaks are often seen. In permanently humid regions, flowering occurs throughout the year. The seeds mature about three months after flowering. Early growth is fast and with good rainfall conditions nursery plants may bear fruits after the first rainy season, direct sown plants after the second rainy season. The flowers are pollinated by insects especially honey bees.

Harvest

When the fruits begin to open, the seeds inside are mature. Collection is best done by picking fruits from the tree or hitting and shaking the branches till the fruits break off. Seeds collected from live fences can normally be reached by hand. For taller trees it is possible to collect the fruits in a small bag that is attached to a stick. In Costa Rica it is estimated that a tree produces about 30 kg fruits per year or about 12 kg seed. The yield per hectare is about 4800 kg seed.

Processing and handling

After collection the fruits are transported in open bags to the processing site. Here they are dried until all the fruits have opened. It has been reported that direct sun has a negative effect on seed viability and that seeds should be dried in the shade. When the seeds are dry they are separated from the fruits and cleaned.

Storage and viability

The seeds are orthodox and should be dried to low moisture content (5-7%) and stored in air-tight containers. At room temperature the seeds can retain high viability for at least one year. However, because of the high oil content the seeds cannot be expected to store for as long as most orthodox species.

Dormancy and pretreatment

Freshly harvested seeds show dormancy and after-ripening is necessary before the seeds can germinate. Dry seed will normally germinate readily without pretreatment. If this is the case, it is not recommended to remove the seedcoat before sowing. Although it speeds up germination there is a risk of getting abnormal seedlings.

Sowing and germination

Germination is fast, under good conditions it is complete in 10 days. Germination is epigeal (cotyledons emerge above ground). Soon after the first leaves have formed, the cotyledons wither and fall off. In the nursery, seeds can be sown in germination beds or in containers. Although the seedlings grow very fast they should stay in the nursery for 3 months until they are 30-40 cm tall. By then the plants have developed their repellent smell and will not be browsed by animals.

Physic nut can be established from nursery seedlings, bare root or containerised, by direct sowing, transplanting of wildlings or planting of cuttings. The choice of propagation method depends on use. Plants propagated by seeds are generally preferred for the establishment of long-lived plantations for oil production. Direct sowing should only be used in areas with high rainfall and the seeds must be sown after the beginning of the rainy season when sufficient rainfall is certain. For quick establishment of hedges and plantations for erosion control, directly planted cuttings are best suited. Cuttings of 30 cm length have been found to have the highest survival rate. Plants propagated by cuttings will normally produce seed within one year of planting and growth is rapid.



Fruits and seed of *Jatropha curcas* L. Photo: Jacob Jepsen.

Selected readings

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Khaya senegalensis (Desr.) A. Juss.

Taxonomy and nomenclature

Family: Meliaceae

Synonyms: *Swietenia senegalensis* Desr.

Vernacular/common names: African mahogany, dry-zone mahogany (Eng.); acajou d'Afrique, acajou du Senegal, caïlcedrat (Fr.); homra, murraya (Arabic); zunzatin (Benin); dalehi (Cameroon); ogonwo (Ghana); jalo (Gambia); kpitili (Guinea); kaya (Indonesia); yala (Mali); ono (Nigeria); kail (Senegal); caïlcedrat, African mahogany, khaya wood (trade names).

Distribution and habitat

The area of natural distribution is from Senegal to Sudan and Uganda, south to the rainforest zone. It occurs in riverine forests and scattered in high-rainfall savannah woodland. It grows at 0-1800 m altitude in areas with 700-1750 mm rain/year and a dry season of 4-7 months. It is one of the most drought-tolerant *Khaya* species but prefers moist sites and this seems to be more important for growth than nutrient availability. Saplings are very sensitive to fire but adult trees are relatively resistant. Plantations have been successfully established in Asia and Latin America.

Conservation status: logging and local exploitation are largely uncontrolled and poorly monitored. In northern parts of the range, exploitation may be leading to genetic erosion. Natural regeneration from seed is poor but does occur from suckers. On the 2002 IUCN Red List of Threatened Species it is listed as vulnerable.

Uses

The timber is rated as one of the best African mahogany woods. It is moderately hard and of medium density (0.6-0.8). The heartwood is deep red-brown with a purplish tinge and the attractive appearance makes it one of the most favoured timbers for furniture.

Besides timber, the species is valued for medicinal purposes, especially the bark is used to treat a number of diseases. The leaves are used for fodder at the end of the dry season but the forage value is low. In West Africa the seed oil is used for cooking. The seeds have an oil content of 67% and are rich in oleic acid. The wood ashes are used for storing millet seed. Because the wood is difficult to saw, only small logs and branches are used as firewood.

Botanical description

A deciduous tree, 15-20 m tall, reaching up to 35 m on fertile soils; diameter up to 1.5 m and with 8-16 m clean bole; buttresses not prominent or absent. The bark is dark grey, the slash dark pink with red latex. Leaves are compound, up to 20 cm long, with 3-7 pairs of usually opposite leaflets; each leaflet is 7-12 cm long, 3-5 cm wide, underside grey.

The flowers are small, about 5 mm, with white petals; unisexual, but with well-developed vestiges of the opposite sex, making it difficult to distinguish between male and female flowers. Flowers are borne on up to 20 cm long, much branched inflorescences.

Fruit and seed description

Fruit: the fruit is an upright, almost round, woody capsule, 4-10 cm long with 4 valves that open at maturity (a distinction from *K. ivoriensis*, that is closely related, but has 5 valves). Inside the valves the seeds are arranged in rows with 6-18 seeds per valve.

Seed: the seeds are brown and flattened, about 2 x 2.5 cm, with winged margins. There are 2500-7000 seeds per kg.



Khaya senegalensis. Cultivated, at Singapore Botanical Garden. Photo: Thomas Schöpke

Flowering and fruiting habit

Leaves are shed in the dry season and are directly replaced. Flowering occurs shortly before or in the beginning of the rainy season and the flowers are pollinated by insects. In Burkina Faso flowering occurs from November to December, in Guinea from November to February, in the Sudan February to March and in Côte d'Ivoire twice a year, principally from August to December.

The fruits mature in Burkina Faso from February to May, in Guinea from February to July, in Côte d'Ivoire mostly from January to April, with a second fruiting period July to September and in Tanzania from January to March. The trees begin to produce seed when they are 15-25 years old. In most places fruiting is regular and the fruits remain on the tree for most of the dry season. The seeds are dispersed by wind and may be carried away as far as 100 m.

Harvest

The seeds are mature when the fruit colour changes from grey to black. Mature capsules can be collected from the tree or from the ground after shaking the branches but it is not advisable to collect seeds that have been lying on the ground for some time.

At the time of maturity, the seeds have a very low moisture content.

Processing and handling

After collection the fruits are left in the sun until they open and release the seeds. After extraction, the seeds are dried in the sun.

Storage and viability

The seeds are orthodox and should be stored at low moisture content. In a recent study in Burkina Faso seeds were stored at -18, 3-5 and 25°C. The results showed that the seeds retain full viability regardless of storage temperature for at least two years. The seeds are sometimes heavily attacked by larvae and packing with CO₂ can be necessary.

Dormancy and pretreatment

The seeds are not dormant and pretreatment is not necessary.

Sowing and germination

Germination is epigeal; it is normally good, often close to 100%, and is completed after about two weeks.

To produce container plants, seeds are sown in sandy clay substrates under shading. Nursery costs are higher than for bare-rooted stock but plants are able to tolerate up to 10 days without rain. After 6-7 months the plants can be planted in the field but longer time in the nursery is preferable.

In areas with regular rainfall after planting, stump planting is possible but normally not preferable. The species also propagates well from coppice, shoots and root suckers.

The species is susceptible to attack by *Hypsipyla* shoot bores and it is recommended growing it in mixed stands.

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Seeds of *Khaya senegalensis* from Burkino Faso (NB. grid has 1 cm divisions). Photo: Dorthe Jøker, DFSC

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Markhamia lutea (Benth) K. Schum

Taxonomy and nomenclature

Family: Bignoniaceae

Synonym: *Dolachandrone platycalix* Baker, *Markhamia platycalix* Sprague.

Vernacular/Common names: Nsambia, mgambo (Swahili).

Distribution and habitat

Markhamia platycalix is native to East Africa but has been widely dispersed by cultivation. Its native range covers the wetter parts of Ethiopia, Kenya, Tanzania, Uganda and Rwanda.

It is a typical pioneer species of the humid forest, growing at altitudes 700- 2000 m.a.s.l., 800 – 2000 mm annual rainfall with short dry season(s). It grows best on well drained farm soil. It can also grow on quite heavy clay soils provided it is not water logged. It is quite light demanding.

Uses

The wood is hard, durable (moderately resistant to termites) and easy to work and thus much favoured by carpenters.

The large conspicuous yellow flowers make the species a popular ornamental, and it is frequently planted as a roadside or park tree in cities and towns.

Although not nitrogen fixing, the species is frequently used as agroforestry tree as it is fast growing, wind resistant and provides both flowers for apiculture, good quality wood and green mulch. It tolerates pruning well and can be renewed by coppicing.

Botanical description

Markhamia platycalix can grow into a very large tree of > 40 m. The stem is often crooked with basal fluting. Old bark grey-brown or reddish, flaking in irregular patches. Leaves opposite, compound, imparipinnate with 4-6 pairs of opposite leaflets plus a terminal leaflet. Leaflets are oval-ovate, 5-12 cm long, 2½-5 cm wide with pointed tip and short stalk. Large flowers in panicles. They consist of a bell-shaped, 5 lobed corolla tube with two lips above and 3 lips below. 4 stamens basically united with corolla tube. Ovary consist of two carpels.



Flowering branch of *Markhamia*. www.gardentia.net

Fruit and Seed description

Fruit: The fruit can be up to 1 meter with many seeds. It is straw coloured or brownish at maturity. Seeds are attached in a long row to the central fruit part, and remain so for a while after the fruit valves split apart.

Seed: The seed is oblong, about 2½ cm wide including an almost transparent wing. handling unit is the seed. There are about 70-75000 seed per kg.



Leaves, flowers and fruits of *Markhamia lutea*. From Dale and Greenway 1961

Flowering and fruiting habit

Flowering period is often long. In West Kenya (Kakamega area) flowering occurs at the end of the rainy season in August – September. Fruit development and maturation takes place during the dry season and fruits are mature about 6 months after flowering. Eastern Kenya flowering period is December-January and fruits are mature from July-August. Pollination is by insects e.g. bees.

Harvest

Fruits must be harvested from the tree before dehiscence because the small light seeds are otherwise widely dispersed by wind. Fruits are best collected by climbing and breaking off the fruits with a sharp hook. Best quality seeds are from fruits with mature yellow-whitish colour and about to open.

Processing and handling

Seeds must be extracted from the fruits, possibly with a short after-ripening period to make the fruits open naturally. Once the fruits are dry, they can be opened and fruit parts manually removed. Fruit wings tend to gather moisture and fungi careful drying is advisable.

Storage and viability

The seed exhibit orthodox storage behaviour and dry seeds can be stored for several years at room temperature. Cold storage prolong longevity.

Dormancy and pretreatment

Seeds will usually germinate readily after sowing. However, some related species appear to exhibit moderate photo-dormancy and it is recommended to sow seeds under light.

Sowing and germination

Best germination is achieved when seeds are sown directly on the surface without covering them with soil. Germination is epigeal. Germination is often < 50% even under optimal conditions.

Vegetative propagation

The tree coppices well and can be rejuvenated by coppicing many times.

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Melia azedarach L.

Taxonomy and nomenclature

Family: Meliaceae

Synonym: *Melia sempervirens* (L.) Sw., *Melia dubia* Cavanilles, *Melia composite* Willd.

Vernacular/common name: Chinaberry, Persian lilac (Eng); Geringging, Mindi (Ind. Java); Marambung (Ind. Sumatera);

Related species of interest: The genus *Melia* contains several important multipurpose species, e.g. *M. volkensii* in E. Africa and *M. toosendan* in Indochina. *M. azedarach* is also closely related to *Azadirachta indica* (Neem - formerly called *Melia azadirachta*) with which it is often confused, e.g. because of related names.

Distribution and habitat

Natural distribution obscured by cultivation and naturalisation. The species originates from southern Asia (India-Pakistan-Iran). It has been introduced and widely cultivated in East-southern Africa, Middle East, America (Bermuda, Brazil and Argentina), Australia, SE Asia-Pacific islands, and southern Europe. In Indonesia it grows mainly in the dryer eastern part of the country.

The species is most competitive in relatively dry areas with less than 900 mm annual rainfall. It occurs from lowland up to 1000 (-1400) masl. It prefers well-drained, deep, sandy loam soil, with pH 5.5-6.5

Uses

The wood is light with density of 0.42-0.65. It can be used for construction, panel, ornament, boxes, matches. It is often planted as a fuelwood species. Fruits and leaves are toxic to humans and livestock. Plant parts contain a number of compounds, e.g. azadirachtin with medical and insecticidal - anti-parasitic properties. The leaves are used to relieve headache, bark is used to treat skin diseases and laxative, and the extracts of leaves and seed are used as insecticide.

Botanical description

Deciduous tree up to 45 m tall, clear bole up to 20 m tall and no buttress. Young bark is grey black and will change to reddish brown with the increasing of age, light to deep furrowed, peels off in small to larger flakes. Leaves compound, bi-pinnate, alternate on the tip of twig, up to 40 cm long. Leaflets ovate or oblong-lanceolate, 2-7 cm long, acute to rounded base,

apex acuminate, margin entire to variously serrate.

Inflorescence is a panicle, axillary or in axil of rudimentary leaves on short shoots, 10-22 cm long. Flowers are purplish and fragrant, bisexual or male, 5-merous, with tubular calyx, 6-7 mm long and 2 mm in diameter.



1. Tree habit; 2. Leaf; 3. Flowering branch; 4. Section through flower; 5. Fruits. From: PROSEA Asia 11

Fruit and seed description

Fruit : Fruit an ellipsoid-globose drupe, 2-4 cm long, 1-2 cm in diameter, exocarp thin and smooth. Endocarp (stone) brownish yellow when ripen.

Seed: Stone ellipsoid 3.5 mm long, 1.5 cm diameter, cross section often somewhat star-shaped. Brown-grey with rough surface. Each stone contain 2-4 (rarely 5) morphological seeds. There are 57.000 seeds (stones) /kg.

Flowering and fruiting

Flowering and fruiting start when trees are 5-6 year old. In aseasonal climate flowering and fruiting may occur almost continuously throughout the year. In seasonal climate flowering occurs mainly at the beginning of the dry season and fruits are mature at the beginning of the rainy season. Fruiting season is often long even in seasonal climate.

Fruit Harvesting

Seed collection can be done by collecting from the ground after natural fall or after shaking fruit bearing branches. As infructescences tend to concentrate at the end of long branches, these can be pruned by using long-handled tools. The production of fresh fruits is 10-15 kg per tree.

Processing and handling

Fruits should be separated after collection in fully mature and not fully mature fractions; the latter should be after-ripened for some days under shaded and humid conditions until they take mature colour. Stones from mature (soft) fruits may be extracted manually by rubbing with sand and then cleaning with running water. Larger quantities can be extracted by using mechanical equipment designed for de-pulping fleshy fruits, e.g. coffee de-pulper, Dybvig macerator or adapted food processors. After extraction and cleaning in water, stones should be dried for some days until moisture content is about 15-10% (drying may be omitted or minimised if seeds are to be sown quickly after processing).

OBS: When depulping fruits and disposing waste of fruits precautions must be observed to avoid any oral intake by humans and animals. Ingestion can cause acute poisoning and in extreme cases be fatal.

Storage and viability.

The seeds are semi recalcitrant. They should be kept in high moisture content (10-15%). Fresh stones (moisture content \pm 22%) are kept in plastic and then stored in a tin can in a cold room with the temperature of 18-20°C, RH 70-80%. Using this treatment, the germination percentage of the seeds can be maintained up to 20-30% after 10-12 weeks in storage.

To prevent fungal attack, seed can be mixed with fungicide powder, for instance Dithane M-45 or Benlate.

Dormancy and pretreatment.

Seeds of *M. azedarach* are hard and may take up to 3 months to germinate without pretreatment. Pretreatment should aim at breaking the physical barrier to water absorption and expansion of the embryo. Pretreatment can be done manually by cracking or cutting part of the endocarp, or by treatment with sulphuric

acid (H_2SO_4). Acid treatment should be with high concentration acid (beware of safety precautions!) for 40 minutes.

Sowing and germination.

Germination is epigeal. Sowing after pretreatment in plastic pots with the mixture sand and soil (1:1). Suitable practice is by burying the seeds into the media in horizontally, $\frac{3}{4}$ part depth then covered with fine sand. Since stones contain more than one seed a germination percentage of >100% can be achieved. Transplanting medium may consist of a mixture of soil, sand and manure (7:2:1) and added 1 spoon of TSP or NPK in every 1 m³ of media. Transplanted seedlings are plantable in the field after 3-4 month.

Phytopathological problems

Seedlings are, as most other Meliaceae, prone to attack by shoot borers, for *M. Azedarach* e.g. by *Hypomeces squamosus* and *Aristobia approximata*.

Vegetative propagation

Propagation by stem cutting, marcotting or root suckers is possible but is reportedly difficult.

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THIS NOTE WAS PRODUCED IN COLLABORATION WITH INDONESIA FOREST SEED PROJECT.

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Melia volkensii Guerke

Taxonomy and nomenclature

Family: Meliaceae

Synonyms: none

Vernacular/common names: Melia, tree of knowledge (Eng.); mukau (Kenya); boba (Somalia).

Distribution and habitat

The area of natural distribution is the semi-arid zone of Ethiopia, Somalia, Kenya and Tanzania where it is found at altitudes between 350 and 1700 m, in areas with mean annual rainfall of 300-800 mm.

Common in deciduous bushland in association with acacia-commiphora vegetation. It can grow on most soils; sandy, clay and shallow stony soils, but preferably with good drainage.

Uses

The species is mainly planted for its timber which is durable and termite resistant. The timber is used for construction and furniture and is one of the principal species used to make log hives because the wood is easy to work and shape. It coppices well and is fast growing with a rotation of 10-15 years.

Twigs, leaves and fruits are used to make fodder for goats, cattle and sheep during the dry season and trees are commonly planted around homesteads for shade and firewood.

In parts of Kenya it is the most commonly planted tree on cultivated and cleared lands. The trees are planted at 10-15 m spacing and pruned to avoid competition for light with the crops. Pruning is carried out during periods when other fodder sources are scarce. Because of its drought tolerance and high timber value, this species has great potential for smallholders especially in marginal areas.

Like neem, *M. volkensii* contains compounds (although not azadirachtin) that are toxic to insects and aqueous extracts of the fruits are traditionally used to control fleas and ticks.

Botanical description

Deciduous tree, 6-20 m tall with diameter typically about 25 cm. The crown is open and the bark is grey and fairly smooth.

Leaves are bright green, up to 35 cm long, compound, with 3-7 deeply lobed leaflets that are densely hairy when young. The flowers are small, white and fragrant, arranged in loose inflorescences.

Fruit and seed description

Fruit: the fruit is a 3-4 cm long, ovoid drupe, yellow at maturity later turning pale grey due to the deposit of cork. Each fruit contains one seed that is enclosed in a very hard and thick endocarp (stone). There are about 200 stones per kg.

Seed: the seeds are oval, about 2 cm long and 0.5 cm wide. At one end is an appendage called the caruncle.



Tree in cropland. Photo: Bernard Muok

Flowering and fruiting habit

The tree is deciduous, shedding its leaves early in the dry season, and new leaves emerge two to three weeks before the onset of the rains. On cultivated lands the leaves are normally shed later into the dry season. Reproductive buds develop only at the end of branches. They are generally larger than the vegetative buds.

Flowering and fruiting do not follow a seasonal pattern. It can take place two or three times per year but fruits, even on the same branch, can be at very different stages of maturity. Fruits normally ripen 12-13 months after the time of flowering.

The trees have been reported to start flowering as early as 2-3 years old. It is unknown how the flowers are pollinated but bees visit the flowers indicating insect pollination. The seeds are dispersed by large mammals that feed on the fruits.

Harvest

Mature fruits can be collected nearly all year round. When the seeds are mature the fruits change colour from green to yellowish-green and the pulp becomes

soft. The endocarp becomes very hard and brittle and the colour of the seedcoat turns from light brown to almost black.

It can be misleading to use only fruit colour as a sign of maturity. During development, cork is deposited on the surface of the fruit. This affects the fruit colour and makes it difficult to distinguish between mature and immature fruits.

Collection is fairly easy, when the trees are shaken the mature fruits, and only those, will drop easily from the tree. A grown tree can produce up to 300 kg of fruits per year. At the time of harvest the fruits have a high moisture content (about 40%) and must be treated gently, protected from direct sun and brought to the processing site as quickly as possible.

Processing and handling

It is important that the fruits are processed quickly after collection to avoid fermentation.

The stones (seed + endocarp) are extracted in a depulper or by using a paste and mortar. After removing the pulp, the stones are washed and surface dried.

Storage and viability

There have been conflicting reports on storage methods. According to a study carried out at KEFRI, Kenya, storage behaviour is orthodox and if the seeds are properly dried (10-15% moisture content) and stored in airtight containers at 3°C they can retain high viability for years. There are other studies that indicate the seeds do not tolerate drying.

Dormancy and pretreatment

One of the factors that limits the use of this species is seed dormancy. The type of dormancy is not yet completely known but it seems to be caused by the extremely hard endocarp and/or the seed coat.

There are effective ways of pretreatment but they are all very labour intensive. To get optimal germination the seeds must first be extracted using a knife to remove the endocarp. After extraction the caruncle is removed and the seedcoat is nicked or cut with a knife. Extracted seeds are very susceptible to fungal infections so extraction should wait until just before sowing.

The traditional method of pretreatment, using stones that have been eaten and excreted by animals, only improves germination slightly.

Sowing and germination

Extracted and scarified seeds will normally germinate very quickly. Before sowing it is recommended to soak the seeds in water for 18 hours.

Optimal temperature for germination is 25-37° and studies have shown that once the seeds have been imbibed they are damaged by temperatures below 25°C and above 37°C. As a result of this, it is strongly recommended to shade seedbeds and only water early in the morning and late in the evening when soil temperatures are low.

The seedlings are highly susceptible to damping-off. Vegetative propagation by root cuttings is possible while there has been little success using stem cuttings as rooting is difficult.



Fruit (top left); stones after depulping (top right); seeds. Photo: William Omondi, KEFRI

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Milicia excelsa (Welw.) C.C. Berg

Taxonomy and nomenclature

Family: Moraceae

Synonyms: *Chlorophora excelsa* (Welw.) Benth., *C. alba* A. Chev., *C. tenuifolia* Engl., *Maclura excelsa* (Welw.) Bureau, *Milicia africana* Sim, *Morus excelsa* Welw.

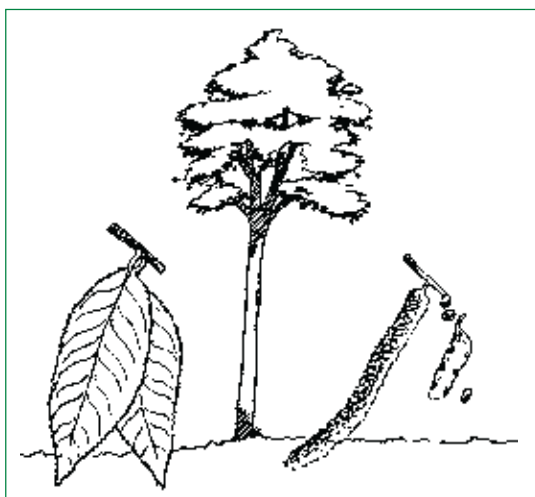
Vernacular/common names: ioko (Hausa); iroko (Yoruba); mvule (Swahili); rock-elm (Eng.); iroko (trade name).

Related species of interest: the two African *Milicia* species, *M. excelsa* and *M. regia* are known together as iroko and logging companies do not distinguish between the two. *M. regia* has a more western distribution, occurring from Senegal to Ghana. Where the two species overlap, hybridisation may take place.

Distribution and habitat

Widespread in tropical Africa from Guinea-Bissau to Mozambique where it is found in lowland rain forests and wetter savannah woodland areas. It can grow with about 700 mm rain/year provided it has access to a supplementary source of water and it tolerates a wide range of soil types but not impeded drainage and waterlogging.

The species suffers from heavy exploitation, and on the IUCN Red List it is considered close to qualifying for 'vulnerable'. East Africa was once a major source of the timber, which was used as a teak substitute until supplies became short. West Africa continues to export large quantities.



Leaves, tree habit, male spike, fruit and seeds. (Hines and Eckman 1993).

Uses

With wood that is equivalent in value to teak, *M. excelsa* is one of the most important timber trees of tropical Africa. The heartwood is durable, workable and resistant to termites and marine borers. It is also extremely resistant to preservative treatments whereas the sapwood is permeable. The gravity is about 0.55 g/cm³. It is mainly used for outdoor construction work, furniture, boats, cabinet-work, paneling, frames and floors.

The bark, its ashes, leaves and latex are used in local medicine and the trees play a major role in many local cultures where they are considered sacred, or parts of the tree serve ceremonial purposes. The leaves are edible and are used as mulch. It is often planted as a shade tree and along roads as an ornamental.

Botanical description

Deciduous tree up to 50 m tall and with a diameter up to 10 m. The bole is straight and cylindrical, branchless up to 20 m or more. Bark is dark, fairly rough and flaking of in small scales but rarely fissured. When cut, the slash exudes white latex. The crown is umbrella-shaped and fairly flat at the top. Leaves simple and alternate, 10-20 cm long. Young leaves are velvety and with serrate margins while older leaves are glabrous and have entire margins.

The species is dioecious and male and female trees are slightly different in appearance, male trees having longer and more slender trunk and crown and forking being more common in male than in female trees. Flowers are born in single spikes; male flowers white, closely crowded in a slender, pendulous catkin up to 20 cm long; females greenish, in a shorter and wider spike that looks hairy from the projecting styles.

Fruit and seed description

Fruit: the fruit is a syncarp, i.e. the entire female inflorescence forms one aggregate structure consisting of small nutlets surrounded by the fleshy perianth. The fruit is green, 5-7.5 cm long, 2.5 cm thick, wrinkled and fleshy and resembling a fat green caterpillar. There are about 70 seeds per fruit.

Seed: small and light brown, about 1.5 mm long and 1.0 mm wide. It is thinner at the scar end and has a thin seed coat. There are 400,000-500,000 seeds per kg.

Flowering and fruiting habit

Flowering generally takes place at the end of the dry season after the trees have shed the leaves or with the new leaves. Male trees often set flowers before female and normally male trees flower every year whereas some female trees only flower every two years. After pollination, which is by wind, the fruits take 5-6 weeks to mature. The ripe fruits are dispersed by bats, birds and squirrels that readily eat the fruits.

Harvest

The fruits have a short ripening period and once ripe they fall to the ground where they begin to ferment immediately and timing of the seed collection is crucial. During the flowering season it is advisable to record the sex of the trees in the seed source in order to facilitate seed collection.

The fruits do not change colour during maturation and a cutting test is necessary to determine maturity. When the seeds are mature, the fruit pulp softens and the endosperm inside the seed is white and firm.

Collection is best done from the tree by cutting down small twigs with fruits. If the fruits are collected from the ground, it must be done daily and on tarpaulins.

As the fruits begin to ferment rapidly, they will not tolerate temporary storage and must be transported to the processing site as quickly as possible. During transport the fruits should be kept in open bags and with only small amounts in each bag. The bags should be protected from direct sun and, to avoid overheating, must not be stacked or packed tightly.

Processing and handling

At the processing site the fruits are spread out in a single layer, preferably on a rack to allow air circulation. If the seeds are not fully mature, they are left in the shade for a few days to afterripen. Fully mature seeds should be extracted immediately.

To remove the pulp, seeds are soaked in water for about one day and then macerated by hand. Empty seeds float on the water but some report that so do many viable seeds and that this method is not recommendable. Pulp and other impurities are removed by skimming. Depulping can also be done in a depulper, seed thresher or in a cement mixer where seed and gravel are mixed 2:1. About 40 kg fruit produces 1 kg clean seed.

When the seeds are completely clean, they are dried in the shade for a few days in a well-ventilated place. To absorb excess water the seeds are best dried on a piece of plywood or paper. During drying, the seeds must be turned from time to time and the board or paper under the seeds changed when wet.

Storage and viability

The seeds are tolerant to desiccation and low temperatures. If dried to 8% moisture content or less and stored in airtight containers at 0-5°C, full viability

can be retained for at least one year.

However, storage of this species can be problematic and when possible, the seeds should be sown within one year of collection.

Dormancy and pretreatment

The seed is not dormant and pretreatment is not necessary.

Sowing and germination

The seeds are sown in a seedbed and transplanted to containers after three weeks. Germination is usually good, attaining about 30% after two weeks and 60-90% after four weeks. The germination percentage depends largely on the number of empty seeds. In the nursery the seedlings must be grown under shade cloth or screen to be protected from attacks by gall-forming psyllids.

After about four months when the seedlings are 30 cm tall, they are ready for planting in the field. Stumps (27 cm root length, 2 cm diameter) or striplings (2.4 cm tall) are generally transplanted in the field but in some places the most common technique is to plant in plastic bags.

It is found that constant temperature as well as complete darkness retard germination and if the germination test is carried out in a cabinet, it should be under fluctuating temperature and light regimes.

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Moringa oleifera Lam.

Taxonomy and nomenclature

Family: Moringaceae

Synonym: *Moringa pterygosperma* L., *Moringa polygoba* DC, *Guilamdia moringa* L.

Vernacular/common names: Horseradish-tree, Ben-oil tree, Drumstick-tree

Distribution and habitat

The geographical distribution ranges from subtropical dry to tropical moist forest areas. Native to India, Arabia, and possibly Africa and the East Indies; widely cultivated and naturalized in tropical Africa, tropical America, Sri Lanka, India, Mexico, Malabar, Malaysia and the Philippine Islands.

Moringa is mostly a dry zone, hot region species, from about 250-1000 mm annual precipitation, but it is occasionally found in areas with less than 50 mm and in the Philippines it occurs also up to 3000 mm annual rainfall. Annual temperature range mostly between 18.7 and 28.5°C, but as the species occurs even above 1000 masl, it is likely to tolerate lower temperatures. It is reported in areas with tolerant to light frost. Grows best on a dry sandy soil and pH of 4.5 to 9. Drought resistant.

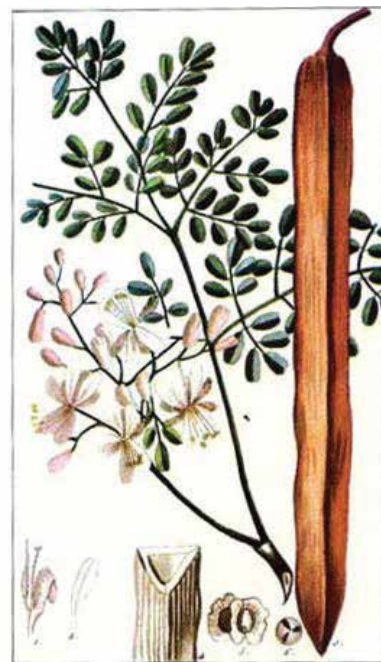
Uses

Almost every part of plant is of value for food. Seed is said to be eaten like a peanut in Malaya. Thickened root is used as substitute for horseradish. Foliage eaten as greens, in salads, in vegetable curries, as pickles and for seasoning. Pounded leaves used for scrubbing utensils and for cleaning walls. Seeds yield 38-40% of a non-drying oil, known as Ben Oil, used in paint and for lubricating watches and other delicate machinery. Oil is clear, sweet and odourless, never becoming rancid. It is edible and useful in the manufacture of perfumes and hairdressings. Wood yields blue dye. Leaves and young branches are relished by livestock. Commonly planted in Africa as a living fence (Hausa) tree. Bark can be used for tanning; it also yields a coarse fiber. All parts of the plants have wide applications in traditional medicines.

Botanical description

Short, slender, deciduous, perennial tree, growing to about 10 m tall; rather slender with drooping branches; branches and stems brittle, with corky bark. Leaves feathery, pale green, compound, 3-5-pinnate, 30-60

cm long, with many small leaflets, 1.3-2 cm long, 0.6-0.3 cm wide, lateral ones somewhat elliptic, terminal one obovate and slightly larger than the lateral ones. Main root thick. Inflorescence an erect spreading panicle. Flowers fragrant, white or creamy-white, 2.5 cm in diameter, 2 cm long, 5-merous; stamens yellow.



Moringa oleifera Lam.

Fruit and Seed description

Fruit: pendulous, brown, triangular, semi-dehiscent pods, splitting lengthwise into 3 parts when dry, 30-50 (-120) cm long, 1.5-2.5 cm wide, containing about 20 seeds embedded in the pith. Pod tapering at both ends, cross section triangular, 9-ribbed.

Seed: Seeds light or dark brown, sub-globose, 1-1.4 cm diameter, with 3 papery wings, 0.5-2.5 cm long. There are 3,700-6,000 seeds per kg.



Flowering and fruiting habit

The plant starts bearing pods as early as 6–8 months after planting but regular bearing commences only after the second year. The tree bears for several years. Flowering and fruiting often more or less continuously with some peak seasons. In India and Sri Lanka, fruiting may peak between March and April and again in September and October. In Indochina peak flowering is in January - February. Development from flower to green, vegetable size fruit is about 55-70 days, with additional 30-50 days to reach maturity. Individual, >3 year old, mature trees may produce from 600-1200 fruits per year, occasionally up to more than 2000.

Harvest

Maturity criteria are when pods are light brown and dry and start to split open. The mature pods are mostly harvested from the trees using long handled tools or pulling down fruit bearing branches.

Processing and handling

After drying the pods in the sun, the dried pods are put in a bag and threshed with a stick. The seeds are then separated from the chaff by hand or by winnowing. Seeds are dried in the sun with good aeration (thin layers of seeds) for approximately 3-5 days to reduce moisture content to between 5 and 8%.

Storage and viability

Seeds are orthodox / desiccation tolerant and can be stored dry and cold for several years without loss of viability.

Dormancy and pretreatment

Pre-sowing is not necessary

Sowing and germination

Germination is epigeal. Germination rate typically 50% - 90%. Germination starts in few days and all seeds have completed germination within 2 months. Seeds can be sown either in containers or directly at the planting site.

Vegetative propagation

Stem cuttings are usually preferred because they root easily. In India, the plant is propagated by planting 1–2 m long stake cuttings, from June to August. Shield budding is successful, and budded trees begin to bear fruit in 6 months and continue to give a good crop for more than 13 years.

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Podocarpus falcatus (Thunb.) R.Br. ex Mirb.

Taxonomy and nomenclature

Family: Podocarpaceae

Synonyms: *Afrocarpus dawei* Stapf, *A. falcatus* (Thunb.) C.N. Page, *A. gracilior* (Pilger) C.N. Page, *A. usambarensis* (Pilger) C.N. Page, *Decussocarpus falcatus* (Thunb.) de Laubenfels, *D. gracilior* (Pilger) de Laubenfels, *Nageia falcata* (Thunb.) Kuntze, *N. meyeriana* (Endl.) Kuntze, *Podocarpus elongatus* L Herit ex Pers., *P. gracilior* Pilger, *P. gracillimus* Stapf, *P. meyeriana* Endl., *Podocarpus usambarensis* Pilger, *P. usambarensis* var. *dawei* Melville, *Taxus falcata* Thunb.

Vernacular/common names: East African yellowwood, outeninqua yellowwood (Eng.); zigba (Ethiopia); mse mawe, olvirviri, owiriwiri (Tanzania); musenene, obwipe, omufu (Uganda); outeniekwa-geelhout, umsoniti (Africaans); umSonti (Zulu); podo (trade name).

Distribution and habitat

Native to East and Southern Africa from Sudan in the north, west to Congo and south to the Cape province. It is found in various types of vegetation, including Afromontane forest. In Afromontane forest it is frequently one of the dominant or co-dominant species ('Podocarpus forest' or e.g. Juniperus-Podocarpus forest). It is often seen persisting in patches of relic forest and as a single tree left in derived grassland or farmland.

It grows at 1500-3000 m altitude in areas with 1200-1800 mm rain per year. It prefers a warm and humid climate, in dry areas plantations fail. Tolerates moderate frost but not drought.

Uses

The attractive yellow or yellow-brown timber is popular for the manufacture of fine furniture. It is of high quality with very fine grain, the density varying from 480 to 599 kg/m³ at 12-15% moisture content. The timber is also used as standard building timber, for flooring and roofing and it is suitable for firewood. The bark contains 3-6% tannin and is used for tanning leather, the fruit is edible and oil from the seeds is used for medicinal purposes. The large, dense crown makes it suitable for shade and windbreaks and the attractive shape has made it popular as an ornamental tree in cities. In some countries it is used as a Christmas tree instead of pine or fir. In the natural environ-

ment the species is an important provider of nesting sites and food for a number of bird species.

Botanical description

A medium to large tree, up to 60 m tall but quite smaller if planted. The bark is rather thin and smooth, grey or brown, on older branches flaking in irregular pieces. Crown is dense, pyramid-shaped and symmetrical. Leaves are 3-5 cm long, narrow and often sickle-shaped, twisted at the base so that the leaves are held upright. The plants are dioecious (female and male flowers on different trees). Male cones are small, about 10 x 3 mm, positioned in leaf corners 1-3 together. In the female structure usually only one seed is produced at the end of a woody stalk.

Fruit and seed description

Podocarpus belongs to the gymnosperms so no fruit layer is produced, the seeds are borne "naked" inside the cone. Each seed is almost round and up to 2 cm in diameter. The seed resembles a drupe, with a fleshy, about 3 mm thick outer layer and a very hard, 4-8 mm thick inner layer. At maturity the seeds are of a deep yellow colour.



Natural occurrence of *Podocarpus gracilior* at Asella (approx. 2500 m a.s.l.) Ethiopia. Photo by H. Keiding, DFSC.

Flowering and fruiting habit

The trees in southern Africa flower in September to May and peak fruiting takes place from December to May. In Ethiopia fruits are ripe around March and in Tanzania in January to April. As the seeds take a full year to develop, seeds at some stage of development can be found on the tree throughout the year. Ovaries that have not been pollinated still grow to full size and empty seeds are produced. Heavy seeding typically occurs every 2-4 years. The flowers are mainly wind-pollinated and the seeds are dispersed by birds, bats and wild pigs.

Harvest

When the seeds have turned yellow and the skin begins to loosen, they are ripe. The ripe seeds are collected from the tree or from the ground soon after shedding. After lying on the ground for a short time the fruits will turn brown. Freshly collected, ripe, seeds have a moisture content around 70% (entire seed), the embryo itself around 20%.

Processing and handling

At harvest time the seeds can be at different stages of maturity and it may be necessary to after-ripen the seeds for a few days in bags that allow ventilation, e.g. sisal or jute. Care must be taken to prevent the seeds from drying out as it is very difficult to remove the skin once it has dried.

After collection, the outer, fleshy layer is removed. This is important, as it is believed the outer layer contains a substance that inhibits germination. For bulk quantities, the seeds are soaked in water for 24 hours and then pounded in a mortar. After mixing with water, the broken skin and pulp can be cleaned off. For small quantities of seed the fleshy layer can be removed with a knife. Removal of the outer layer reduces the weight to about one fourth. After cleaning the seeds are dried in the shade. After removal of the fleshy layer and after drying there are about 250 seeds per kg.

Storage and viability

The seeds tolerate desiccation down to a few % moisture content and in cold store (4-5°C), they will maintain high viability for several years. At ambient temperature the seeds cannot be expected to store for more than six months. Furthermore, the seeds do not tolerate storage below 0°C.

Dormancy and pretreatment

It seems the seed has two types of dormancy; a chemical, which is overcome by removing the fleshy layer and a mechanical, imposed by the hard seedcoat. The seedcoat has pores and water can enter into the seed but the hardness restricts germination. To ensure a high and even germination the seedcoat must be broken and removed. This can be done in a

vice but it is very time-consuming. Freshly collected seeds will normally germinate well, up to 60% in nine weeks, even with seedcoat but once the seeds have been dried, germination can take more than six months unless the seedcoat is removed. Some reports say that soaking in saturated salt water just before sowing can improve germination. Others recommend stratification between two layers of compost for 3-5 days in order to weaken the seedcoat.

Sowing and germination

The seeds are sown directly in nursery bags or in seedbeds in a mixture of compost and sand (1:1). The seed must be pushed into the mixture and covered with a fine layer of soil. The mixture must never be allowed to dry out.

Vegetative propagation by cuttings is also possible. The cuttings should be taken from end shoots (as opposed to cuttings from lateral branches and shoots) in order to produce plants with upright growth.



Seed of *Podocarpus falcatus* from Tanzania. The seed on the left has been cut through. (NB. grid has 1 cm divisions).

Photo by Dorthe Jøker, DFSC

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Pongamia pinnata (L.) Pierre

Taxonomy and nomenclature

Species name: *Pongamia pinnata* (L.) Pierre

Family: Fabaceae

Synonym(s): *Pongamia glabra* Vent., *Derris indica* (Lam.) Benn., *Millettia pinnata* (L.) Panigrahi

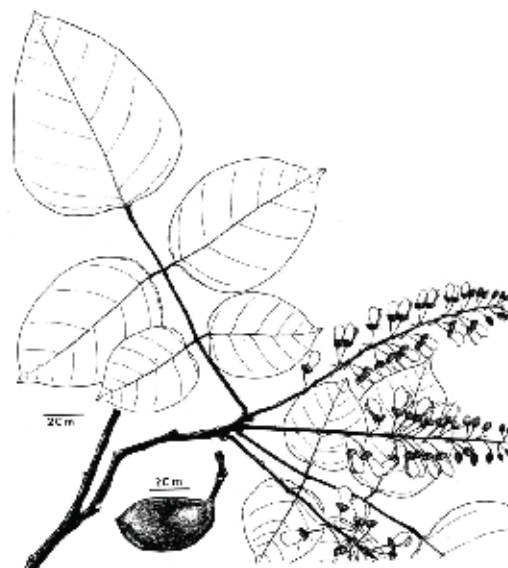
Vernacular/Common name: Karanj, Pongam (India), Karum tree, Indian beech (English), Thiuwia (Burmese), Paripari, Malapari (Malay), Bangkong (Javanese), Kanji, pongam, karanga, karanj (Trade name).

Distribution and habitat

The species is considered to be a native of Western Ghats of India. It is introduced into cultivation to other parts of India, China, Japan, Thailand, Malaysia and some pacific islands chiefly in the littoral regions of south-eastern Asia and Australia. It can grow in vast variety of ecological conditions including saline, alkaline black soil (including vertisols), waterlogged or sandy soil, lowland forests on limestone, rocky coral outcrops of the coast, mangrove forests along tidal streams and rivers and also in the plain lands, but better growth is seen in deep well drained moist sandy loam soil. It occurs up to an elevation at 1200m. The range of temperature of its habitat is 0-50°C and rainfall is 500-2500 mm. The tree is drought resistant, slightly frost hardy and highly tolerant of salinity. It is shade-bearer and is considered to be a good tree for planting in pastures, as grass grows well in the shade. However it cannot resist prolonged drought. The trees require a dry season of 2-6 months.

Use

Wood is moderately strong, tough, but needs water seasoning for prevention of insect attack. It is used locally for agricultural implements, such as ploughs, yokes etc., cartwheels, oil mills rafters post, cabinets, tools, etc. It is also a good source of fuel wood. The oil produced from the seeds is known as pongam oil that has many industrial and medicinal uses. The seeds contain 27-39 percent of fatty oil, which is used for leather dressing, soap making, lubrication and illumination. It is also used for treatment of scabies, herpes, leucoderma and other skin diseases. Roots, bark, leaves and flowers are used as local medicines. The seed oil is also used in villages as biodiesel to run generators for electricity. The seed cake is used as manure and as pesticide. The leaves are used as fodder and also as green manure for rice and sugarcane fields. Flowers are considered as good source of pollen and nectar for honeybees. The tree is a host of lac insect and for the



hemi parasitic sandalwood, *Santalum album*. It is used as road-side plantation and for afforestation especially in water shed wastelands, lateritic soil, mined out areas, coal mine spoils and brackish water and inundated areas.

Botanical description

Pongamia pinnata is a medium sized nearly evergreen or briefly deciduous glabrous tree with short and crooked bole and spreading shady crown reaching a height of 15-25m. Bark is greyish green or brown, smooth or covered with tubercles. Leaves alternate, imparipinnate with long slender leafstalk, hairless, pinkish-red when young, glossy dark green above and dull green with prominent veins beneath when mature. Leaflets 2-4 pairs plus terminal leaflet, short-stalked, ovate elliptical or oblong, 5-25 cm long and 2.5-15 cm wide; base abruptly acuminate, rounded to cuneate, margins entire, slightly thickened, bright glossy above, prominent veins underneath. Inflorescence raceme-like, axillary, 6-27 cm long, bearing pairs of strongly fragrant flowers. Flowers are clustered (2-4 together), short-stalked 15-18 mm long. Calyx campanulate, 4-5 mm long, truncate, finely pubescent; corolla white to pink, purple inside, brownish veined outside, 5-toothed, standard rounded obovate 1-2 cm long, with basal auricles, often with green central blotch and thin silky hairs on back; wings oblong, oblique, slightly adherent to obtuse keel.

Fruit and seed description

Fruit: Pods variable in size and shape. Short-stalked, el-

liptic to obliquely oblong 4.0 to 7.5 cm long and 1.5-3.2 cm broad, yellowish grey when ripe, flattened but slightly swollen, slightly curved, compressed with a short curved beak, brown, thick-walled, leathery to sub-woody, hard, indehiscent, 1-2 seeded. 460-530 dry pods per kg.

Seeds: Seed compressed, elliptical or reniform, 1.7-3.0 cm long and 1.2-1.8 cm broad, flattened, oily, wrinkled with reddish brown, brittle, leathery testa. Seed weight exhibits very large variation which may relate to individual or provenance variation. Some data indicates seed weight 810-1410 seeds per kg; others have 1000 pure-seed-weight about 1650 -1900g, which is equivalent to mere 530 - 600 seeds per kg.

Flowering and fruiting habits

The tree starts bearing at the age of 4-7 years. The flowering and fruiting time varies in different region. Usually flowers appear in April-July and pods ripen from December to June. The yield of seed may range from 9 to 90 kg tree. Pods need to decompose before the seeds can germinate. Herbivores do not like the seeds. In riverside and coastal habitats, the pods are dispersed by flowing water.

Seed collection

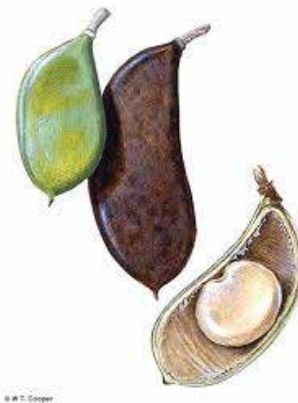
Mature pods are collected when the pods turns greenish brown and seeds are light brown with 20-25% moisture content. Collection by spreading is a tarpaulin under the tree, shaking the tree or looping the branches or plucking the pods. Seeds are extracted from pods by light hammering or pressing a knife along the sutures to break them open. Seeds are spread in one layer on cement floor and dried in shade with proper aera to aeration till the moisture content of seed has reduced to 4-6%.

Dormancy and pretreatment

Seeds have no dormancy, so pre-sowing treatment is not required. However seeds can be soaked in water for 24 hrs before sowing to hasten germination. Germination of fresh seeds is 75 to 80 percent.

Storage and viability

Pongamia pinnata seed are orthodox. Seed can tolerate 4-5% mc and freezing temp at low mc. Seeds can maintain high viability for about five years at ambient temperature (15-35°C) and mc 4-5%. Lowering the storage temperature extends viability. Seeds can be treated with Bavistin 0.2% to prevent fungal attack during storage.



Sowing and germination

Sowing preferably in the beginning of hot season. Seeds start germination after about 10 days and complete in about a month. Seedlings with 2 pairs of leaves are pricked out in polythene bags in the evening and should be watered profusely. Seedlings attaining about 60 cm by the beginning of the next rainy season are transplanted in the field at a spacing of 3x3 m in pits of approximately 30x30x30 cm.

Phytosanitary problems

The important pests of this species are *Parnara mathias*, *Gracillaria spp*, *Indarbela quadrinotata*, *Myllocerus curvicornis*, and *Acrocercops spp*. Attacks by these insects cause whitish streaks and the formation of galls on affected leaves. *Aspongopus brunneus* has been found to cause 20-30% damage to nursery seedlings in India. Both adults as well as nymphs suck the sap from the seedlings. Several fungi attack the seedlings and the trees. *Ganoderma lucidum* causes root rot and *Fomes merilli* attack the tender shoots and leaves and cause early defoliation in the seedlings and trees. Poor storage conditions implies a risk of fungal infection e.g. by *Aspergillus spp*, *Penicillium spp*, *Chaetomium spp* and *Dothiorella spp*. *Phyllachora pongamia* and *Ravenelia hobsoni* cause leaf-tar spot and rust respectively.

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Prosopis juliflora (Sw.) DC.

Taxonomy and nomenclature

Family: Leguminosae, Mimosiadeae

Synonym: *Mimosa juliflora* Swartz

Vernacular/Common names: Mesquite (general for S. American *Prosopis* spp.), Velvet mesquite.

Related species of interests. *Prosopis* encompasses a large number of important tree species from dry zones, several of them with high salt tolerance. Main distribution is in America (e.g. *P. alba*, *P. tamarugo*, *P. chilensis*, *P. pallida*); in Africa occurs *P. africana* and in S. Asia *P. cineraria*.

Distribution and habitat

Prosopis juliflora is indigenous to northern South America (Columbia and Venezuela), Central America (Guatemala, Honduras, Panama) and some Caribbean Islands (West Indies). It has been widely planted in many dry areas in the tropics, where it has often spread and become a noxious weed.

P. juliflora is a species of the very hot and dry semi-deserts, with 150-700 mm rain and temperatures approaching 50°C. It grows from sea level to 1500 masl. It has an exorbitant ability to form deep growing roots and survive extremely dry conditions. It can grow on most arid soil types including alkaline and saline types.

Uses

A MPIS with many applications. The wood is hard, heavy, durable, and rot-resistant. It is easy to work and is used for most types of woodwork and carpentry articles. It doesn't reach large dimensions, so it has limited use in larger constructions. It makes excellent charcoal and firewood.

Flowers produce abundant nectar and are useful for honey production. Tannin can be extracted from the bark and the sap yields a fine rubber. Pods and to a certain degree leaves are used as fodder for livestock. Flour made from pounded dry pods is a traditional food among some American indians.

Because of its superior drought resistance, the species can be used for reclamation and rehabilitation of degraded and saline arid land, e.g. mines and dune stabilisation.

Botanical description

Prosopis juliflora is a small, usually < 12 meter deciduous tree or shrub. The crown is often wide, umbrella-shaped and open. Branches are characteristic zig-zag formed with long thorns in pairs at each bend. The thorns are modified stipules.

Leaves pinnately compound with 10-15 pairs of 5-10, linear-oblong leaflets, with rounded apex, hairy and glabrous.

The flowers are placed in long cylindrical spikes; they are regular and the corolla is pentamerous.



Plate from book: Flora de Filipinas (1880-1883), Francisco Manuel Blanco (O.S.A.)

Fruit and Seed description

Fruit: The indehiscent pods are long, pulpy, and yellowish when ripe. They are 10-15 cm long, cylindrical and slightly constricted between the 8-15 seed.

Seed: Seeds are very hard-coated. They are oval – elliptic, 2½-7 mm long, 1½-4 mm wide, smooth, light brown. 1000 seed weight 35-40g, equivalent to 25-30,000 seed per kg.

Flowering and fruiting habit

Flowering may start as early as 2-3 years. Pollination by various insects including bees. *P. juliflora* can have a very high fruit production



Free standing tree. www.unesco.org/csi/

Harvest

Harvest by picking up pods under the trees or beating or shaking fruit bearing branches. Harvest time is not critical unless seeds are strongly attached by bruchids or pods are removed by browsers.

Processing and handling

Seeds should be extracted from the dry pods by breaking the pods, e.g. by beating, flailing or threshing. After disintegration of pods, seeds are extracted by a combination of sifting and winnowing.

Alternatively pods can be fed to goats and the seeds, most of which pass undamaged, can be extracted from the dung.

Storage and viability

Seeds dried to < 6-7% can be stored seeds can be stored at ambient temperature for 20 to 30 years. For long term storage cooled conditions are recommended.

Dormancy and pretreatment

Seeds exhibit very strong physical dormancy and very few seeds will germinate without pretreatment. High germination percentage can be achieved by manual scarification e.g. nicking, filing or hot wire burning. Bulk treatment e.g. by pouring boiling water over the seeds and letting them cool and imbibe in the water for 24 hours. Non-imbibed seed can be given a second treatment. Alternatively seeds can be scarified in 20% sulphuric acid for 1 hour or concentrated sulphuric acid for 20 minutes.

Sowing and germination

Germination is epigeal. Seeds may be sown in pots or seed beds for later transplanting. Germination is usually fast with paracotyledons unfolded after 4-5 days. With efficient pretreatment, germination can be more than 95%.

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Prunus africana (Hook f.) Kalkman

Taxonomy and nomenclature

Family: Rosaceae

Synonyms: *Pygeum africanum* Hook f.

Vernacular/common names: red stinkwood, bitter almond, iron wood, (Eng.); Kanda stick (Cameroon); ol-koijuk, mueri, mutimailu (Kenya); kotofihy (Madagascar); olkonjuku (Tanzania); gyabazito, gwabuzito (Uganda); roostinkhout, bitteramandel, umDumizula (South Africa); muchambati, muchati (Zimbabwe); mueri (trade name).

Related species of interest: *Prunus crassifolia* (Harm.) Kalkm. is endemic to Kivu (Zaire) although more specimens are required to confirm the status of this species. *P. africana* and *P. crassifolia* are the only African species in the genus *Prunus*.

Distribution and habitat

Native to the tropical African mountain forests from Nigeria in the east across the mainland to Kenya and Tanzania, and south from Ethiopia to South Africa. It grows at altitudes between 900 and 3000 m in areas with mean annual rainfall of about 2000 mm. The species has a high light requirement and grows best in forest gaps. It tolerates light frost and waterlogging and is little drought-resistant.

Unsustainable exploitation and habitat loss have led to a decline in the species and it is listed as vulnerable on the 2002 IUCN Red List of Threatened Species. However, due to its very large geographical range it is in no way in danger of extinction.

The species is fairly easy to cultivate but it is being done only on a relatively small scale, compared with the level of demand. So far cultivation is restricted to Cameroon and Kenya.

Uses

Traditionally the species has been used in local medicine for a number of purposes and today the bark and its extracts are used by the international pharmaceutical industry for the treatment of prostate disorders. With an 'Over The Counter' value estimated at US \$ 220 mill. per year, the trade is on a larger scale than that of any other wild-collected African tree. The bark is harvested from wild populations in the Afromontane forests of Madagascar, Cameroon, Kenya and Zaire.

The timber is hard and durable. It is used for the

manufacture of various household products and produces high-quality firewood. The leaves can be used for mulch and green manure, the flowers make good bee forage and the attractive shape makes it a popular garden shade tree. In the Afromontane forests the fruits of *P. africana* are an important food source for a number of rare birds and mammals.

Botanical description

A medium to large tree, 10-24 m tall, about 1 m in diameter and with bluish-brown, rough bark. Leaves are alternate and simple, 5-15 cm long, shiny green and with finely toothed margins; the leaves have a faint smell of almonds when crushed. Flowers are bisexual, small, white and fragrant, solitary or in 3-7 cm long inflorescences.

Fruit and seed description

Fruit: the fruits are rounded, often bilobed drupe, about 1 cm in diameter. The fleshy layer surrounding the stone is thin and intensely bitter. At maturity the fruits are dark red or reddish-brown. There are one or two seeds per fruit.

Seed: the seeds are oval and delicate. There are 3500-6000 seeds (stones) per kg.



Details of foliage, flowers and fruits. Drawing from the Flora of Tropical East Africa.

Flowering and fruiting habit

In Kenya the trees flower between November and February and ripe fruits are available 4-6 months later. In South Africa flowering occurs October to May and fruiting September to January. The flowers are pollinated by insects and fruits are dispersed by birds and monkeys that eat the fruits.

Harvest

The fruits are mature when the colour of the skin has changed to deep red. Mature fruits can be collected from the tree or from the forest floor soon after shedding. Fruits that have been lying on the ground for more than a day should not be collected. Mature seeds have a moisture content of about 50%.

Processing and handling

After collection the fruits are depulped without delay. The fruits are soaked in water for a few hours and then the pulp can be removed by rubbing the fruits against a wire mesh under running water or mixing the fruits with sand and then rubbing them against a wire mesh.

In general the seeds must be handled very carefully all through the process of collection, processing and storing. Careless handling can affect seed quality seriously.

Storage and viability

The reports on storage physiology of *P. africana* are contradictory, the seeds have been termed orthodox by some and recalcitrant by others. However, a recent study has shown that the seeds are tolerant to desiccation and can be dried down to 5-10% moisture content without loss of viability and also that they can tolerate storage at -20° C.

Seeds that are fully mature when collected will retain high viability for at least three months even at room temperature. Immature seeds, even if they have been after-ripened, loose viability faster.

Dormancy and pretreatment

Freshly collected, mature seeds normally germinate well, 70-80%. However, there are some indications that the seeds need after-ripening. It is not necessary to remove the pericarp as it does not mechanically restrict germination.

Sowing and germination

The unit for sowing is the depulped fruit (the stone). Germination normally takes place within 30-50 days. In nature, a fruiting tree can produce thousands of seedlings (wildings) that can be collected and transplanted. However, it is often seen that the wildings do not transplant well. In Cameroon the species has been propagated from cuttings. Without the use of hormones, about 10% of the seedlings had rooted after three months.

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Tree left in a farm after clearing the bush. Photo by: Munjuga, Prunus Net, ICRAF

THIS NOTE WAS PREPARED IN COLLABORATION WITH KENYA FOREST RESEARCH INSTITUTE

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Ximenea americana L.

Taxonomy and nomenclature

Family: Olacaceae

Vernacular/common names: wild plum, blue sour plum and tallow nut (Eng.). Local names: olemo (Luo), mutoywo, mutenywa (Sebei), mtundakula (Swahili, Giriama, Digo), mukungambura (Kikuyu), madarau, madarud (Somali), ol-amai (Maasai), Tonga (Bambara), leanga (Moré).

Related species of interest: the other species of *Ximenea* native to Africa, *X. caffra* (large sour plum), is less spiny and with larger leaves than *X. americana*. The flowers are either solitary or in single stemmed groups whereas *X. americana* has branched inflorescences.

Distribution and habitat

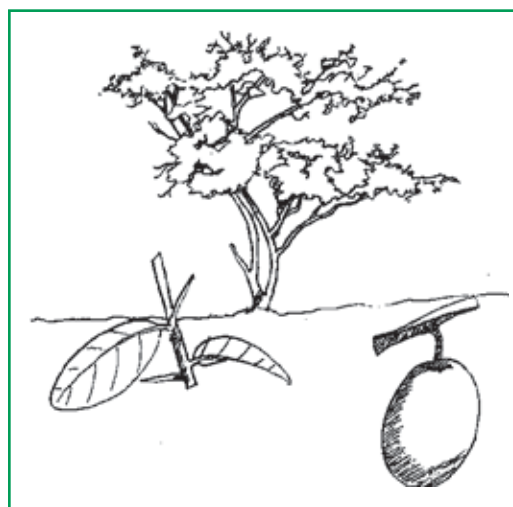
This species is widespread throughout the tropics: Africa, India and South East Asia to Australia, New Zealand, Pacific Islands, West Indies, Central and South America. It is mainly found in semi-arid bushland but also in many types of dry woodland, sandy open woodland, bushland, stony slopes and riverine and coastal thickets. It is frequently found on coastal dunes, along water courses and on stony slopes. It occurs at altitudes up to 2000m, and where rainfall exceeds 500mm per year. It grows on many soil types; however, they are often poor and dry. This species is a root hemiparasite, i.e. it is able to take water and nutrients from other plants through the roots, but does not depend on this for survival.

Uses

The heartwood is yellow-red to brown-orange, fine textured and regular. The wood is very hard, heavy and durable, and is used for tool handles. The timber usage is limited due to the thinness of the trunk. The wood is also used as fuel wood. The oil from the seed has multiple uses; it is traditionally used to soften leather, as well as being used as a cosmetic and skin ointment. The edible fruit is made into a type of beer, and the pulp is used in preserves and to make jellies. Bark, roots and leaves are used in local medicine, to treat ailments such as leprosy, fever, headaches, ulcers and skin complaints. An infusion of the leaves is used as an eye wash, and also for toothache and constipation. The tree is also planted as an ornamental, as hedge plant and for the shade it provides.

Botanical description

X. americana is a small tree or shrub, up to 6m tall, with zigzag branches. The bark is black or grey-brown, smooth when young, but becoming rough and developing fissures with age. It usually has stiff axillary spines; however, it is often unarmed when inland and towards the north of its distribution. The simple leaves are alternate or clustered on spur shoots. The seedling morphology is variable and when young the leaves are densely hairy, but they become smooth and shiny with growth. The pale bluish-grey leaves are typically 4-7.5 by 2-4.5cm, and are often folded upwards along the midrib. The apex of the leaves is rounded and slightly notched, the base is broadly tapering or rounded. When growing near the coast the leaves are often fleshy, however, when inland the leaves are thinner. Flowers are greenish-cream, scented and 5-10mm long; in small, branched inflorescences.



Ximenea americana. From Hines & Eckman (1993)

Fruit and seed description

Fruit: the yellow-red edible drupe is oval, approximately 2.5cm in diameter. Each fruit contains one large endospermic seed within its green pulp.

Seed: the seeds are c. 1.5cm by 1.0cm, and have a mean thousand seed weight of 600-800g; however, the weight varies depending on the environmental conditions during development. The seeds are endospermic, with a small embryo near the tip, and a thin testa. They have up to 60% oil content, and the seed coat ratio (seed coat mass/whole seed mass) is 0.36, on average.

Flowering and fruiting habit

The flowers are unisexual and male and female flowers occur on different plants. Flowering and fruiting varies between localities, but flowering typically occurs in the dry season. In Kenya flowering occurs in July and August, while fruiting takes place from January to April. In southern Africa flowering occurs in September to December, with fruiting taking place in December to February. In many places it flowers and fruits throughout the year. On good sites trees may produce fruit after 3 years of growth. The fruits are dispersed by animals.

Harvest

Yellow-red, mature fruits are collected by either hand picking, or shaking the branches to release the fruit.

Processing and handling

Seeds are after-ripened for 2-3 days after collection, until the fruits have reached full maturity. The fruits are kept at air temperature, high moisture levels and are ventilated. Care must be taken when after-ripening the fruit, since germination of the seeds can be reduced if the fruits are allowed to ferment. Therefore, the fruits should be processed as soon as they are ripe. The seeds are extracted by rubbing the fruit on a wire mesh to remove the pulp, and then washing the seeds in running water to remove the mucilage. The seeds can then be cleaned by hand sorting, and dried in either the sun or the shade.

Storage and viability

The seed is orthodox and should be stored at low moisture content and as cold as possible. It tolerates drying to 3.2% mc and temperatures as low as -20°C. For short term storage, the seed can be stored moist. It is essential for the successful moist storage of orthodox seeds that the seeds are ventilated frequently. After 17 days of moist storage in vermiculite at 26°C, germination was 100% (initial germination before storage was 93.4%). Seeds of this species have been stored in the MSB for nearly 20 years and X-ray analysis of the seed lots gave 90-100% viability.

Dormancy and pretreatment

Removal of the seed coat prior to germination or sterilisation of the seeds (e.g. by immersion in sodium hypochlorite for 5 minutes) can increase germination.

Sowing and germination

Germination is hypogeal. Seeds readily germinate between 26 and 36°C, with the germination rate being fastest at 31°C. Under such conditions the seeds germinate c. 90% in 8-30 days, in the laboratory or sown in sand in the nursery. When the seed coats are intact the seeds germinate in about 16 days, removing the

days. It is not recommended, however, to remove the seed coat before sowing as it may damage the seed and reduce germination.

Table 1. Germination data from MSB.

Pretreatment and storage conditions	Temp (°C)	Germination (%)
Storage at -20°C	26	80
Desiccated	26	80-88
Seed coat removed	26	94
Untreated	26	87
Untreated	11	0



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Schinus molle L.

Taxonomy and nomenclature

Family: Anacardiaceae

Synonyms: *Guatteria grandiflora* Donn. Sm., *Schinus angustifolius* Sessé & Moc., *S. areira* L., *S. bituminosus* L., *S. huigan* Molina, *S. molle* var. *areira* (L.) DC, *S. molle* var. *argentifolius* Marchand, *S. molle* var. *huigan* (Molina) Marchand, *S. occidentalis* Sessé & Moc.

Vernacular/common names: arbol del Perú, arveira, molle, pimienta, pirul, pirwi, tzactumi (Sp.); California pepper tree, Peruvian mastic, pink pepper (Eng.); poivre rosé (Fr.); Peruanischer (Brasilianischer) pfeffer (Ger.); qundo berbere (Amharic); felfel-kazib (Arabic); mpilipili (Swahili); berebere-tselim (Tigrigna).

Distribution and habitat

The area of natural distribution is the Andes region, mainly Peru. It is found at altitudes up to 3900 masl, in areas with 300-700 mm rain/year. It tolerates high temperatures and once established it is extremely drought resistant; it is resistant to frost but not for long periods.

A fast growing pioneer species that is typically found in disturbed areas with secondary growth, roadsides and on agricultural lands. It grows well on stony sites and slopes. Prefers sandy, well-drained soils but is tolerant to most soil types and also to salinity and alkalinity.

Introduced to Central and North America, Europe and Africa and in some places it has become naturalised.

Uses

All parts of the tree have a high content of essential oil. It has a long history of medicinal uses throughout South and Central America and even today herbalists use it, especially for viral and bacterial infections.

The wood is used for firewood and charcoal; it is moderately hard and heavy with a density (air-dry) of 0.54-0.68 g/cm³, easy to work, durable and termite resistant and therefore suitable for posts.

The resin is used as a mastic, latex is produced from many parts of the tree, juice is produced from the fruits and the seeds are used as a substitute for pepper. It is planted for soil conservation, soil improvement, windbreaks, shade and as an ornamental.

Although the tree is ever green and keeps about 75% of its foliage around the year, the fallen leaves, branches and fruits contribute significantly to soil

fertility. The ability to grow on stony sites and steep slopes makes it suitable for erosion control.

Botanical description

Evergreen tree with weeping foliage, 6-8 m tall, on good sites up to 15 m; trunk short with dark brown, deeply fissured and flaking bark, exuding a sticky latex when damaged.

Leaves compound, 15-30 cm long, with 15-41 leaflets; leaflets yellowish-green, 2-5 cm long, lanceolate with entire or serrate margins. The leaves have a peppery smell when crushed.

Flowers unisexual, small and pale yellow, in 10-15 cm long panicles. Female and male flowers normally on different trees.



Tree with mature fruits. Cochabamba, Bolivia. Photo: Dorthe Jøker, DFSC.

Fruit and seed description

Fruit: small, round drupes, 5-9 mm in diameter, bright red when mature, later turning black. The pulp is thin and leathery; it has a sweet taste and contains aromatic oils. There are one or two seeds per fruit.

Seed: 2-4 mm in diameter, round, brown-black, furrowed when dry. There are 30,000-40,000 seeds per kg.

Flowering and fruiting habit

Within the area of natural distribution flowering occurs in September to December and fruits are ripe in December-January. In East Africa fruits are collected in March.

All fruits do not mature at the same time and within a cluster the fruits will often be at different stages of maturity.

Harvest

The seeds are mature when the fruits have turned red. The fruits are collected directly from the tree.

Processing and handling

After collection the fruits are dried in the sun. If there are very different stages of maturity, it may be necessary to after-ripen the green, unripe fruits.

When the fruits are dry, they are pounded using a pestle and mortar and then winnowed to separate the seeds from the fruit pulp.

Storage and viability

The seed is orthodox and will retain viability for 2-4 years if dried to a moisture content of 7-10% and stored in airtight containers at 10°C, or better 0-4°C.

Dormancy and pretreatment

The oil in the pericarp may inhibit germination and it is important to wash the seeds thoroughly in running water for 24 hours before sowing. This will also prevent the seed from attracting ants in the seedbed and from fungal infections.

Sowing and germination

The seeds are sown in seedbeds or directly in containers with two seeds per container. It is recommended to use a light and permeable substrate, maybe because inhibitors need to be washed out before the seeds can germinate.

Germination starts after about two weeks and is normally terminated after four weeks. Germination is reported to be 60-80% but in some places, especially where the species is grown outside the area of natural distribution, low germination in the nursery is a problem. Under normal circumstances 1 kg of pure seed will yield 17,000 seedlings. When the seedlings are 30-35 cm tall, they are ready for planting in the field.

Vegetative propagation by cuttings is also possible. The trees are easily established and are fast growing. After one year the trees will normally have attained a height of 3 m and they reach maturity in less than 20 years.

It has a low-branching habit and pruning of lower branches is recommended when the tree is young. Coppicing, pollarding and looping are also viable methods of management.

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Dry seed and panicle with mature fruits. Photo: Dorthe Jøker, DFSC.

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Sclerocarya birrea (A. Rich.) Hochst.

Taxonomy and nomenclature

Family: Anacardiaceae

Synonyms: *Commiphora subglauca* Engl.; *Poupartia caffra* (Sond.) H. Perrier; *Sclerocarya caffra* Sond.; *S. caffra* Sond. var. *dentata* Engl.; *S. caffra* Sond. var. *oblongifoliata* Engl.; *S. schwein-furthiana* Schinz

Vernacular/common names: marula (trade name); hameid (Arabic); gna (Chad); mu-mugga (Ghana); maroela, mufula (South Africa); umganu (Swaziland); mupfura (Zimbabwe); mng'ong'o (Swahili).

Subspecies/Varieties: *Sclerocarya birrea* subsp. *birrea*; *Sclerocarya birrea* subsp. *caffra* (Sond.) Kokwaro; *Sclerocarya birrea* subsp. *multifoliata* (Engl.) Kokwaro

Distribution and habitat

Native to Africa where it is widely distributed between 16°N and 20°S in wooded grasslands, riverine woodlands and bushlands. It prefers well drained sandy soils and loams but is often found growing on rocky hills. Occurs at low to medium altitudes in areas with 200-1600 mm rain per year. Subsp. *caffra* is known to be highly salt tolerant.

The species has been introduced to Israel where it was successfully established in the Negev Desert.

Uses

The marula is a valued fruit tree and all parts of the fruit are edible. The juicy pulp is rich in vitamin C. It is used in jams and jellies and, on a commercial basis, to produce marula beer and liqueurs like, in South Africa, Amarula. The seeds have a high oil content (~60%), consisting mainly of unsaturated fatty acids, and are also rich in protein and minerals. They are eaten raw or cooked.

The bark is widely used in the treatment of dysentery and diarrhoea due to its high antibacterial activity. The wood is used for carvings and fuel, fibres from the inner bark for making rope, fruits and leaves are a source of fodder and the tree provides shade and acts as a wind break.

Botanical description

Tree, normally about 10 m tall, on favourable sites up to 20 m. Bark grey, flaking in patches exposing the underlying light yellow tissue.

Leaves alternate, compound, with 7-13 pairs of

opposite leaflets plus the terminal leaflet. Leaflets are dark green above, much paler and bluish-green below. The leaves are crowded near the ends of branches. The species is principally dioecious with male and female flowers on different trees, but occasionally a tree can bear flowers of both sexes. Flowers in 5-8 cm long inflorescences at the end of branches.

Fruit and seed description

Fruit: a round drupe, up to 3.5 cm in diameter, yellow at maturity. The pulp is juicy and adheres tightly to the stone. The stone is 2-3 cm long, hard, with one to four cavities, each usually containing one seed. Each cavity has an opening covered with a lid (operculum) that remains firmly attached until germination.

Seed: the seeds are small and fragile, covered with a thin seed coat. 500 stones per kg. has been reported.



Tree habit. Botswana. Photo: Roeland Kindt, University of Gent

Flowering and fruiting habit

The trees are deciduous, standing bare for several months during the dry season. Flowering occurs at the end of the dry season just before the leaves appear and the fruits mature at the beginning of the rainy season. In the Sahel flowering occurs in January-March, fruiting in March-April; in the Sudan flowering is in January-April, fruiting in April-June;

in southern Africa flowering is in September-November, fruiting in February-June.

The fruits abscise before they are mature. At the time of fruitfall the fruits are still green and firm and final ripening takes place on the ground. Trees can begin to set seed as early as at the age of 5 years.

Harvest

When the fruits have turned yellow they are mature. At this stage they have already been abscised, so fruits are normally collected from the ground.

When mature, the seeds have a high moisture content, up to 30% and to avoid fermentation of the pulp the fruits must be brought to the processing site as soon as possible.

Fruit and seed processing and handling

After collection it is vital that the seeds are processed and dried as soon as possible. If the seeds are kept at initial moisture content for just a few days they will lose viability.

Before depulping, the fruits are soaked in water for 24 hours. The fleshy pulp can then be removed using a cement mixer. The fruits are mixed with gravel in the proportion of 1 kg gravel to 2 kg fruits. With a large amount of water, this is stirred in the mixer. When the stones are clean, they are separated from pulp and gravel and washed clean with water. After extraction, the stones are spread out on a mesh and dried in the sun for at least two days.

Storage and viability

The seeds are orthodox, they can withstand substantial water loss and low storage temperatures. If dried below 10% moisture content they can retain viability for up to 4 years.

Dormancy and pretreatment

The hard endocarp (stone) forms a physical barrier to seed germination and removal of the opercula (lids) will significantly improve germination and the seeds will germinate faster and more uniformly. This must be done manually with a small chisel and is normally too time consuming to be feasible.

Germination has also been reported to be improved if the stones are cracked in a vice but this must be done carefully as the seeds are very fragile and easily damaged. Furthermore, cracking may increase seed microflora. It is not recommended to extract the seeds. Treatment with acid has shown good results.

There are some indications that the seeds need after-ripening, in some seedlots it was observed that germination improved after the seeds had been stored for 3-6 months. However, this may also have been the result of loosening the operculum over time.

Sowing and germination

Germination is epigeal. If the opercula have been removed, germination is fast and uniform, reaching 70% after one week and 85% after two weeks from sowing. Without treatment, germination may take as long as nine months. Vegetative propagation with cuttings has proven successful.



Mature fruits of *S. birrea* subsp. *caffra*, Botswana. Photo: F.E.M. Cook



Stone with opercula removed to facilitate germination. Photo: Andrew McRobb (copyright Royal Botanic Gardens, Kew, with permission)

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Senna siamea (Lam.) Irwin et Barneby

Taxonomy and nomenclature

Family: Fabaceae (Caesalpinioideae)

Synonyms: *Cassia siamea* Lam.; *Cassia florida* Vahl.; *Senna sumatrana* Roxb.; *Cassia arayatensis* Naves.

Vernacular/common names: Bombay blackwood, iron wood, kassod tree, Siamese senna, Thailand shower, yellow cassia (Eng.); casse de Siam (Fr.).

Distribution and habitat

Native to South and Southeast Asia, exact natural distribution obscured by cultivation. Widely planted throughout the tropics.

It can grow under a wide range of climatic conditions, but performs particularly well in lowlands with a monsoon climate with annual rainfall of 500-2800 mm, mean annual temperature of 20-31°C and dry periods of 4-8 months. It should not be grown at altitudes above 1300 m and does not tolerate temperatures below 10°C.

Prefers moist, well-drained, fertile soils with pH 5.5-7.5. It can grow on degraded, infertile soils but it is not recommended as this species is not nitrogen-fixing. Susceptible to strong winds because of the shallow root system.



1, Tree habit; 2, flowering and fruiting branch; 3, flower; 4, Pods. From: Plant Resources of South-East Asia.

Uses

The wood is dense and excellent for fuel, although it produces some smoke when burning. The heartwood is decorative and durable. The foliage is used for green manure and fodder for cattle, sheep and goats but is toxic for pigs and poultry.

The species is also used for erosion control, land reclamation (including abandoned mine areas), shade, shelter, ornamental and as host for sandalwood. Although not a nitrogen-fixing species it is suitable for agroforestry and is used in taungya systems and as a shade tree in tea and coffee plantations.

Botanical description

Medium-size, evergreen tree, 10-12 m tall, occasionally reaching 20 m. The bole is short; crown dense and rounded at first, later becoming irregular and spreading; young bark grey and smooth, later with longitudinal fissures. Leaves alternate, 15-30 cm long, compound, with 6-14 leaflets each ending in a tiny bristle. Flowers bright yellow, in large, up to 60 cm long, upright, pyramid-shaped panicles.

Fruit and seed description

Fruit: flat, indehiscent pod, 5-30 cm long, constricted between the seeds. About 20 seeds per pod.

Seed: bean-shaped, greenish-brown, 8-15 mm long. There are 35,000-45,000 seeds/kg.

Flowering and fruiting habit

Flowering and fruiting begin at the age of 2-3 years. Flowering occurs mainly in the hot season but in many places it flowers abundantly throughout the year.

Harvest

When the pods have turned brown, they can be harvested from the tree. It is also possible to collect mature, half opened pods from the ground.

Processing and handling

After harvest the pods are dried in the sun for a few days until they open and release the seed.

Storage and viability

The seeds are orthodox and can be stored for several years in hermetic containers at ambient temperature with 11-15 % mc.

Dormancy and pretreatment

Fresh seed requires no pretreatment but stored seed need scarification by nicking or with boiling water followed by soaking in cold water for 24 hours.

Sowing and germination

It is important that the seeds are sown in full sunlight, as even a little shade will reduce germination considerably. The seeds can be sown directly in lines or patches at a depth of 4-5 cm and thinned to 30 cm spacing at the end of the first rains and to 1.8 x 1.8 m the following rainy season.

In arid areas, container-grown stock is recommended e.g. in polythene bags with a mixture of forest soil and decomposed leaf litter. Regular watering is important. The seedlings are ready for outplanting when they are 30-35 cm tall. It is also possible to use stumps for planting. Direct seeding is often used to establish plantations of this species.

Phytosanitary problems

The seeds are susceptible to attacks from insects such as *Caryedon lineaticollis* and *Bruchidius maculatipes*.

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Ornamental tree. Photo: Rafael T. Cadiz

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Sterculia setigera Delile

Taxonomy and nomenclature

Family: Sterculiaceae

Synonyms: *Sterculia tomentosa* Guill. & Perr., *S. cinerea* A. Rich.

Vernacular/common names: English name: karaya gum tree; Local names: tartar, faider and telieh, posemporgo (Mooré), kongosira (Bambara).

Distribution and habitat

The species is widespread in tropical Africa and is common locally. The natural distribution range stretches from Senegal to Cameroon in West Africa, eastwards to Eritrea, and southwards to Angola. It grows in Savannah type vegetation on a variety of soil types, thriving on poor soils as well as on hilly/stony sites. Not classified on the IUCN Red list of threatened species.

Uses

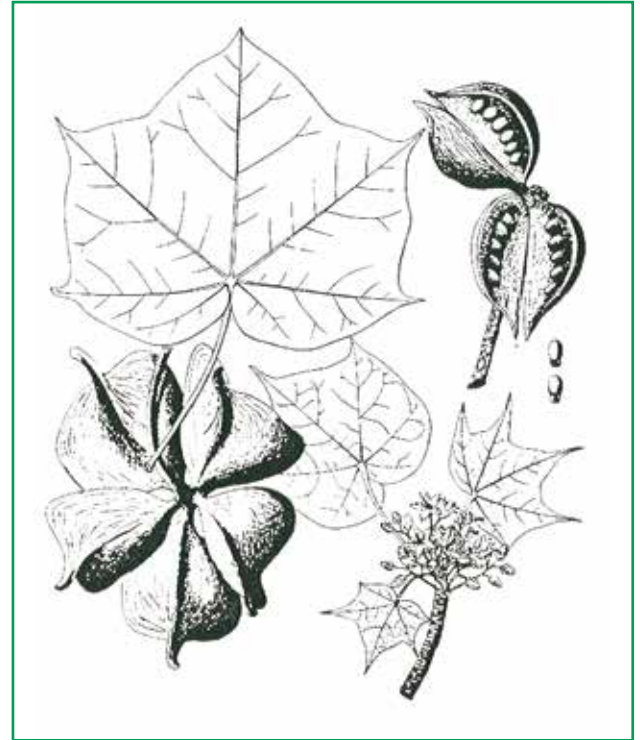
The wood is white and very soft, which makes it unsuitable for fuel wood and charcoal. It is therefore used for non timber forest products (NTFP). It is used for insulation and concealed items in carpentry. The tree produces a water-soluble gum (karaya). This can be tapped and used in cooking as an emulsifier, stabiliser and viscosifier; the gum is used medically as a laxative, diuretic and tranquilliser, and technically as an adhesive and for glazing pottery. The bark is used for rope making and the bark sap can be made into a refreshing drink. In local medicine the bark is also used to treat snake bites, leprosy, syphilis, coughs, bronchitis, rickets and insanity. The seeds can be eaten and contain an edible oil, while the leaves are used as fodder for cattle.

Botanical description

A deciduous tree, growing to c.16 m, with a spreading open crown and large twisted branches. The bark is grey to purple in colour and flakes to reveal a greenish-yellow smooth bark beneath. If the bark is cut it reveals a red inside and exudes a white gum and watery sap. The leaves are simple, alternate, 6-20 cm long and 6-20 cm wide, with 3-5 triangular lobes. They are covered with stellate hairs on both sides, but more densely on the underside.

The flowers are unisexual, apetalous, pedicellate, with 5-lobed conical calyx. They are green or yellowish in colour, and striped or tinged red inside.

The flowers are c. 12 mm in diameter, and are produced on shoots from the previous year.



Sterculia setigera. From Berhaut, J. Flore Illustrée du Sénégal, Direction des Eaux et Forêts, Government du Sénégal, 1975

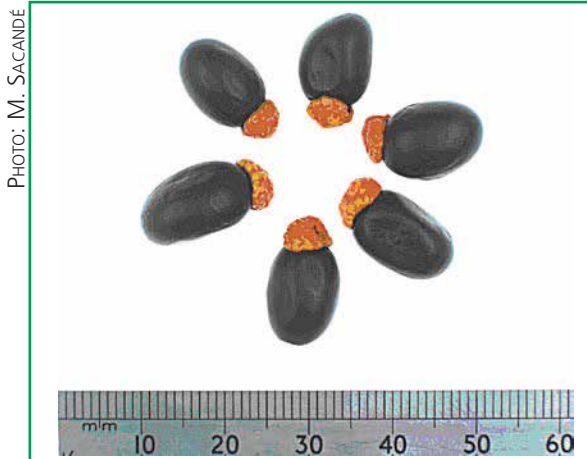
Flowering and fruiting habit

Dioecious. Flowering usually occurs during the second half of the dry season, either before or in connection with leaf flushing. The tree flowers in the Sahelian region between February and April with fruit maturation in December.

Fruit and seed description

Fruit: Compound dry fruits composed of 3-5 separate boat-shaped follicles, which are arranged to form a star shape. Each follicle is 6-10 cm long and 4-5 cm across, with a pointed apex. They are velvety outside and inside with pungent bristles along the placenta line where the seeds attach. They have a thin wall, under 5 mm thick, and are greenish or brown when ripe. Each part of the fruit contains c. 12 seeds.

Seed: The deep-purple coloured ellipsoid seeds are 10-14 mm in length, and have a mean thousand seed weight of 350 g. Each seed has a small yellow-brown aril at the base where it attaches to the fruit. The seed contains c. 26% oil.



Cleaned arilated seeds of *S. setigera*

Harvest and processing

The pods are harvested from the trees when they have started opening but seeds are still attached to the rim of the fruit. Sun drying and mild mechanical impact will detach the seeds. The aril may be removed during seed processing or in connection with sowing.

Storage and viability

The seeds of this species show 'orthodox' seed storage behaviour, and are under long-term storage conditions at RBG, Kew (i.e. -18°C in air-tight containers at a seed MC of 5±1%) since 1991. X-ray analysis indicated viability of 90-100%.

Dormancy and pretreatment

Physical dormancy caused by hard seed coat is overcome by scarification e.g. using a scalpel, knife, file or hot wire. The aril ostensibly imposes both physical restriction to water absorption and chemical inhibitors. Removal of the aril is easiest when softened after soaking in water.

Sowing and germination

Seeds germinate 95% when the covering structure is removed and the seed coat then chipped, and incubated at 25°C, 8/16 h photoperiod. The seeds germinate optimally at temperatures between 20-30°C. Germination is epigeal, and under optimal conditions takes c. 2 weeks to complete.



Germinating *S. setigera* seeds on agar

Selected readings

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Swietenia macrophylla King

Taxonomy and nomenclature

Family: Meliaceae

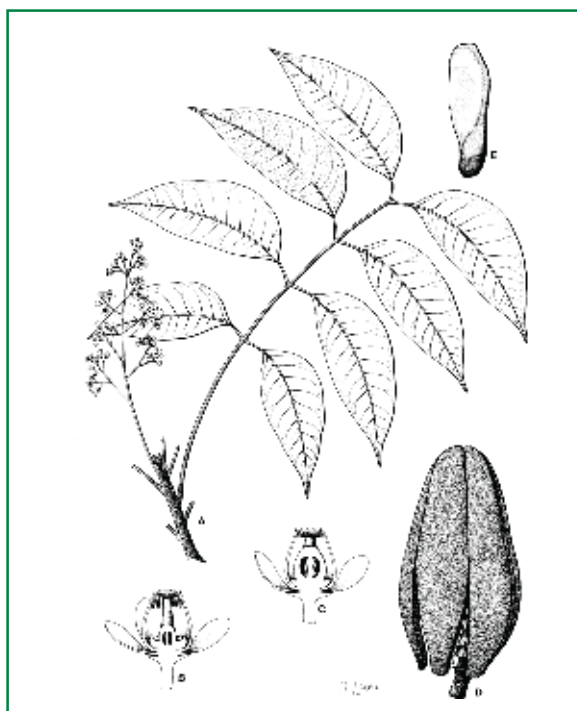
Synonyms: *Swietenia candolei* Pittier, *Swietenia krukovii* Gleason, *Swietenia belizensis* Lundel, *Swietenia macrophylla* King var. *marabaensis* Ledoux et Lobato, *Swietenia tessmanii* Harms.

Vernacular/common names: Honduras mahogany, big/broad/large leaved mahogany (Eng.); caoba (Sp.); echtes mahagoni (Germ.)

Related species of interest: The genus consists of two other species, *S. mahagony* and *S. humilis*. The three species are poorly defined biologically, in part because they hybridise freely.

Distribution and habitat

Humid zone species of the new world; widely distributed, natural as well as cultivated; native to Mexico (Yucatan), Central and northern South America (Amazon region). Extensively planted mainly in southern Asia and the Pacific; also introduced into West Africa.



A, flowering branchlet; B, male flower; C, female flower; D, fruit; E, seed. Illustrations by J. Loken from Pennington, ID., 1981. Meliaceae, Flora Neotropica, 28. Used with permission.

Uses

Mahogany is one of the most valuable furniture timbers in the world due to the decorative and attractive timber with good technical characteristics. It is widely planted in the tropics in reforestation and afforestation programmes. In agroforestry systems it is used for shade and fuelwood.

Botanical description

Usually evergreen tree, up to 30-35 m. Bark grey and smooth when young, turning dark brown, ridged and flaky when old. Leaves up to 35-50 cm long, alternate, glabrous, paripinnate; 4-6 pairs of leaflets, each leaflet 9-18 cm long. Flowers small and white in large, 10-20 cm long, branching panicles.

Fruit and seed description

Fruit: dehiscent, usually 5-lobed capsule, erect, 12-15 (-22) cm long, greyish brown, smooth or minutely verrucose. Outer valves woody, 5-7 mm thick, inner valves much thinner. In the centre is a woody, 5 angled columella extending to the apex.

The fruits split open from apex or base when they are ripe and dry. Seeds are hanging from the columella by their wing, leaving conspicuous scars after their release. Usually 35-45 seeds per fruit.

Seed: brown, oblong, compressed, crested and extended into a wing at the attachment end, 7.5-15 cm long incl. wing with extensive air spaces. The seeds are dispersed by wind. There are 1800-2500 seeds per kg.

Flowering and fruiting habit

Flowers are unisexual and the tree monoecious. The flowers are pollinated by insects. Hybridisation is frequent, especially with *S. mahagony* where the species grow together. Usually only one flower of the inflorescence develops into a fruit, the others being aborted. Development from flower to mature fruit takes 9-12 months. Flowering and fruiting are regular annual from 10 to 15 years of age but fruit set can be low due to lack of pollinators. The long development time for the fruit makes crop assessment possible several months before harvest. Flowering usually takes place when trees are leafless or just coming into new leaf shortly before the rainy season.

Some phenology data are summarised here:

	Flowering	Fruiting
Central and northern S. America	April-June	Jan-March
Southern S. America	Sept-Oct	July-Aug
British Virgin Is. and Puerto Rico	May-June	Sept-Oct
Costa Rica	March-April	Dec-Jan
Solomon Islands		June-Sept
Philippines	March-June	Dec-March

Harvest

The fruits are preferably collected from the trees just before they split open or from the ground immediately after seed fall. Seed production varies according to site and year. A crucial factor for seed production is pollination efficiency, which may be erratic especially outside the natural range of distribution. A mature tree of *S. macrophylla* can produce up to 200 mature fruits in a year or about 4.8 kg of seeds. However, usually the production is only 2.5 - 4 kg per tree for trees with fairly exposed crowns.

Processing and handling

Mature dry fruits or dry seeds collected from the forest floor can be stored for some days in sacks without significant deterioration. However, in order to reduce bulk it is often preferable to initiate processing in the field. The fruits will split open when dried for 1-4 days, depending on maturity, after which the seeds are easily released by gentle shaking of the fruits. Fruit parts (valves and columella) are removed by hand. Further reduction of bulk by manual dewinging may be desired.

Storage and viability

Seed is orthodox and if stored at 3-7% moisture content at low temperatures (1-5°C), it will retain high viability for several years. If the seed is stored in paper bags at room temperature, 7-8 months storage can be expected without loss in viability. Initial moisture content in mature seeds is 9-12%. Germination percentage of fresh seeds is 60-90 %.

Pretreatment

Pretreatment is generally not necessary but germination of seeds with low moisture content may be enhanced by soaking in water for 12 hours.

Sowing and germination

Under test conditions seeds are germinated in sand at fluctuating 35-30°C or constant 30°C and 12/12 for 8/16 hours light /dark. In the nursery, seeds are sown in a bed of light sand in 3-7 cm deep furrows or holes

or directly in containers. Germinating seeds should be kept moist and under shade. Seeds will germinate in 10-21 days. The seedlings are kept under shade until outplanting, which can take place when they are about 50-100 cm tall.

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Stem variation in *Swietenia macrophylla*. Philippines. Photo: Lars Schmidt, DFSC.

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Tamarindus indica L.

Taxonomy and nomenclature

Family: Fabaceae

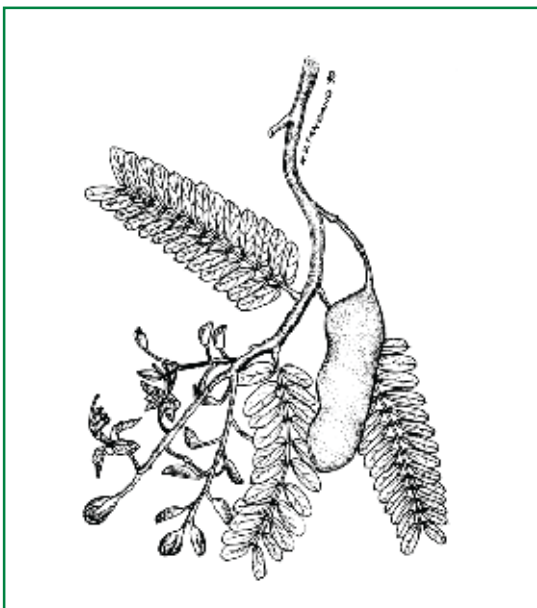
Synonyms: *Tamarindus occidentalis* Gaertn. *T. Hook.*, *T. umbrosa* Salisb.

Vernacular/common names: tamarind, Indian tamarind, Indian date (Eng.); tamarinier (Fr.); imli (Ind.).

Distribution and habitat

The origin of *T. indica* is uncertain but it is probably indigenous to the dry savannahs of tropical Africa. Long ago it was introduced to Asia where it has become naturalised, and in recent times also to the tropics in the western hemisphere.

It performs well in both semi-arid and humid monsoon climates and can grow on a wide range of soil types. Essentially a tree of the tropics, it tolerates temperatures up to 47°C but is very sensitive to frost. It is mainly grown in areas with 500-1500 mm rain/year but tolerates down to 350 mm if irrigated at the time of establishment. In the wet tropics with over 4000 mm rain, flowering and fruitsetting is significantly reduced and in India it is not grown in areas receiving more than 1900 mm rain/year. Regardless of total annual rainfall, it produces more fruit when subjected to a fairly long dry period.



Flowers, foliage and fruit. From: Plant Resources of South-East Asia. No. 2.

Uses

Tamarind is mainly grown for the fruits but is also a valuable timber species. The fruit pulp has a high content of vitamin B and is eaten fresh or made into jam, chutney, juice or sweets. Flowers, leaves and seeds are also edible and used in a variety of dishes.

The wood is hard and very heavy with purple-brown heartwood that is used for furniture. It provides good firewood and is excellent for making charcoal. The leaves have a high forage value but as lopping reduces fruit yield, tamarind is rarely used for fodder. The deep roots make it very resistant to storms and suitable for windbreaks. It has been tested as an agroforestry species in India but although the reduction in crop yield is less than e.g. with teak, the spreading crown makes it little compatible with other species. The dense shade makes it more suitable for firebreaks as no grass will grow under the trees.

Although a legume, tamarind is not nitrogen-fixing.

Botanical description

Evergreen tree, up to 30 m tall with dense, spreading crown and short trunk. The leaves are up to 15 cm long, alternate and compound with 8-18 pairs of leaflets, each 1-3.5 cm long. Flowers small, yellow streaked with pink, 5-10 together in 3-5 cm long inflorescences.

Fruit and seed description

Fruit: indehiscent pod, brittle, 5-15 cm long, more or less curved and constricted between the seeds. There are 1-10 seeds per pod, embedded in the sticky pulp.

Seed: up to 18 mm long, irregular, reddish, dark brown or shiny black, with hard and smooth testa.

There are 1800-2600 seeds/kg.

Flowering and fruiting habit

Although evergreen, the tree may remain leafless for short periods. Flowering normally occurs synchronous with new leaf growth, which in most areas happens during spring and summer but some trees may flower much later. The flowers are probably pollinated by insects. The fruits develop during the rainy season and are ripe about 6 months later. The trees begin to produce fruits when they are 8-12 years old and may continue for 200 years.

Harvest

When the pods begin to show cracks on the surface and rattle when shaken and the first pods fall to the ground, the seeds are ripe and collection can begin. Collection can be done from the tree or from the ground after shaking the branches but it is suspected that weevil infection is more prevalent in pods collected from the ground.

Processing and handling

If the pods are dry when collected, it is not necessary to dry them in the sun before processing. The pods are indehiscent and must be opened manually. There are various methods of extraction. One method where the pods are broken, e.g. with a hammer, soaked in water for 12 hours and then macerated by hand. Pods, pulp and dead and empty seeds will float on the water while full seeds sink. When separated, the seeds are dried in the sun. Another method is to pour the pods into a cement mixer with gravel in a weight proportion of 2:1 (seed:gravel) together with as much water as possible. After the treatment the mixture is floated and seeds that sink are recovered.

Regardless of extraction method the seeds are dried in the sun before storage. After drying the seeds can be cleaned by winnowing or in a seed cleaner to remove fibres.

5 kg of fruits yield about 1 kg seed.

Storage and viability

The seeds are orthodox and should be stored at low moisture content. If stored at 5-10°C the seeds can retain a high viability for several years. Infestation by insects can be a problem and it may be necessary to store the seeds with CO₂.

Dormancy and pretreatment

Reports on the necessity of pretreatment are contradictory. Some say the seeds have no dormancy and need no pretreatment, others use scarification as for other legume seeds. For bulk treatment boiling water or seedgun can be used, for seed testing in the laboratory hot wire scarification is recommended.

Sowing and germination

The seeds can be sown in seed beds or in medium to large size polytubes. Containers are recommended if seedlings remain in the nursery for more than four months. After that, the deep tap root will make transplanting difficult. Germination is epigeal. It starts 7-10 days after sowing and normally takes at least a month to complete. During germination, the seedlings should be protected from the sun.

When the seedlings have reached a height of 30 cm they are ready for planting in the field. If growth is poor, the seedlings can be retained in the nursery for another year but then they will normally require root

pruning and should be treated with care during transport. Vegetative propagation by branch cuttings, budding and grafting is possible.

Phytosanitary problems

Insect attack during storage can be a major problem.

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Mature fruit bearing tree. Photo by H.P.M. Gunasena.

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Tectona grandis L.f.

Taxonomy and nomenclature

Family: Verbenaceae

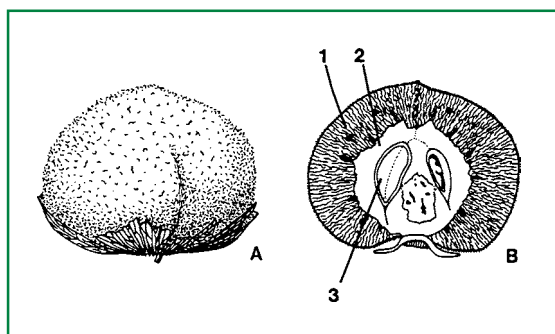
Synonyms: None

Vernacular/common names: jati (Indonesia); sagun (India); lyiu (Myanmar); mai sak (Thailand); teak (Eng.); teck (Fr.); teca (Sp.)

Distribution and habitat

The area of natural distribution covers the Indian sub-continent, Myanmar, Thailand and the western part of Laos. Northern limit is latitude 25°N in Myanmar and southern limit 9°N in India. Teak's longitudinal limits are 70°-100°E. Within this area, the occurrence is discontinuous, the natural teak forests being separated by mountain ranges, plains, farmland and other types of forests.

In Indonesia, teak is not a native species, but it has been grown on Java for centuries.



A, Fruit with remains of calyx; B, longitudinal section of fruit - 1, mesocarp; 2, endocarp; 3, seed. Line drawing: Birthe Vejlgård.

Uses

Teak is widely used as a plantation species on sites with a seasonal tropical climate. It is often grown in agroforestry systems and is one of the most versatile timber species, used for heavy and light construction work, house building, carpentry, wood carvings etc.

Botanical description

A large deciduous tree which, under favourable conditions, may reach a height of 30-40 m. In dry habitats growth becomes more stunted and branching more widespread and bushy. On good sites, clear boles of 15-20 m or more can usually be obtained, as lower branches are shaded out. Fluting and buttresses are often found at the base of older trees.

The bark is thick, grey or light greyish-brown. The leaves are large, 25-50 cm long and 15-35 cm wide, opposite, elliptic or obovate, the underside grey and densely covered with red glandulous hairs.

The flowers are small (6-8 mm in diameter), whitish and bisexual. They appear in large panicles containing up to a few thousand flower buds, which open only a few at a time during the flowering period of 2-4 weeks.

Fruit and seed description

Fruit: the fruit is a hard, irregularly rounded drupe. It varies in size from 5-20 mm, the most common size being between 11 and 17 mm. Its structure consists of a thin papery outer layer (the persistent calyx), a thick corky middle layer (mesocarp) and a stony inner part (endocarp) which contains the 4 seed chambers. Number of fruits per kg varies around 1100-3500 with an average of approx. 2000 fruits/kg. This corresponds to approx. 500 fruits per litre.

Seed: the seeds are oval and about 6 x 4 mm. Only rarely have all 4 seed chambers fully developed seeds, the normal number being 1-2. Usually only one seed per fruit manages to develop into a seedling.

Flowering and fruiting habit

Teak normally starts to flower 6-8 years after planting. Flowering takes place in the rainy season, starting about one month after the first rains. Teak usually flowers every year, but with large variation in intensity between years. Pollination is by insects. Sometimes flower and fruit setting is greatly disturbed by defoliating insects which also eat the flower buds. The fruit attains its full size in approximately 50 days, but it is not mature until 120-150 days after fertilization. A sign of maturity is that fruits can be shaken from the tree, or fall to the ground naturally.

Harvest

Teak fruits are usually collected from the ground. In seed source areas, the ground is usually cleaned and sometimes burnt to prepare seed collection. To ease collection, a cover can be spread out on the ground. The fruits fall over a period of 3-4 months in the dry season. Seed collection should be done at least twice in a season, so that early fallen fruits do not remain on the forest floor for long. The amount of fruits which can be collected depends on age of stand, location and type of stand and it is difficult to give exact figures about seed

production. Generally, seed production is in the order of 20-30 kg/ha/year in plantations and seed production areas with low management, whereas in seed orchards with more intensive management seed production may be as high as 200-300 kg/ha/year.

Processing and handling

After collection, the fruits are cleaned for branches, leaves and rotten and damaged fruits and then dried in the sun for 2-3 days. After drying, the calyx is removed in a cement mixer, seed thresher or by squeezing and beating the seed in a bag. Finally the impurities are removed by winnowing.

Seed storage

Teak seed stores well and may keep its germination capacity for several years provided the seed has low moisture content before storage and is protected against fluctuations in temperature and humidity during storage.

If seeds are to be used in the same planting season, no special storage is needed. Seed can be piled in a convenient place near the nursery, preferably in a shed or in a storeroom, but not necessarily dried. Seed can be stored this way for maximum 3-4 months. Seed can be stored for up to two years at around 12 % moisture content and stored in airtight containers (glass jars or sealed plastic bags) and kept in a dry, shaded and relatively cool place. If stored at low moisture content and in a cold store (0-4°C), the germination capacity of the seed can be maintained for 5-10 years.

Dormancy and pretreatment

Germination of teak is often poor and sporadic but the exact nature of dormancy is not known. The most common method of pretreatment is to soak the fruits during the night and dry them in the sun during the day, repeating this for 1-2 weeks.

A better method is dry heat. The seeds are heated for 1-5 weeks at 50° C or 48 h at 80° C. This method is difficult to implement for large seed lots as it requires a large oven, but it can improve germination considerably

Sowing and germination

Sowing is done directly in the field or in the nursery. If sown directly, normally 3-4 seeds are sown per hole to secure that at least one seedling will develop. This method is very demanding in terms of quantity of seed.

Sowing in the nursery is done in a seedbed with soil or sand. The seed is covered with a thin layer of sand or soil not to be washed away by rain or be eaten by rodents and other animals. It is important that the seed is not sown too deep, as this will reduce germination rate drastically. Teak plants are very sensitive to shade, and when there is large variation in germination time, the later germinating seedlings can be shaded to death if they emerge under a large seedling. Germination generally starts 10-12 days

after sowing, but spreads over a very long time, especially if no pretreatment has been made.



Natural teak forest close to Ban Cham Pui, Lampang district, Northern Thailand. Photo: Erik Kjær, DFSC

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Terminalia brownii Fresen.

Taxonomy and nomenclature

Family: Combretaceae

Synonym: *Terminalia confertifolia* Steud. ex A. Rich.
Terminalia cycloptera R. Brownii.

Vernacular/common names: Darot, subagh, subaraya (Arabic); mbarao, mwalambe (Swahili); biress, hare-ri, (Somali)

Related species of interest: The genus *Terminalia* includes a number of valuable trees and shrubs mainly in Africa, e.g. *T. mollis*, *T. spinosa* from E. Africa; *T. superba* and *T. ivorensis* from W. Africa and the ubiquitously cultivated coastal and ornamental *T. catappa*.

Distribution and habitat

Terminalia brownii is naturally distributed in E. Africa, e.g. Kenya, Uganda, Tanzania, Eritrea, Ethiopia and Somalia, extending southwards to Malawi

The species grows in moist savannahs of the semi arid regions, where it is part bushland or woodland. In dry areas it grows near rivers or wadies. Altitude range from 600-1,800 masl and rainfall range 500 – 1,300 mm. It can grow on a wide range of soil types but is mainly found on sandy loam soils and does not thrive on heavy clay soil with poor drainage.

Uses

The wood is strong, durable and termite resistant. It is used for all types of construction purposes and household implements, e.g. handles, mortars and pestles. Leaves are fodder for livestock. The sap is rich in tannin. Extracts from the tree are used in traditional medicine for humans and livestock. The tree is often planted as an ornamental amenity tree in towns and parks.

Botanical description

Terminalia brownii is a small (< 20 m) deciduous tree with round or flat crown, often straight bole. Branches tend to appear from whorls, which gives the tree a layered appearance. Young bark light and pubescent, old bark grey and fissured. Leaves alternate – spirally arranged at the end of the branches; simple, entire, elliptic-ovate, 5-8 cm long, 3-5 cm wide, petiole 2-3 cm, glabrous below, apex pointed. Flowers small, white in 7-10 cm long many-flowered spikes, with an unpleasant smell. Individual flowers consist of calyx, 5 stamen and ovary; no petals. Flowers are hermaphroditic or male.

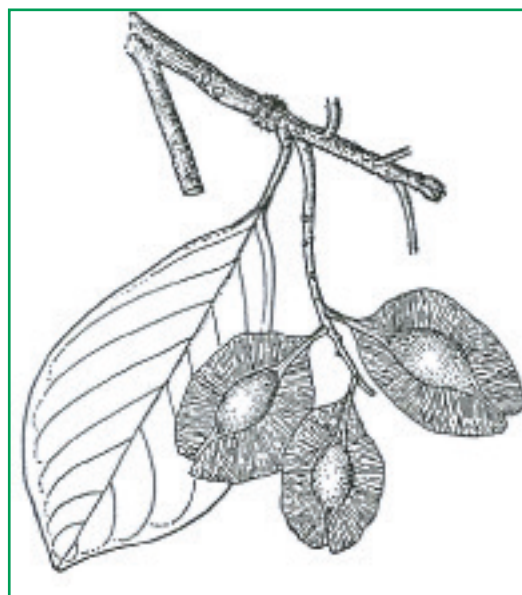


Flowering branch. (source untraceable)

Fruit and Seed description

Fruit: The fruit is a woody samara. It is broadly elliptic-ovate, 2½-3½ cm long, flat, with an 1-1½ cm broad wing surrounding the central fruit part. The fruit is purple red at maturity, turning chocolate brown with age.

Seed: The seed handling unit is the samara. It is very hard and the morphological seed cannot easily be extracted. 1000 seed weight of entire fruits is about 260 g; i.e. about 3-4,000 seeds per kg.



Fruits of *T. brownii*. From Dale and Greenway 1961

Flowering and fruiting habit

Flowering is generally at the latter part of the dry season extending into the rainy season, in the seasonal

East Africa from March-April – June with subsequent fruiting from October to November. Pollination by insects, mainly flies. Fruit development takes 4-5 months. Fruits are dispersed by wind or water.

Harvest

Harvest by picking up fruits under the trees or beating or shaking fruit-bearing branches. Harvest time is not critical as mature seed will usually stay on the tree for some time, extending the fruiting season to several weeks.

Processing and handling

Seeds do not need extraction as the whole fruit is stored and sown. For storage space saving, fruits may be de-winged manually.

Storage and viability

The seed exhibit orthodox storage behaviour, and dry seeds (< 6-7%) can be stored for several years even at ambient temperature. Cool storage presumably extends longevity.

Dormancy and pretreatment

Seeds exhibit moderate physical and possible mechanical dormancy. Cutting part of the fruit open at the opposite end of the radicle will speed up imbibition.

Sowing and germination

Germination is epigeal. Seeds are usually sown directly in pots in the nursery in a sandy loam nursery soil. Germination is slow, which is mainly caused by restriction to water absorption

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World Agroforestry Centre. Species database.

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Trichilia emetica Vahl

Taxonomy and nomenclature

Family: Meliaceae

Subspecies/varieties: there are two recognised subspecies, subsp. *emetica* and subsp. *suberosa*.

Synonyms: *Trichilia roka* (Forssk.) Chiov., *T. umbrifera* Swynn., *T. somalensis* Chiov., *T. grotei* Harms, *T. jubensis* Chiov.

Vernacular/common names: um shara, um hagi, safsaafa (Arabic.); Cape mahogany, Natal mahogany (Eng.); muwamaji (Kenya); Jan saiwa (Nigeria); gormas (Somalia); mafura, mgolimazi (Tanzania); roo-essenhout, ashapa (South Africa); musikili (Zambia); mafura nut (trade name).

Distribution and habitat

The species as a whole is widespread in most of sub-Saharan Africa. Subsp. *emetica* is found in Eastern Africa from Sudan in the north to Botswana and Swaziland in the south. Subsp. *suberosa* is confined to West Africa, extending, in the eastern part of its range, into Sudan and Uganda where the two subspecies may hybridise.

Both subspecies grow in riverine forests and on various types of woodland. Subsp. *emetica* is generally found in open riverine forests and open savannah woodlands subject to grass fires while subsp. *suberosa* prefers the more fertile soils of river banks and seasonally flooded riverbeds. It grows from sea level up to 1800 m in areas with 500-2300 mm rain per year.

Uses

Trees are planted in agroforestry systems to provide shade and the wood is used for timber and firewood. The wood works well; it is light (560-597 kg/m³), usually pinkish in colour and with little difference between heartwood and sapwood. It is vulnerable to borers but produces beautiful furniture. Also used for carvings, musical instruments, dugout canoes and other minor uses.

From the seed aril is made a milky suspension used for cooking. Seed oil (mafurra or mafurreira tallow) is used for manufacturing soap and cosmetics and making candles. The oil is obtained by skimming the water in which the seeds have been boiled after being ground and pounded.

The pressed seedcake that is left after extracting the oil contains approximately 16% protein and is

suitable as a fertiliser. The seeds are unfortunately not suitable for human consumption. Bark, roots and seed oil are used for medicinal purposes.

The trees are often planted along roads as an ornamental and in cities to provide shade. Because of the spreading, evergreen crown it has become popular for planting in car-parking areas.

Botanical description

Evergreen or semi-evergreen tree, 8-20 m tall. Subsp. *suberosa* is generally a smaller tree or even a shrub. Bark dark grey to brown, corky in subsp. *suberosa*. Leaves compound with 4 to 5 pairs of leaflets plus a terminal leaflet. Leaflets elliptic, 12-15 cm long with entire margins. Flowers creamy-green, in about 5 cm long, compact heads. The sexes are separate but male and female flowers are similar in appearance.



Cluster of fruits. Photo from: van Wyk (1994).

Fruit and seed description

Fruit: a woody, dehiscent capsule, rounded, 2.5-3 cm in diameter; creamy, green or light brown and velvety on the surface. The fruits are borne in dense, pendent clusters. Each fruit has an up to 1 cm long neck connecting it to the stalk. At maturity it splits into 2 or 3 valves exposing the 2-6 seeds.

Seed: the seeds are 15-20 mm long, shiny black and almost completely covered by the bright red aril. There are typically 500-1000 seeds per kg.

Flowering and fruiting habit

In South Africa the trees flower in August-October and fruits mature in December-March. In Tanzania flowering is in July-November and fruit setting is in February-April. Seed production varies from year to year, some years very little seed is produced.

Little is known about the biology of this species but it has been reported that hornbills eat the seeds and thus disperse them.

Harvest

When the capsules begin to open it indicates the seeds are mature. It is recommended to collect ripe fruits from the tree just before opening. Seed collected from the ground often has a low quality.

Processing and handling

The seeds are recalcitrant and should be treated accordingly during transport and processing. It is important that the seeds are not allowed to dry, as even a few percent reduction in moisture content will lower the viability. During all steps, the fruits/seeds should be protected from direct sunlight and wind. Pack fruits/seeds in small containers with only a few kg in each and avoid stacking containers on top of each other.

To extract the seed, it is recommended to spread the ripe fruits out on a mesh in the shade until all the fruits have opened and then separate the seeds from the debris by shaking. However, great care must be taken to avoid desiccation. After extraction, the seeds are immersed in water and empty seeds and debris that float on the surface are removed. The fleshy aril is then removed by maceration in water and the seeds are spread out in thin layers on a mesh until they are dry on the surface. 4 kg fruits contain about 1 kg seed.

Storage and viability

The seeds do not tolerate drying and should be stored hydrated, i.e. at the moisture content they have after extraction. Recent trials showed that even a few percent reduction in moisture content will reduce germinability but also that when stored with fresh moisture content at 16°C the seeds can retain almost full viability for at least 4 months.

Even without aril the seeds are highly susceptible to fungal infections during storage.

Dormancy and pretreatment

It is not clear whether the seed have dormancy but both germination percentage and speed increase drastically when the aril is removed. In a recent trial, germination of freshly harvested seeds increased from 20% to 93% by the removal of the aril and germination time decreased from 14 to 8 days.

Sowing and germination

Germination is epigeal. In the nursery germination normally takes 10-20 days to complete. Seeds can be sown either in seedbeds or in containers. After 6-8 months the seedlings are ready to be planted out. Outplanted seedlings require some shade and they are sensitive to weed competition.

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Tree habit. Photo: van Wyk (1994).

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Vitellaria paradoxa Gaertn. f.

Taxonomy and nomenclature

Family: Sapotaceae

Synonyms: *Bassia parkii* G. Don, *Butyrospermum paradoxum* (Gaertn.) Hepper, *B. parkii* (G. Don) Kotschy, *B. niloticum* Kotschy, *Lucuma paradoxa* (Gaertn.) A. DC., *Mimusops capitata* Baker, *M. pachyclada* Baker.

Vernacular/common names: shea-butter tree (Eng.), karité (Fr.) Two subspecies are recognised, *paradoxa* and *nilotica*.

Distribution and habitat

Widespread in the savannah regions across Africa from Senegal to Ethiopia. Subsp. *paradoxa* occurs in a wide latitudinal belt between 5° and 15°N from Senegal to the Central African Republic. Subsp. *nilotica* is found in Sudan, Uganda, eastern Ethiopia and western Zaire. The species is rarely found outside its natural distribution range, but it has been introduced to Honduras where it is known as tango.

The two subspecies differ in altitudinal range. Subsp. *nilotica* occurs at higher altitudes (650-1600 m) than subsp. *paradoxa* which is mainly found at 100-600 m altitude, occasionally up to 1300 m. Mean annual rainfall in the area of distribution is 600-1400 mm and with 3-7 dry months (less than 50 mm rain). Subsp. *paradoxa* is generally more drought resistant than *nilotica*. Like other wide-ranging African tree species it can grow on a variety of soil types.

Uses

The main product is shea butter (karité) which is extracted from the seeds. It is one of the most affordable and widely used vegetable fats in the Sahel and plays an important role in the economy of the region. It is especially important in areas with less than 1000 mm rain/year that are not suitable for growing oil palms.

The timber is of good quality, termite resistant and generally very durable but is normally used only when the tree has passed the fruit-bearing age. Shea nut cake is increasingly used for livestock and poultry feed, and leaves and young sprouts serve as forage.

The trees are traditionally favoured and protected by farmers and has played an important role in soil and water conservation in semi-arid West Africa.

In agroforestry systems, *V. paradoxa* can be combined with many cereal crops.

Botanical description

The size of the mature tree varies from 7 to 25 m. In cultivated fields the height is typically 15-20 m. The bole is short, 3-4 m, sometimes up to 8 m with diameter less than 1 m and with thick bark that protects old trees from bush fires; slash is reddish, with white latex. Most of the leaves are borne in terminal whorls, 20-30 together. The leaves are simple, 10-25 cm long and with wavy margins.

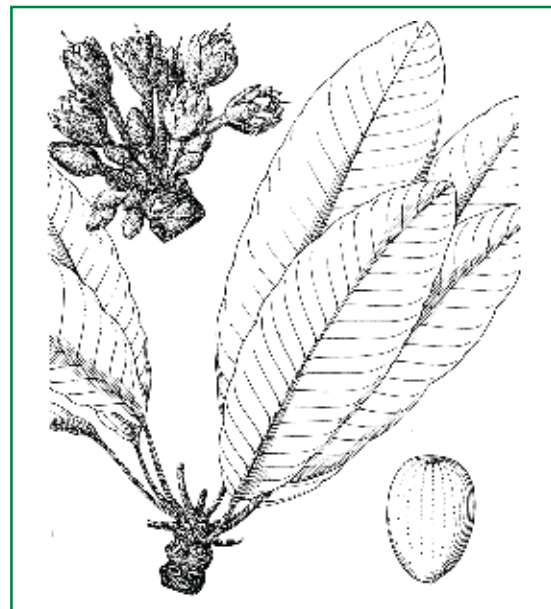
Flowers hermaphrodite, in clusters, 10-40 together, cream-yellowish and fragrant.

Fruit and seed description

Fruit: round or oval berry, 4-8 cm long, normally with one seed, occasionally 2 or 3. At maturity the fruits turn yellowish green or brown and the edible pulp becomes soft and develops a sweet or astringent taste.

Seed: up to 5 cm long; testa is shiny dark or pale brown and with a large, pale hilum almost covering one side. At 7% moisture content there are 150-300 seeds per kg.

The seed is commonly called a nut (shea nut) and the embryo is called a kernel.



Foliage, flowers and fruit of subsp. *paradoxa*. From: Flora of Tropical East Africa.

Flowering and fruiting habit

The flowers are pollinated by bees. In the Sahel, flowering occurs December-March, when the tree is

almost leafless, and the fruits mature in April-September. The phenological events are timed with the changes of seasons. Leaf fall, flushing, flowering and fruiting are noted principally as dry season events. Fruit maturity is associated with the change from dry to wet season and normally coincides with the first rains.

Fruit production typically begins when the trees are 15 years old and may continue for 300 years.

Harvest

The fruits are collected from the ground but must not be left for long on the ground as they germinate quickly. Fruit yield may vary tremendously from year to year and 10-200 kg fresh fruits/tree have been reported.

Processing and handling

After harvest the fruits are soaked in water and the pulp is removed manually.

Storage and viability

The seed is recalcitrant and does not store well.

Optimal storage conditions are 15°C at 30% moisture content. At the time of harvest the moisture content is around 40% and germination is 90-100%. The reduction in mc from 40 to 30% results in a moderate loss of viability but the storability is improved. At 15°C the seed can be stored for at least 3 months without reduction in viability. Seeds stored at 25° C showed 40% germination after 8 months. (Results are from the IPGRI/DFSC project on recalcitrant seed)

Dormancy and pretreatment

The seeds have no dormancy and need no pretreatment. However, the pulp should always be removed before sowing to improve germination.

Sowing and germination

Due to the difficulties of storage, seeds should be sown shortly after harvest. Sowing can be done in polythene pots (27 x 17 cm) or in seedbeds at 20 x 15 cm spacing. The seeds should be covered with at least 5 cm of soil. The shoot normally appears within 2 months of sowing but in subsp. *paradoxa* there may be a delay of up to 5 months.

For seedlings raised in pots there are varying recommendations as to when they should be planted out. Some say 14-24 weeks while others advise waiting for two years. Seedlings that are grown in seedbeds are normally planted out as balled (with soil around the roots) planting stock after 12 months. Bare-root stock generally gives poor results.

The seeds can also be sown directly in the field. This avoids the difficulties associated with transplanting the seedlings with their large taproots but the seeds are often heavily predated by rodents.

Germination of direct sown seeds is typically only 40-50%. Regardless of planting method, wide spacing, site preparation and weeding are essential to ensure a high rate of survival.

Phytosanitary problems

The larvae of *Mussidia nigrioella* and *Ceratitis silvestrii* feed on the pulp of mature fruits.



Tree habit

Selected readings

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