FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 97-01
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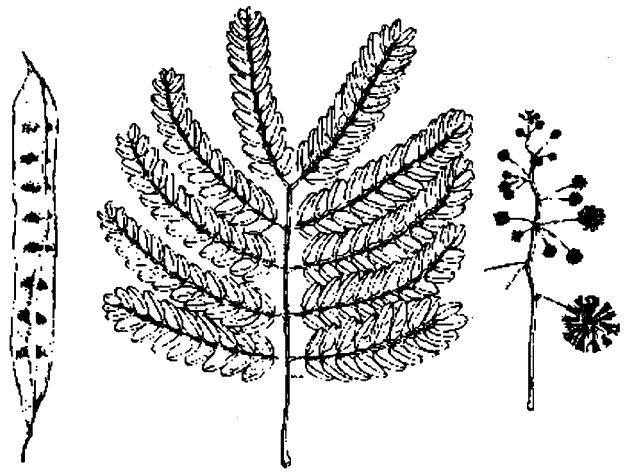
Albizia procera : White Siris for Reforestation and Agroforestry

Albizia procera is a large, fast-growing tree that occurs on many different sites. Like other Asian *Albizias*, it occurs in forests and savanna woodlands, but prefers moister sites than its relatives. This species provides wood for a variety of purposes, nutritious fodder for livestock and shade for tea plantations. It is an important reforestation and agroforestry species. It is commonly called white siris or tall albizia and has many regional names.



Source: Little and Wadesworth, 1964

Botany

Albizia procera (Roxb.) Benth. is usually 60-70 cm in diameter and 25 meters in height. Troup (1921) reports trees as large as 95 cm in diameter and 36 meters in height. Mature individuals are characterized by a tall, clear, erect, sometimes curved trunk and large branches which form a thin, spreading crown. The bark is nearly smooth, whitish to light-greenish gray or light-brown. It exfoliates in thin flakes with red undersides (Troup 1921). Lateral roots are wide-spreading and the taproot stout. The bipinnate leaves, reddish when juvenile, mature to a length of 12-25 cm; leaflets are 2-4 cm long and 8-16 mm wide.

Flowering varies by geographic location; January to March in Indonesia (Djogo 1992), June to September in India, (Troup 1921) September in Manila (Hensleigh and Holaway 1988) and August to October in Puerto Rico (Parrotta 1987). Flowers are borne on racemes 8-25 cm long near the end of a twig. Numerous greenish-yellow flowers form whitish heads 20-24 mm in diameter. Individual flowers, 6-7 mm long, have long white threadlike spreading stamens about 10 mm long (Little and Wadsworth 1964). The reddish-brown flat pods, 10-20 cm long and 18-25 cm wide, are produced in large numbers and ripen 3-5 months after flowering. The mature brown pods, each containing 6-12 seeds, usually remain on the tree until the twig bearing the pods is shed (Troup 1921, Little and Wadsworth 1964). The natural regeneration of white siris is generally good. Following the beginning of the rainy season large numbers of seedlings are common near mature trees. Seedlings, saplings and mature trees coppice vigorously from stumps and roots (Parrotta 1987).

Ecology

White siris is a component of tropical and subtropical moist and wet forest types where rainfall is 1000-5000 mm/yr. It develops best when rainfall is above 2500 mm/yr. Growing to elevations of 1200 meters, this species is also common on moisture savannas and swamp forests. In its natural habitat, maximum temperatures vary from 37-46° C and minimum temperatures from 1-18° C. Once established white siris is drought tolerant. It is susceptible to frost (Troup 1921, Djogo 1992).

Like many nitrogen fixing trees, white siris survives on a variety of soils. It grows best on moist alluvial soils, well-drained loams or clay soils (Brandis 1906, Venkataramany 1968). Its ability to grow on dry, sandy, stony, and shallow soils makes it a useful species for reforestation of difficult sites. Good survival and rapid early growth have been reported in afforestation trials on both saline and alkaline soils (Ghosh 1976). It does not tolerate suppression, but will survive moderate shade between the seedling and small tree stage (Venkataramany 1968).

In India, white siris is dominant to co-dominant in mixed deciduous forest; or found as scattered individuals or in small groups in savanna woodlands (Benthall 1933, Bor 1953). In Puerto Rico, white siris is an aggressive pioneer, forming pure stands on abandoned farms and other disturbed sites. It is also common in pastures at elevations below 600 meters, including areas receiving as little as 800 mm of annual rainfall.

Distribution

The native range of *A. procera* is South and Southeast Asia between latitudes 30 degrees N to 15 degrees S. The tree occurs naturally in India, Nepal, Bangladesh, the Andaman Islands, Burma, southern China, Laos, Thailand, Cambodia, Vietnam, Malaysia, the Philippines, Indonesia, Papua New Guinea, Melanesia and northern Australia (Nielsen 1979). It is naturalized in the Virgin Islands and Puerto Rico.

Uses

Agroforestry. Natural regeneration of *A. procera* is often encouraged on farms to provide small timber, fuelwood, charcoal, fodder or shade. Seedlings are planted in family forests or home gardens for the same purposes. *Albizia procera* can be cultivated as shade for tea plantations.

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However, *Albizia odoratissima* is preferred for this purpose because of its rapid early growth, fuller crown and resistance to red spidermites. The protein-rich fodder of *A. procera* is eaten by cattle, buffaloes, goats, camels and elephants in South Asia and the Philippines. However, the fodder is not utilized in Nusa Tenggara, Indonesia.

Wood. Durable, strong and resistant to termites, the wood is light- to chocolate-brown with light and dark bands. It is difficult to saw due to interlocking grain and has a specific gravity of 0.6-0.9. The wood is used to produce wheels, carts, boats, furniture, flooring, posts, agriculture implements, boxes and carvings. This species is considered a promising source of pulp for high-quality paper (Parrotta 1987).

Other Uses. Trees are often planted for shade or beautification along roads. *Albizia procera* is commonly used in traditional medicines (Venkalarammany 1968). The bark contains tannins and a reddish gum. Also, it can be used to make a poison. The leaves are used to treat ulcers and have insecticidal properties (Parrotta 1987). In the Philippines, the cooked leaves are eaten as a vegetable (Hensleigh and Holaway 1988).

Silviculture

Propagation. Seeds are small, greenish-brown, elliptical to round, flat and have a hard, smooth seedcoat. There are 20,000-24,000 seeds per kilogram (Roshetko 1997). Insect damage to seed is common in Indonesia (Djogo 1992) but not in India (Troup 1921). Fresh seed germinates readily without treatment (Parrotta 1987). Clean seed can be stored at room temperature for 10 months with minimal loss of viability (Roshetko 1997). Seed that has been stored should be treated before sowing; cut through the seedcoat with a knife or file, or soak seeds in boiled water for 3 minutes. After either treatment, soak seed in cool water for 12-24 hours and sow immediately (Roshetko 1997).

In the nursery, seed should be sown in containers or beds. Seedling growth is favored by loose soil, sufficient soil moisture, full sunlight and the absence of weeds. Healthy seedlings produce a thick, long taproot. After two months in the nursery containerized or bare-root seedlings should be transplanted to the field. Direct sowing of white siris is successful given abundant soil moisture and regular weed control (Troup 1921). Propagation is also possible by stem or root cutting and stump sprouts. Plantations should be weeded twice in the first year and once during the second. During weeding, soil should not be unduly exposed; only weeds directly interfering with seedlings should be removed (Venkataramany 1968).

Growth and Management. In Bangladesh, plantation trees have reached heights of 0.3 and 4.5 m in 1 and 5 years. In Burma 6-year-old trees average heights and diameters of 12.8 m and 16 cm, respectively. In Indonesia, 17-year-old trees average heights and diameters of 24.3 m and 22.4 cm, respectively. Total standing volumes of 87 m^3/ha have been reported in 8-year-old plantations in Burma and of 151 m^3/ha in 17-year-old plantations in Indonesia. Natural forests are managed for timber production by coppicing on a 40-year rotation. Fuelwood plantations are managed on a 20-year rotation (Venkataramany 1968).

Symbiosis

Albizia procera forms symbiotic association with *Rhizobium* bacteria enabling it to fix nitrogen and thrive on infertile soils. The application of phosphorus fertilizer can improve nodulation and nitrogen fixation, particularly on infertile soils.

Limitations

Because of its aggressive growth white siris may be a potential weed. This is particularly true in the Caribbean where white siris grows faster than many native species.

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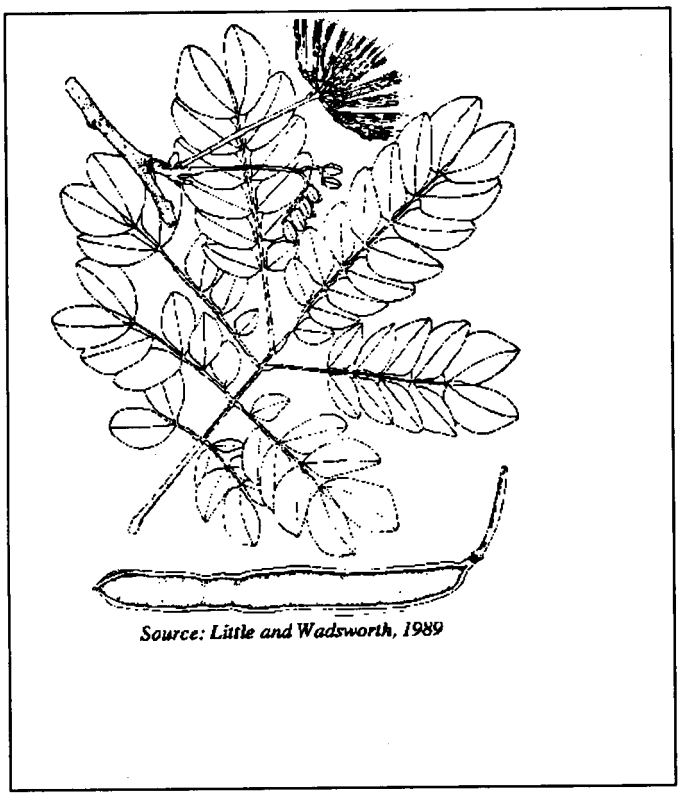
NFT Highlights

NFTA 95-02
(Replaces 87-06)

A quick guide to multipurpose trees from around the world **September 1999**

Albizia saman : pasture improvement, shade, timber and more

Albizia saman (Jacq.) F. Muell. (Leguminosae, Subfamily Mimosoideae) is a fast growing tree which obtains a large size. It is most common as a pasture, shade or ornamental tree, but has numerous uses. This New World tree is so widely cultivated and used in Southeast and South Asia it is often mistaken as native to that area. It was formerly classified as *Samanea saman, Pithecellobium saman* and *Enterolobium saman.* Common names include saman, monkey pod, raintree, cow tamarind, algarrabo and guango.



Source: Little and Wadsworth, 1989

Botany

Albizias are related to and often mistaken for Acacias—in the Philippines acacia is a common name for *A. saman. Albizia saman* can obtain a height of 30-45 m and diameter breast height (DBH) of 150-250 cm. Open-grown specimens have short stems and stout wide-spreading nearly horizontal branches. The umbrella-shaped crown may be wider than the height of the tree. The brown gray bark is rough and furrowed into ridges and plates (Little and Wadsworth 1989). Limb bark is lighter in color. Twigs are stout and green. The bipinnately compound leaves are 25-40 cm long dark green above and light green below. The stalkless leaflets are arranged in pairs numbering from 12 to 32 (Little and Wadsworth 1989). Leaflets are wider towards the apex. Both leaves and leaflets are progressively larger towards their terminal ends.

The showy flower heads, composed of many narrow pink flowers, are found near the end of twigs and appear from March to September (Hensleigh and Holaway 1988). The dark-brown to black pods are hard and thick with a raised seam. They are 8-20 cm long and about 2 cm wide. The pods do not readily open and remain on trees for long periods. Seeds are red-brown oblong and squarish. There are 5000-8000 seed/kg.

Ecology

Albizia saman is found in the tropics from sea-level to 1000 meters where the temperature is 20-35° Celsius. It is a common component of dry forests and grass savannas. Annual rainfall in these areas is 600-3000 mm/year. *Albizia saman* easily survives dry seasons of 2-4 months. While more common on drier sites, this species grows best in moist, well-drained fertile soils (Hensleigh and Holaway 1988). It tolerates heavy clays and infertile or waterlogged soils. Although normally found in neutral to moderately acid soils, it will grow in soil with pH as low as 4.6 (Franco et al. 1995).

Distribution

This species is native from Southern Mexico and Guatemala south to Peru, Bolivia and Brazil. It is naturalized throughout the tropics and has been introduced to sub-tropical areas.

Uses

Shade and ornamental. *Albizia saman* is planted along roads throughout the tropics. In parks and commons, its high arching branches provide welcome protection from the heat of the tropical sun. Having crowns of great diameter, trees furnish ample shade. Trees serve as windbreaks and are cultivated for their beautiful pink flowers.

Wood. The wood of *Albizia saman* is highly valued for the manufacture of furniture, cabinets, decorative veneers, bowls and other handicrafts. The chocolate heartwood and yellow sapwood form a beautiful contrast. The light-weight wood (specific gravity 0.48) is strong, durable, works easily and takes a good finish (Chudnoff 1984). It shrinks so little that products made from green wood dry without warping (NAS 1979). *Albizia saman* is a good quality fuel and charcoal, producing 5200-5600 kcal/kg (F/FRED 1994). Other uses of the wood include fencing, construction timbers, plywood and the manufacture of crates, wheels and boats.

Pasture and fodder. *Albizia saman* is a valuable component of pasture systems. Its shade protects livestock

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from the hot tropical sun. Its nutritious pods contain 12-18% crude protein and are 40% digestible (F/FRED 1994). Relished by livestock, pods are an important dry-season fodder. Tree leaves are also nutritious, but are not an important fodder. The shade and nitrogen-rich leaf-litter of *A. saman* improve the nutritional value of understory grass (Allen and Allen 1981). During the dry-season, grass beneath trees remains green and succulent while exposed grass becomes dry and unpalatable. Leaves fold inward at night which may increase the amount of moisture, rain and dew, reaching the understory. In the morning leaves unfold giving full shade and conserving soil moisture.

Agroforestry. This species is used as shade for tea, coffee, cacao, nutmeg and vanilla. Performance has been fair in alley- and hedgerow-cropping studies. Initial growth is slower than other woody perennials, but *A. saman* coppices well and yields nitrogen-rich green manure. However, shallow roots and large branch size compete heavily with companion crops, especially in dry areas. In these systems, *A. saman* must be heavily pruned. In most areas, other species will be more appropriate for alley- and hedgerow-cropping studies. *Albizia saman* is appropriate in home gardens where it provides a service role and multiple products simultaneously.

Other uses. Children eat the pods which contain a sticky sweet-flavored pulp. A fruit drink is also made from the pulp. Honey is produced from the flowers. The bark yields gums and resins. In Thailand, *A. saman* is an important host plant for lac production (Subansenee 1994).

Silviculture

Propagation. Seeds of *A. saman* have hard, impermeable seedcoats. Two methods of seed scarification are recommended. For small quantities of seed, cut through the seedcoat opposite the micropyle, or pointed-end of the seed, taking care not to damage the seed embryo. For large quantities of seed, pour boiled water over the seeds, soak and stir for two minutes. Drain off the hot water. The hot water should equal five times the volume of seeds. With either method of scarification, the seed should be soaked in cool water overnight before sowing (NFTA 1989). Seed should be sown at a depth equal to its width in large nursery bags. The recommended nursery mixture is 3 parts soil: 1 part sand: 1 part compost. Seedlings should receive partial shade for 2-4 weeks and then be exposed to full sunlight. After 3-5 months seedlings will be 20-30 cm tall and ready for field planting. Direct sowing is possible, but success depends on rigorous weed control. *Albizia saman* can be propagated by cutting or stump cutting.

Management. Open-grown *A. saman* have short trunks and spreading limbs which are considered poor form for timber production. Close spacing, 1.5x2 meters, does produce straighter trees with less branching, but boles retain a spiral form. For this reason, *A. saman* is not commonly planted in single-purpose timber plantations. In pastures, home gardens or other multiple-purpose plantings, tree spacing will depend on companion plants and management strategy.

A light-demanding species, *A. saman* grows fast and is tolerant of heavy weed competition. However, survival and growth can be improved through vigorous weed control until trees achieve dominance over competing vegetation. Wood production varies by site and management system. A good site can produce 10-25 m^3/hectare/year under a 10-15 year rotation (F/FRED 1994).

Symbiosis

Albizia saman forms nitrogen fixing symbiosis with many strains of *Rhizobium*. In the field it readily forms root nodules.

Limitations

Heterophylla cubana, *Psylla acacia-baileyanae* and other defoliators are common pests (Braza 1990) but do not cause serious stress problems. Wide spreading branches and shallow roots make *A. saman* susceptible to damage during intense storms. The destruction of natural forests threatens the genetic diversity of this species. In response to this threat, the Oxford Forestry Institute has included *A. saman* in its gene conservation program (Hughes 1989).

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NFT Highlights

A quick guide to useful nitrogen fixing trees from around the world

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Alnus acuminata : Valuable Timber Tree For Tropical Highlands

Alnus acuminata is a fast-growing species valued for its wood, watershed protection and soil improvement. Native from Mexico to Northern Argentina, it is known as: aliso (Mexico, Argentina, Colombia, Ecuador and Peru); aile, ilite (Mexico); ramrám, lambdn (Guatemala, Costa Rica and Peru); jaúl (Costa Rica); palo de lama (Guatemala) and; cerezo and chaquiro (Colombia). Easily propagated from seed or by natural regeneration, *A.acuminata* is a popular agroforestry species in its native range. It has been successfully introduced into southern Chile and southern New Zealand.

Botany

Alnus acuminata ssp. *arguta* (Schlectendal) Furlow (Betufaceae) grows to 30 m in height and to 50 cm in diameter (after 30 years) in natural conditions. Maximum age may be 60 years (L Fournier, personal communication). The leaves are simple, alternate, elliptical, 6 to 15 cm long, 3 to 8 cm wide, border double dentate, deciduous or semideciduos. The upper leaf surface is dark green and the lower surface is pale, whitish to light green. The bark is light-grey or silvery with yellowish lenticels. Crown shape is open rounded to pyramidal. Male and female flowers occur in separate catkins on the same branch. Inflorescences are cone-like with lignified scales, dark brown when ripened, and bearing more than 100 fruits per cone. The fruit is a small membranous-winged samara, 2 to 3 mm long that contains one seed. Dispersal is mainly by the wind. Seeds ripen in February, March and August in South America (NAS, 1980), and from September to January in Costa Rica (Rajas et al., 1991).

There is considerable confusion in the taxonomy of *Alnus acuminata*. Furlow (1977) reported the species as *Alnus acuminata* H.B.K., but in his last revision (1979) he classified it as *Alnus acuminata* ssp. *arguta*. The species also has been described as *Alnus jorullensis* H.B.K. by Carlson and Dawson (1985). Holdridge (1951) concluded that if subspecies populations exist they apparently intergrade into each other and because of similarities in wood and silvicultural characteristics they may be considered as a single species, at least from a forestry viewpoint.

Distribution and ecology

Alnus acuminata is native to the American continent ranging from Mexico to Northern Argentina in elevations between 1,200 and 3,200 m.a.s.l. where annual rainfall is 1,000 to 3,000 mm or more. The species occurs where mean annual temperature ranges between 4°, and 27°C; however it can withstand temperatures dipping briefly below 0° C (NAS, 1980).

Alnus acuminata is a fast-growing pioneer species that regenerates naturally in open, disturbed areas. It grows in moist soil environments, usually along the banks of streams, rivers, ponds, and swamps where it typically forms dense pure stands. It also can be associated with wet flood plains, or moist mountain slopes, although it may be adapted to somewhat drier conditions. However, it is usually restricted to zones with extra soil moisture such as cool, tropical highlands, and cool, high-latitude regions with abundant rainfall where mist and cloud cover can be a source of fog-drip precipitation. In tropical highlands of Central and South America, clouds and mist are important in supporting *Alnus acuminata* and grass, when associated, through the dry season.

Alnus acuminata prefers deep, well-drained soils with high organic matter content. However, it is commonly found growing on shallow soils, such as landslides. Rojas et al. (1991) report that it will grow in soil with pH as low as 4.5.

Wide-spaced Alnus acuminata in a Costa Rican pasture. Photo: Nancy Glover.

Uses

Timber. *Alnus acuminata* wood is light brown-yellow to pink, odorless, and tasteless, without differences between the heartwood and the sapwood. Reports on specific gravity vary from 0.34 to 0.39 (Tuk, 1980) and 0.5 to 0.6 (NAS, 1980). The calorific value is 19,250 kJ/kg (CATIE 1986). The wood dries easily and preserves well. It has even grain, seasons fairly well, and is easy to work and finish by hand or machine. Despite its light weight it is tough and strong, and is sometimes used for construction. Timber is also used for fuelwood, posts poles, light lumber, boxes, broom handles, domestic implements, plywood cores, particle board, and musical instruments. A match company in Colombia evaluated more than 20 native species and found *Alnus acuminata* wood best suited for making stick matches (Ing. R. Arismendi, Personal Communication).

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Agroforestry. Farmers in Costa Rica have grown *Alnus acuminata* in pastures and as a shade tree for coffee crops for more than 90 years. Trees are regenerated naturally or planted from nursery stock at spacings of 8 to 14 m (about 100 trees/ha).

One benefit of including trees in cattle pastures is greater milk production--cows on pastures with *Alnus acuminata* produce more than cows on pastures without it (Budowski, 1983). Farmers in Costa Rica sometimes construct crude fences around individual seedlings to protect them from livestock. Protection is needed until trees grow tall enough that livestock can not browse new growth.

Silviculture

Propagation. *Alnus acuminata* is propagated by seeds (more than 2 million pure seeds/kg). Seeds are recalcitrant and must be planted quickly-viability decreases from 70% to 20% in a few months. Seed viability can be extended by storing seed in airtight containers at 5°C-viability is 50% and 31 % after 2 and 3 months, respectively (Rojas et al., 1991).

No seed pre-treatment is necessary. Rojas et al. (1991) recommend broadcasting seed in germination beds (15 to 20 g of seed per ml of bed) and covering them with a very thin layer of mixed soil and sand. The germination bed should be a 1:1:2 mixture of fine soil, sand and organic material. Seeds should be watered twice daily with a very fine mist to maintain soil humidity. Overwatering may cause damping-off. Germination starts 6 to 7 days after sowing and is complete within 15 days. The most vigorous seedlings should be transplanted to pots or back plastic bags 20 days after germination. Seedlings may be planted out when they are 20 cm tall (in about four months). Bare-root seedlings and stump cuttings are possible alternatives to container-grown seedlings. Seedlings do not compete well with weeds so frequent weeding is important (Rojas et al., 1991).

Management. *Alnus acuminata* is grown in plantations mainly in Colombia and Costa Rica, but in other countries as well. In Colombia, an initial spacing of 2.6 x 2.6 m (1,480 trees/ha) is common (Sieco Smit, 1971). In Costa Rica, an initial spacing of 3 x 3 m is preferred. At least two thinnings are recommended, the first after the third year and the second after 10 to 15 years, leaving 250 to 350 trees per hectare. Trees are harvested in rotations of about 20 years. Average annual wood production is 15 to 20 M^3 per hectare. According to Canet (1985), a stand of 30-year-old trees with a density of 35 trees/ha yielded 70 m3/ha of timber, 18.3 ton/ha of dry fuelwood, and 3.6 ton/ha of leaves and fine branches. *Alnus acuminata* resprouts vigorously from the stump after cutting.

Symbiosis

Alnus acuminata, like other *Alnus* species, forms a symbiosis with actinomycetes of the genus *Frankia*. Rojas et al. (1991) report that nodules begin to grow on 13-day-old nursery seedlings. Estimates of nitrogen fixation for *Alnus* species vary widely between 62 kg/ha/yr for *A. sinuata* in Alaska and 125 kg/ha/yr for *A. glutinosa* to 320 kg/ha/yr for *A. rubra* in Oregon (Carlson and Dawson, 1985). In a 2-year-old *A. acuminata* plantation in the Colombian highlands (1200 trees/ha), Carlson and Dawson (1985) estimate an annual increase in soil nitrogen of 279 kg/ha. Acetylene reduction values for 120-day-old *A. acuminata* greenhouse seedlings inoculated with a crushed nodule suspension were between 32.5 and 86.4 *p*mol of ethylene produced per gram of nodule dry weight per hour (Russo and Berlyn, 1988).

Pets and Deseases.

Alnus acuminata is susceptible to attack by defoliators (*Nodonota irazuensis* and *Nodonota* ca. *parvula*, Coleoptera, Chrysomelidae). A stem borer *Scolytoes alni*, (Coleoptera, Scolytidae) has been observed in Costa Rica during the dry season. Vertebrates such as *Sciurus* sp. (Rodentia, Sciuridae) may cause debarking and *Sylvilagus brasiliensis* (Lafomorpha, Leporidae) may destroy seedlings. Fungi such as *Fusarium* sp. and *Trichoderma* sp. may damage seeds; *Colletotrichum* Sp. and *Phomopsis* sp. may affect leaves; and *Rosellinia* sp. may affect stems and roots in mature trees (CATIE, 1991).

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NFT Highlights

NFT 90-06

A quick guide to multipurpose trees from around the world **November 1990**

Alnus nepalensis : A Multipurpose Tree For The Tropical Highlands

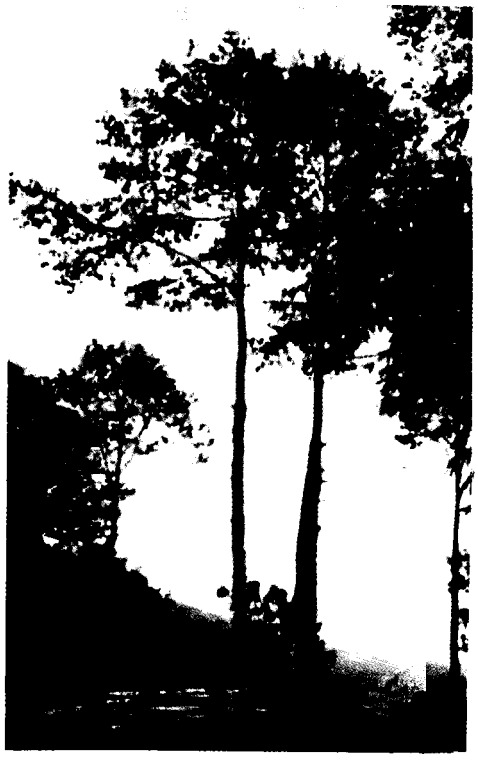
Alnus nepalensis D. Don. (Betulaceae) called utis in Nepal, maibau in Burma, and Indian or Nepalese alder in English, is one of 35 species of alder worldwide. *Alnus* is one of 15 genera of trees that fix nitrogen but are not in the legume family.

BOTANY. Utis is a deciduous or semideciduous tree with a straight trunk that reaches up to 30 m in height and 60 cm (rarely to 2 m) in diameter. The bark is dark green or grey, often with yellowish patches and short, raised lenticels. The leaves, which are frequently damaged by insects, are alternate, elliptical, 6-20 cm long, 5-10 cm wide, entire, denticulate or sinuate. The upper leaf surface is dull or shiny dark green, the lower is pale with dot-like, yehow-brown scales.

The narrowly cylindrical clusters of tiny flowers, or catkins, occur as male or female separately on the same or different twigs in autumn. Male catkins are yellow, 10-25 cm long, and hang in clusters at the end of twigs. Female catkins are much shorter, erect and woody, and occur on branching side twigs. The fruits, which superficially resemble cones of the pine family, are dark brown, upright on short stalks, elliptical, composed of many spreading, hard woody scales. Empty cones may persist on the tree. The seeds are light brown, circular and flat with two broad membranous wings, more than 2 mm across. Seeds ripen from November to March depending on geographical locality.

ECOLOGY. *A. nepalensis* occurs throughout the Hiinalaya at 500-3000 m elevation from Pakistan through Nepal, northern India, Bhutan and Upper Burma to southwest China and Indochina. It is found naturally in moist, cool or subtropical mountain monsoon climates, with an average annual rainfall of 500-2500 mm and a 4-8 month dry season. Mean annual temperatures range from 13-26°C. Soils tend to be moist and well-drained, varying from loam and loamy sand to gravel, sand, and clay. At lower altitudes particularly, utis occurs on moist sites, such as near rivers and in ravines, but it will colonize rocky sites exposed by landslips, or lands abandoned following cultivation. It occurs naturally in both pure and mixed stands.

Alnus nepalensis is a pioneer species and grows well in full light although it will also tolerate shade. It does not require high soil fertility, but prefers permeable soils and should not be planted on compacted or eroded soils. Utis grows well on soils with high water content, but not on waterlogged soils. It grows poorly on dry, exposed ridge-tops.



Open-grown Alnus nepalensis *in eastern Nepal. (Peter Neil)*

USES. Utis wood is moderately soft with densities of 320-370 kg/M^3 (NAS 1980) to 480-590 kg/m^3 (Lamichhaney 1984). Wood calorific value is low (18,230 kJ/kg - Hawkins 1982, or 20,480 kJ/kg - Webb et al. 1984), but utis wood, like that of other alders, dries rapidly and burns easily. Although not among the best construction timbers, utis has an even grain, seasons fairly well, and is easy to saw and finish by hand or machine. The wood preserves fairly well, but is perishable if subject to alternately wet and dry conditions. The wood is also subject to discoloration by oxidation and fungal sap stain. It is suitable for boxes, splints and matches (Dey and Ramaswami 1960) and for newsprint (Guha 1965).

The foliage is of low to moderate value as fodder. Mature leaves are eaten by sheep and goats, but not cattle (Panday 1982, Singh 1982). Leaves are also used as animal bedding. The tree's bark is occasionally used for tanning and dyeing (Little 1983).

Utis is well known as a species that gives some stability to slopes that tend to slip and erode. Seed has been broadcast to stabilize landslides. In Burma, *A. nepalensis* has been effectively used to reforest abandoned taungya areas (Troup 1921, NAS 1980).

Written by Peter E. Neil, Nepal-United Kingdom Forestry Research Project, Department of Forestry and Plant Research, P.O. Box 106, Kathmandu, Nepal. A full list of references for the highlight is available on request from NFTA.

Cardamom is planted under utis in eastern Nepal (including about 80% of cardamom plantations in Ilam District - Ghimire 1985). On terraced slopes in Nagaland State, India, *A. nepalensis* is commonly pouarded for poles and interplanted with crops such as maize, barley, chili and pumpkin (Zeliang et al. 1985). The trees provide fuelwood, green leaf manure, and help in soil conservation. Farmers in India cultivate utis on the berms (mounded earth borders) of crop fields (Kayasha 1985).

ACTINORHIZAL SYMBIOSIS. *Alnus nepalensis* forms a symbiosis with N-fixing actinomyeetes of the genus *Frankia*. Although the biochemistry and physiology of the 'alder-type' symbiosis with *Frankia* are not fully understood, cell-free preparations of nitrogenase have been obtained from, *Alnus* nodules (Postgate 1979). Studies in West Bengal indicated that nitrogenase activity was highest in young nodules irrespective of tree age and concluded that, *A. nepalensis* is capable of fixing significant amounts of nitrogen (Sharma and Ambast 1984). Sharma et al. (1985) investigating soil properties under five stands in the Eastern Himalaya found that total soil N increased with increasing stand age.

PROPAGATION. The species is readily propagated from seed (1.6 to 2.3 million seeds/kg, if pure). It is orthodox and will retain viability for at least a year if properly dried and stored in seated containers. No pretreatment is needed. Germination starts 1-2 weeks after sowing and is completed 2 weeks later. Transplanting into containers can begin 4-5 weeks after germination. Below 1200 m elevation seedlings should reach planting size (25-35 cm) in 4-5 months, but above this altitude they may take as long as 11 months (Napier and Robbins 1989). Young seedlings are liable to damage by ants and defoliation by frost and are very often killed.

Most planting is done with containerized seedlings, although bare-rooted seedlings have proven successful given proper lifting and handling and moist site conditions. Wildings (natural seedlings) have also been used successfully, especially on north-facing slopes. Direct sowing is an alternative. The seed must be fresh and have a high germination capacity. Ample quantities should be used, and the seed sown on exposed mineral soils. Good results are obtained when soil from under old trees is mixed with seed to facilitate even broadcasting and to introduce *Frankia*. Vegetative propagation has been unsuccessful (Lohani et al. 1980).

SILVICULTURE. *Alnus nepalensis* has a wider range of site tolerance than its natural distribution would suggest. It has been successfully established in plantations in a number of countries, mostly within its natural range, but also in Hawaii and Costa Rica. A spacing of 2.5 x 2.5 m is commonly used for plantations in Nepal, although a closer spacing is desirable for fuelwood crops. Poles and fuelwood can be harvested after five years on good sites.

Utis will coppice after cutting, but successful regrowth seems to depend on season and locality - wet season felling and moist localities being best. Small diameter timber can be harvested in less than 10 years. Longer rotations are needed for ordinary saw timber.

Actual growth rates of *A. nepalensis* vary considerably, particularly in response to differences in soil moisture. Recorded growth in Nepal's middle mountains - compares favorably with figures from West Bengal and Hawaii. A 9-year-old stand in Nepal had a mean annual increment in height of 2.7 m and in diameter at breast height of 2.9 cm. Corresponding figures for 10-year-old stands in West Bengal and 8.5-year-old trees in Hawaii were 1.7 m and 1.6 cm (Homfray 1937) and 0.7 m and 1.2 cm (Whitesell 1976), respectively. In Costa Rica a 3-year-old stand had a mean annual icrement in height of 2.3 m and in diameter of 3.6 cm (Palmer, cited in Lamichhaney 1984). Biomass and volume tables have been produced in Nepal.

PROVENANCES. Research in Nepal has shown local provenances to perform best at any given site. No provenances have proven to be of overall superiority (Lamichhaney 1984, Jackson 1987).

PESTS AND DISEASES. Utis is very susceptible to attack by defoliators (*Oreina* sp., *Anomala* sp.). The stem borers *Batocera* spp. (Webb et al. 1984) and possibly *Zeuzera* sp. (Jackson 1987) may also become pests. An aphid, *Eutfichosiphum alnifoliae*, is a pest of economic importance (Das and Raychaudhari 1983).

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FACT Net

FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 96-02
January 1996

Andira inermis : More Then A Beautiful Ornamental Tree

Andira inermis (Sw.) Kunth ex DC (Berendsohn 1989) is a nitrogen fixing tree that is commonly grown as an ornamental. It has a handsome spreading crown, evergreen foliage, showy pink flowers and responds easily to management. In El Salvador it is known as almendro de río or river almond because its fruits are similar to the fruits of *Terminalia catappa* (beach almond). *Andira inermis* is a multiple use tree that has not been extensively used in agroforestry or other reforestation programs because of relatively slow growth rates; however, it offers refuge for wildlife year-round and could be used as fodder for ruminants and other domestic animals.

Botany

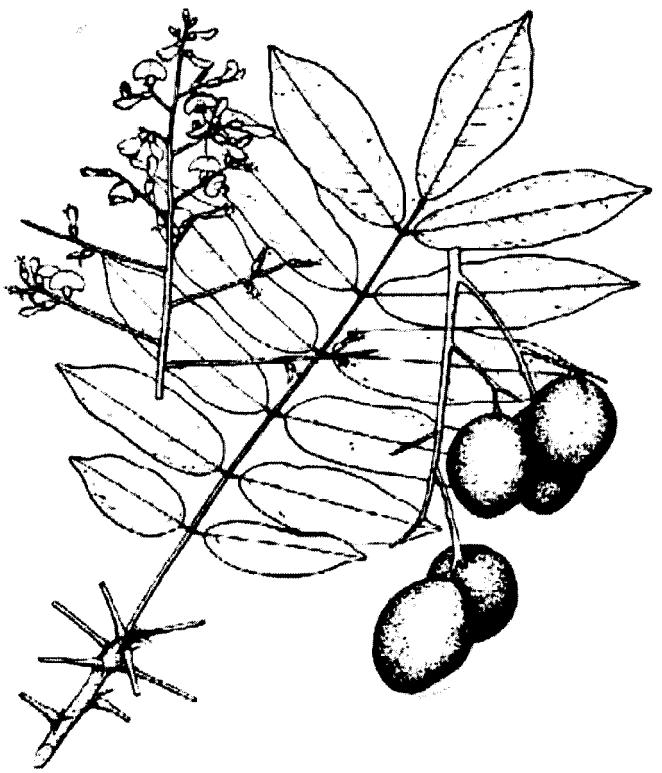
This tree is a legume that belongs to the Papilionoideae sub-family. It grows to 35 m in height and more than 90 cm in diameter (Allen and Allen 1981, personal observations). It has pink flowers in racemes that are self-incompatible and outcrossers (Bawa 1974). It has a dense and spreading crown with bright tan young leaves and shiny green mature leaves with entire margins. Leaves are pinnately compound with 7 to 17 leaflets. The stem has a rough outer surface. It has a drupe-like fruit with one seed that does not open at maturity, an exception among the legumes (Witsberger et al. 1982, Little and Wadsworth 1964). In the Pacific plains of Guatemala, the trunk frequently forms buttresses up to 3 m tall (Standley and Steyermark 1964).

Synonyms include *Andira jamaicensis* (W. Wright) Urban and *Geoffroya inermis* W. Wright (Little and Wadsworth 1964).

The number of common names that *Andira inermis* has is related to its widespread distribution, many uses and botanical characteristics. Names include Almendro de río (river almond) and almendro macho in El Salvador, Guacamayo in Honduras, carne asada in Costa Rica, moca blanca in Puerto Rico, and cabbage angelin, partridge wood or cabbage bark in the United States (Witsberger et al. 1982, Little and Wadsworth 1964).

Ecology

Andira inermis is found in riparian zones, along rivers and in areas with a high water table. It grows in alluvial forests in Central America but may be found in drier areas. It is found along roadsides, river banks, woodlands and pastures, from sea level to 900 m above sea level (Witsberger et al 1982)



Andira inermis. From: Witsberger et al. 1982

Little and Wadsworth 1964). It requires low light for establishment and high light for development. It is an evergreen tree with the foliage continually being replaced throughout the year, especially before flowering (personal observations). In Puerto Rico, two flowering seasons are observed, one between January and February and the second one, between May and September (Little and Wadsworth 1964). In Barro Colorado Island, Panamá, trees may flower for nine months under suitable moist conditions (Croat 1978). This pattern is also observed in trees growing in urban areas in El Salvador where trees flower between December and July (personal observations).

Distribution

Andira inermis is native from southern Mexico to Peru, Bolivia and Brazil. It has been introduced in the Antilles, Caribbean islands, Florida and Africa (Witsberger et al. 1982).

Written by Nadia Evelyn Navarrete, Graduate Research Assistant, Department of Plant Biology, Southern Illinois University, Carbondale, IL 62901 - 6430

Uses

Landscaping. Planted in parks and yards *Andira inermis* is a very attractive tree with a dense, spreading crown, showy pink flowers and bright colored leaves.

Agroforestry. It is used as a shade tree in coffee plantations because it has a spreading crown and responds well to pruning (Witsberger et al. 1982).

Wildlife. Bats eat the fruits. Flowers are visited by bees, birds, and butterflies (Allen and Allen 1981; Janzen 1976; Little and Wadsworth 1964).

Forage. Preliminary studies by scientists at the University of El Salvador showed that the foliage is edible and palatable for ruminants. Research is now being done with rabbits (Jacob Palacios, personal communication).

Wood. The wood is very hard, heavy (0.77g/cm^3), and very resistant to attack by fungi and termites (Guzmán 1947; Little and Wadsworth 1964; Behrendt et al. 1968; Allen and Allen 1981). *Andira inermis* lumber has been used for bridges, railroad tracks and waterfront docks and also to make furniture, billiard-cues, umbrella handles and boats (Little and Wadsworth 1964).

Other uses. The bark is reported to have vermifuge, purgative and narcotic properties (Guzmán 1947). Prunings from shade trees in coffee plantations are good firewood. In the wild, this tree also offers a suitable environment for some plant epiphytes like orchids, bromeliads, mosses and ferns. In conservation programs, it has been used to restore degraded watersheds where moist conditions are prevalent (El Salvador Forest Service, personal communication).

Silviculture

Propagation. Mature fruits are collected and kept under cool conditions. The hard seeds need to be scarified before planting. The El Salvador Forest Service recommends making a cut on the hard fruit endocarp with a file and then planting them in seed beds or plastic bags.

A recent seed treatment study for *A. inermis* compared seeds that were scarified with a file; placed in hot water at two temperatures (70°C and 80°C) for 5, 10, and 15 seconds; or non-treated (Navarrete and Orellana, unpublished).

Seeds started to germinate at week five. Maximum germination for all treatments was observed at week 16. Germination was 43% to 56% for all treatments. The lowest germination recorded was 43% and 46% from seeds at 80°C for 15 seconds and non-treated control, respectively.

Establishment. One-year-old plants, 50 cm tall or more, can be transplanted during the rainy season. *Andira inermis* can also be direct seeded. Two or three seeds, per site, are planted directly in the field (El Salvador Forest Service, personal communication).

Management. In the field, little or no management is done. Occasionally lower branches are pruned to induce faster growth and a straight trunk. In landscaping, top branches are pruned to control height growth.

Symbiosis

Allen and Allen (1981) reported nodulation of *A. inermis* in Hawaii. In Brazil, Faria et al. (1987b, 1986) found that *A. inermis* and six more *Andira* species showed nitrogenase activity with the acetylene reduction assay. They also report that isolated rhizobial strains showed an infective-host range within the cowpea miscellany.

Limitations

Andira inermis does not grow well in areas with a marked dry season. It grows very slowly even with suitable moist conditions (Little and Wadsworth 1964). Bark and seeds are reported to be poisonous (Guzmán 1947).

Processed wood is attacked by borer insects when used under saltwater (Behrendt et al. 1968). Fruits are attacked by the weevil, *Cleogonis* sp. (Janzen 1976) with possible effects on seed germination.

Related Species

There are approximately 30 *Andira* species distributed in Tropical America and one in Africa (Pennington 1995). Some important species in Brazil are *A. racemosa* Lam., *A. fraxinifolia, A. nitida* Mart., *A. frondosa, A. legalis* and *A. anthelmia* (Vell.) Macbr. (Faria et al. 1987a, 1987b, 1986). *Andira galeothiana* Standl. and *A. vermifuga* Mart. are used as fish poison, vermifuge, narcotic or vomiting agents. *Andira retusa* HBK and *A. inermis* yield the alkaloids berberine and angelin. *Andira araroba*, is the source of a fungicide (chrysarobin) used to treat skin diseases (Allen and Allen 1981).

Research Needs

Studies are needed to determine the amount of nitrogen *Andira inermis* provides to crops in agroforestry systems. Provenance and propagation studies are also needed.

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For a complete set of references write to the FACT Net. The author acknowledges the assistance of the Facultad de Ciencias Agronómicas, Universidad de El Salvador.

FACT Sheet

FACT 97-05
A quick guide to multipurpose trees from around the world September 1997

Azadirachta indica : Neem, A Versatile Tree For The Tropic And Subtropics

Azadirachta indica A. Juss. is widely known as neem, a tree that has proven value to both city and farm dwellers throughout the dry tropics and subtropics. Neem has long been recognized as a versatile multipurpose tree for urban regreening, agroforestry, fuelwood production, and for a variety of other products, including biopesticides. *Azadirachta indica* is a member of the Meliaceae (mahogany) family. It has been referred to in the past by the botanical names, *Melia indica* and *M. azadirachta*, which is perhaps why it is sometimes confused with a related species, *Melia azedarach* (chinaberry). The tree is also known as nim, margosa, limba, mimba, nimba, kohomba, and Indian lilac.

Botany

Neem is a small to medium-sized tree, with a short, straight bole. The stem branches at 2-5 m forming a broad, dense, round or oval crown. Total height is 15-25 m, occasionally reaching up to 30 m, with a stem diameter ranging from 30 to 90 cm. Neem is characterized by a long, penetrating lateral root system, which can extend up to 15 m, with a relatively short taproot. Neem has moderately thick, fissured, gray outer bark, with a reddish-brown inner bark. It is evergreen or deciduous depending on the climate; leafless periods are usually brief, occurring during extended drought. Leaves are alternate, imparipinnately compound, 20-38 cm and bunched at the tip of branches. The tree produces many small, sweet-scented, white or cream-colored, bisexual flowers. The fruit is a smooth, ellipsoidal drupe, 1.2-2.0 cm long, containing usually one seed. The fruit is initially green and turns yellow as it ripens in about 12 weeks after full bloom. Neem trees are prolific fruit producers, starting as early as 3-5 years, and becoming fully productive at 10-12 years.

Ecology

Neem adapts to a broad range of climate and soil conditions. It is normally found at elevations between sea level and 700 m. Neem can grow at altitudes up to 1500 m, as long as temperatures remain moderate, as it does not withstand cold or frost. Neem tolerates extremely high temperatures, but its normal range is about 9.5°C - 37°C. It is also highly drought tolerant, and once established, it can survive 7-8 month dry seasons. It requires as little as 150 mm rainfall per year in areas where the root system can access groundwater within 9-12 m of the surface, however, it performs best in zones receiving 450-1200 mm/year. Neem prefers deep, permeable, sandy soils, but can be planted in a wide variety of soil types, including difficult sites where most other species do not perform well. It can thrive on rocky, dry, shallow, infertile soils, but is not recommended for silty or micaceous loams, silty clay soils, saline soils, or where sub-surface hardpan or laterite outcroppings occur (NRC, 1992). Neem should also not be planted on sites where soils become waterlogged or seasonally inundated. It prefers a soil pH in the 6.2-7.0 range, but can grow within a range of 5.0-8.0 pH.

Leaves, seed and flower. Source: Parkar, 1933

Mature neem trees are light demanding, but seedlings tolerate moderate shade during their first growing season, especially on dry sites.

Distribution

Azadirachta indica is indigenous to South Asia, possibly originating in northern Myanmar and the Assam region of India. Neem's natural habitat is dry, deciduous, mixed forest, occurring in association with *Acacia* spp. and *Dalbergia sissoo* (Lemmens *et al*, 1995). It is widespread in India, Pakistan, Myanmar, Sri Lanka, Thailand, Malaysia and Indonesia. Neem has been introduced and established throughout the tropics and subtropics, especially in drier areas in Southeast Asia, the Pacific Islands, Australia, South and Central America, the Caribbean, sub-Saharan Africa, and the Middle East.

Uses

Agroforestry and urban forestry. Neem plays an important role in both urban and rural landscapes. Its well-formed crown and short deciduous period has made it a popular choice for shade plantings around buildings and along roadsides. It is also used on farms as a pasture tree to shade livestock and in boundary rows. Neem is not usually selected for hedgerows or alley cropping, but is used in windbreaks and shelterbelts to protect crops from wind damage and soils from erosion.

Wood products. Neem produces a moderately dense wood, somewhat similar to mahogany. The wood has a specific gravity of 0.52-0.85, averaging 0.68 (NRC, 1992). The heartwood portion is reddish to reddish-brown, while the sapwood has a yellowish-gray or grayish-white color. The wood is hard, durable, dull to somewhat lustrous, aromatic and resistant to insects and fungi. The wood dries with only slight shrinkage, seasons well, and is easy to work, but the rough, interlocked grain does not take a high polish. Neem sawtimber is used in light construction, and to make beams, door and window frames, boxes, crates, carts, axles, yokes, cabinets, panels, boats, oars, cigar boxes, carvings, toys, drums, and agricultural implements. It is also used for furniture, especially wardrobes, book cases, and closets, because the wood repels insects.

Written by Carol Stoney, Program Officer, Winrock International.

Neem trees are often managed under pollarding or coppicing systems to produce posts and poles. The roundwood is also used as fuelwood and makes very good charcoal. At 14% moisture content the wood gives an energy value of 16.92 megajoules/kg (Lemmens, 1995).

Non-timber products. Useful products can be harvested from almost every part of the neem tree. The bark produces tannins, a fiber used to make rope, and a resin used to make glue. Bark is used medicinally as a remedy for fever, and fruit pulp is also used as a tonic. Leaves are used as mulch and green manure, and can also be used as fodder. The leaves have a crude protein content of 12-18%, but because they have a bitter taste, livestock usually prefer other foods. Neem leaves mixed in with stored grain have traditionally been used in India to repel insects and prevent food and seed losses.

Azadirachtin. The principal active compound in the leaves is azadirachtin, which repels pests, acts as an antifeedant, and disrupts insects' growth and reproduction. Several bioactive compounds are found in the leaves and other tissues, however, the neem seed kernels are the main source of azadirachtin. Neem seed contains the most concentrated and accessible amounts of other potentially useful compounds as well. Neem-based pesticides have already been approved for various applications and are being produced commercially in several countries. Low-tech methods have also been developed to produce neem extracts. These methods will be described in a future *FACT Sheet.*

Neem oil and neem seed cake. Neem seeds will yield 40-50% oil when the dry kernels are crushed or pressed through an oil mill. Neem oil is used as fuel for lamps, an antiseptic for animal wounds, a lubricant for machinery, an insect repellent, to remove tobacco suckers, and in the production of soap, toothpaste and cosmetics. It has also traditionally been used for a variety of medicinal purposes, but there is evidence that it should not be ingested orally. Neem oil may also have potential in the development of pesticides and fungicides, although it does not contain azadirachtin (NRC, 1992). Neem seed cake is the residue left after the oil has been extracted from the kernel. Neem cake is used as a fertilizer with insecticidal and fungicidal effect.

Silviculture

Propagation. Neem seedlings can be produced vegetatively by air layering, cuttings, grafting and tissue culture, however, they are usually grown from seed in nurseries as bare-root stock or in containers. Direct sowing is more cost-effective, but may result in poor survival in drier zones. Neem wildlings are an inexpensive source of seedlings, as natural regeneration is normally abundant. Although neem is a prolific seed producer, seed supply is frequently a problem. The viability of fresh seed decreases rapidly after two weeks, and improperly stored seeds have low germination rates. Ripe seed should be collected from the tree and processed immediately. First the pulp is removed and the seeds are washed clean. Seeds are air dried for 3-7 days in the shade, or until the moisture content is about 30%. They can then be stored for up to four months if kept at 15°C. Seed will remain viable even longer if dried to 6-7% moisture content and refrigerated in sealed containers at 4° C.

Sow seed in nursery beds in rows 15-25 cm apart, and 2.5-5 cm spacing within the rows. Seedlings can be pricked out when two pairs of leaves have developed (1-2 months), or the rows should be thinned to 15 cm x 15 cm spacing.

Plastic pots are commonly used to produce neem seedlings, although rigid container systems are used in Haiti with success. Seeds should be sown horizontally at a depth of 1 cm. Fresh seeds will have the highest germination rate, and seedlings will emerge within in 1-3 weeks. Removal of the seed coat may increase germination rates for stored seeds. Both bare-root and containerized seedlings should be raised under partial shade for the first 1-2 months, or until about 30 cm tall, then gradually exposed to full sunlight.

Bare-rooted seedlings are usually kept in the nursery for 1-2 years before outplanting. The roots and shoots of seedlings lifted from nursery beds should be pruned before transplanting. Bare-rooted seedlings can also be prepared for stump planting. Stumps are made from 1-2 year old seedlings by trimming the root to 20-22 cm root and the shoot to 5 cm. Containerized seedlings should be outplanted after 3-4 months in the nursery, when they reach 30-50 cm. Fuelwood plantations are laid out at a 2.5 m x 2.5 m spacing, and then later thinned to 5 m x 5 m. The recommended spacing for windbreaks is 4 m x 2 m. Neem trees managed to maximize fruit yield should be more widely spaced to allow the crown to develop fully.

Management. Young seedlings suffer from weed competition, but weed control is usually only needed during the first growing season. Neem seedlings should also be protected from fire, although mature trees can recover from fire damage. Once the root system is well-established, early growth is rapid for about five years, then slows gradually. Neem responds well to coppicing and pollarding to produce poles, posts, or fuelwood. Coppicing to produce fuelwood is managed on a 7-8 year cycle. Pollarding is used to manage windbreaks, and to produce posts. Yields vary greatly depending on site conditions, but fuelwood production reports range from 6-57 m^3/ha/year.

Limitations

Azadirachta indica has few serious pests or diseases. The most serious insect pests are scale insects, including the neem scale (*Palvinaria maxima*) and the oriental yellow scale (*Aspidiotus orientalis*), both of which can cause considerable damage. The oriental yellow scale has been associated with a widespread neem defoliation in West Africa in the mid-eighties, although severe drought may have previously weakened the trees (NRC, 1992). In the early 1990's another neem die-back in West Africa was reported. This was at first thought to be caused by a soil fungus, but after several years of observation, no specific pathogen or pest was identified. The cause of the disorder is now believed to have been stress-related due to low soil moisture brought on by extended drought and soil compaction.

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FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 98-01
January 1998

Azadirachta indica : Use of neem as a Biological Pest Control agent

The neem tree (*Azadirachta indica*) has been introduced and established throughout the tropics and sub-tropics for its highly valued hardiness, its almost year-round shade, and its multiple wood and non-wood products. Agroforesters have promoted it for use in windbreaks, fuelwood plantations, and silvo-pastoral systems, especially for dry zones and infertile, rocky, sandy or shallow soils. People have long recognized that the leaves, bark, wood and fruit of the neem tree either repel or otherwise discourage insect pests, and they incorporated these plant parts into traditional soil preparation, grain storage, and animal husbandry practices. Through more recent chemical analysis the active compounds in neem tissues have been identified. Several neem-based biological pest control (BPC) products have been developed and approved for commercial distribution in some countries. The neem tree can provide an inexpensive integrated pest management (IPM) resource for farmers, the raw material for small rural enterprises, or the development of neem-based industries.

Neem's active ingredients and their impact on pests

Azadirachtin has been identified as neem's principal active compound. It acts on insects by repelling them, by inhibiting feeding, and by disrupting their growth, metamorphosis and reproduction. Neem-based formulations do not usually kill insects directly, but they can alter their behavior in significant ways to reduce pest damage to crops, and reduce their reproductive potential. Azadirachtin affects insect physiology by mimicking a natural hormone. It has been shown to affect egg production and hatching rates. In larvae, azadirachtin can inhibit molting, preventing them from developing into pupae.

Many foliage feeding species will avoid plants treated with neem compounds or will cease eating after ingesting them (NRC, 1992). Its has proven effective as an antifeedant on about 100 insect species (Read & French, 1993). Thus, the extracts work especially well to protect plants from defoliation without affecting beneficial pollinating insects like honeybees.

Overall tests of neem extracts have shown results on about 300 insect species, mostly in the Orthoptera (grasshoppers, katydids, etc.); Homoptera (aphids, leafhoppers, etc.); Dictyoptera (cockroaches and mantids); Lepidoptera (moths and butterflies); Heteroptera (true bugs); Diptera (flies); Coleoptera (beetles and weevils); Hymenoptera (bees, wasps and ants); Isoptera (termites); Thysanoptera (thrips), and Siphonaptera (flea) orders (NRC, 1992; Randhawa and Parmar, 1993).

Even crudely produced neem extracts can provide excellent control of caterpillars and beetle larvae, and are effective on grasshoppers, leaf miners, and leaf and plant-hoppers. Commercially produced neem preparations can suppress a broad range of pests including insects, centipedes, millipedes, mites, and nematodes.

Traditional uses of neem

Farmers have traditionally used various components of the neem tree such as oil extracted from the seed, neem cake, (the residue left after pressing the oil) and the leaves as well as the wood. Farmers in India use neem cake as an organic manure and soil amendment. It is believed to enhance the efficiency of nitrogen fertilizers by reducing the rate of nitrification and to inhibit soil pests including nematodes, fungi, and insects (Gupta, 1993). Neem leaves and small twigs are also used as mulch and green manure.

Neem leaves and neem oil have also been used traditionally to protect stored grains and legumes. Neem leaves are mixed with the grain in storage or the grain is stored in jute bags treated with neem oil or other neem extracts. These methods can protect food and seed stores from insect pests for several months.

Another traditional agricultural practice involves the production of "neem tea." The seeds are dried, crushed and soaked in water overnight to produce a liquid pesticide that can be applied directly to crops. Crushed seed kernels are also sometimes used as a dry pesticide application, especially to control stem borers on young plants. These home-made remedies are often very effective at repelling pests or acting on insects as a feeding deterrent, even if they do not actually kill them. The strength of home-made preparations can vary due to the concentration of azadirachtin and other compounds in the seed, which can in turn depend on the genetic source of the seeds. It can also be affected by the process of handling and drying the seeds, contaminants in the water, and exposure to high temperatures or sunlight. The active compounds break down quickly, so an application of neem tea can generally provide protection for only about one week.

Neem is a species of the Mahogany family, and although it has some of the characteristics of a cabinetry wood, its grain is rough and does not polish well. Neem wood is, nevertheless, used to make wardrobes, book cases and closets, as well as packing cases because the wood helps to protect the contents from insect damage (Read & French, 1993). The main stem of the tree is also widely used to make posts for construction or fencing, because the wood is termite resistant.

Written by Carol Stoney, Program Officer, and Erin Hughes, Program Associate, Winrock International

Farm-level production and use of neem extracts

Farmers with ready access to seed producing neem trees can prepare their own "neem tea" using simple procedures to extract the active compounds. Ripe seeds should be collected from the trees, and the seeds should be depulped, washed clean and dried as soon as possible after harvesting. Seeds should be dried in the shade for 3-7 days. Seeds should be checked, and any that have been contaminated by mold or fungus should be rejected. The dried seeds are then finely crushed in a mortar or mill. About 500g crushed seeds should be mixed with 10 liters water and the mixture should be left to sit overnight. The next day the mixture should be filtered through fine cloth or gauze. It is then ready to be applied directly to crops using a spraying, brush or swab technique. The mixture should not be applied more than once a week, and treatments every 10-15 days is usually adequate for control of normal pest problems. Unused extract should be carefully stored in a closed container in a cool dark protected area (GTZ, n.d.).

Neem extracts can be made from leaves and other tissues, but the seeds contain the highest concentrations of azadirachtin. Industrial scale extraction processes use solvents such as alcohol, ether, and hydrocarbons instead of water. Some sources claim that the waterbased extracts work nearly as well, although using the method described above it is difficult to determine the concentration and therefore the appropriate amount to be applied. In Pakistan a process of freeze drying the water-based neem extract produces a crystalline powder called "neem bitters" that is water soluble (Read & French, 1993).

Small-scale processing for use in rural enterprises

Although efforts have been undertaken by NGOs to promote neem-based micro-enterprises in rural areas to increase employment opportunities, few have succeeded. Challenges they have faced include difficulty in producing uniform concentrations; problems with packaging, storage, and transportation; and lack of information about potential markets. These are common constraints to the development of small agro-enterprises and probably can be overcome. Neem-based enterprises have special potential where it is possible to reach producers who have a market for organic produce and in areas where commercially distributed pesticides are unavailable or too expensive for the average farmer to afford.

Commercial uses of neem

Neem oil has long been produced in Asia on an industrial scale in soaps, cosmetics, and pharmaceuticals. During the 1980s companies began commercial production and distribution of pest control formulations that use azadirachtin as the principal active ingredient. Interest in BPC agents has developed along with the environmental and consumer rights movements, and the recognition that IPM strategies are needed to sustain agricultural production. New markets for organically grown produce and "natural" products also spurred the development of the BPC industry, and azadirachtin was among the first to be commercialized.

In the United States neem-based BPCs were first approved for use on non-food crops in 1985. After subsequent testing, the Environmental Protection Agency (EPA) regulated the use of Dihydroazadirachtin (DAZA), a reduced derivative of azadirachtin, for use on food crops. In 1996 the EPA exempted raw agricultural commodities from meeting DAZA residue requirements, as long as the chemical is applied as an insect growth regulator or antifeedant at no more than 20gms/acre with a maximum of seven applications per growing season (EPA, 1997). The EPA only allows this exemption if approved commercial products are used; food products treated with home-made extracts would not meet these requirements.

Environmental issues

Neem compounds do not persist or accumulate in the environment after being applied as pesticides. They break down quickly when exposed to sunlight, usually within one week. Commercial preparations contain sunscreens which maintain their effectiveness for 2-3 weeks. Neem extracts may have toxic effects on fish, other aquatic wildlife, and some beneficial insects. Therefore, care should be taken in disposing of any unused extracts, by exposing them to heat or sunlight to break down the active compounds.

Neem fruits are an important source of food for some wildlife, especially birds and bats, although they only digest the pulp, not the seed. Neem compounds have been judged to be relatively non-toxic to mammals. Azadirachtin is so effective against insects, because it imitates a naturally occurring hormone that disrupts insect life cycles, however, this hormone does not occur in vertebrates. The United States EPA has concluded that if approved procedures for its application are followed that, "no unreasonable adverse effects to human health are expected from the use of DAZA" and "there is a reasonable certainty of no harm from dietary exposure" (EPA, 1997). Neem oil has been used traditionally as a topical treatment for skin symptoms in both humans and livestock, but it should not be injested orally.

Issues for research

Researchers believe that even modest efforts at genetic improvement could result in higher seed yields, higher levels of azadirachtin, and other useful compounds in the seed. Management of neem plantations for BPC production will require research to determine appropriate silvicultural practices, such as tree spacing, pruning or lopping to promote seed production, as well as possibilities for intercropping within the plantations. More research is also needed on the other bioactive compounds found in neem and on how they interact to repel or deter insect predators. Some of these also have shown anti-fungal and anti-viral properties. Farmers need better methods for preparing neem extracts to ensure uniform concentrations and quality. They also need better information about how to apply the extracts to maximum effect on different insect species at different life cycle stages. Long-term environmental impacts of the use of neem-based BPCs should be monitored and assessed.

An introduction to neem botany, ecology, distribution, uses, silviculture, and management is provided in FACT-Net's FACT Sheet 97-05: *Azadirachta indica: neem, a versatile tree for the tropics and subtropics* (September, 1997). Key references for this FACT Sheet include:

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NFT Highlights

NFTA 88-06

A quick guide to useful nitrogen fixing trees from around the world November 1988

Cajanus cajan : It's More Than Just A Pulse Crop

A variety of cultivars and the many ways they can be used in farming systems have made pigeonpea (*Cajanus cajan*) popular to small scale farmers. It is the major pulse crop of the semiarid tropics, has been used for centuries in intercropping systems, and is an ideal source of fodder, food and firewood in agroforestry systems.

BOTANY

C. cajan (L.) Millsp. is a leguminous shrub that can attain heights of 5 m. Pigeonpea probably evolved in South Asia and appeared about 2000 BC in West Africa, which is considered a second major center of origin. The slave trade took it to the West Indies, where its use as bird feed led to the name "pigeonpea" in 1692 (van der Maesen 1986). Leaves are trifoliate and spirally arranged on the stem. Flowers occur in terminal or axillary racemes, are 2-3 cm long (Purseglove 1968), and are usually yellow, but can be flocked or streaked with purple or red. Pods are flat, usually green in color, sometimes hairy, sometimes streaked or colored dark purple, with 2-9 seeds/pod. Seeds are, widely variable in color, 6-9 nun in diameter, and weigh 4-25 g/100 seed (Sheldrake 1984). *C. cajan* was long considered to be one of two species (with a minor W. African species) of the genus *Cajanus* DC. However, this genus is now thought to be congeneric with *Atylosia* and *Endomallus*, and also includes species of *Rhynchosia* and *Dunbaria* (van der Maesen 1986). *Cajanus* is now recognized as having 32 species.

ECOLOGY: Pigeonpea is hardy, widely adaptable, and more tolerant of drought and high temperatures than most other crops. It grows on acid sands in the Sahel and alkali clays in India. Frost or excessive soil salinity are not tolerated. and waterlogging for 3-4 days severely reduces yields (Chauhan 1987). Various cultivars are grown from sea level to 3,000 in.

USES: **Food**. Pigeonpea is best known as a human food. Short duration shrubby varieties such as ICPL 87 can yield 5-8 t/ha of grain when grown as sole crops (Reed 1987). In India, decorticated, split dried peas (dam) are an important protein source. Dahl is 25% protein and has a good balance of all amino acids except methionine and cystine, which are slightly deficient for the human diet (Faris et al. 1987). Some anti-nutritional factors are present, but are destroyed by cooking. In the Caribbean and East Africa, pigeonpeas are eaten green as a vegetable and are commercial grown and canned in the West Indies. Vitamin A (470 mg/100g) and C (25 mg/100g) contents of vegetable pigeonpeas are five times those of green peas (Faris et al. 1987). When grown as a perennial, pods may be picked ripe or green for a long time. The vegetable line ICPL24 produced 11 t/ha of green pods in five pickings in Gujarat, India (Faris et al. 1987).

Animal feed. Pigeonpea is an excellent fodder species. Crude protein values of fresh forage range from 15-24% (Whiteman and Norton 1981). Its exceptional nutritional value and high productivity can give good liveweight gains. In Hawaii, Henke et al. (1940) reported cattle weight gains of 280 kg/ha/yr in pure pigeonpea compared with 181 kg/ha/yr in mixed grass pastures over a 6.5 mo grazing period. Foliage is retained well into dry seasons. Although forage production depends on the stage of the crop, growing conditions, and management, experimental yields exceeding 50 dry tons/ha/yr have been reported in intensively managed cut and carry sole stands (Whiteman and Norton 1981). Under less intensive management, 3-8 dry t/ha/yr can be expected. Poor early growth makes it unable to compete well in mixtures with grasses. Grain, whole pods, and milling trash have been proposed as a substitute for soybeans and maize in poultry and pig feed, but deficiencies in some amino acids and antinutritional factors may limit its suitability unless expensive additives or processing are used (Wallis et al. 1986).

Wood. Pigeonpea sticks are an important household fuel in many areas. Productivity more than makes up for comparatively poor fuel characteristics (low specific gravity and high moisture content). Stick yields of 7-10 dry t/ha/yr are routinely reported for medium and early duration lines, and yields of 30 t/ha/yr from irrigated, early duration varieties have been reported in India (ICRISAT 1986). Perennial varieties can produce 10 t/ha/yr of dry material over a 2-3 year period on good sites. Sticks also produce thatch and basket materials.

Other Uses. Pigeonpea is nodulated with *Rhizobium* of the cowpea type and is an effective green manure crop. Whiteman and Norton (1981) recommend incorporating high density plantings at or about the time of flowering. When allowed to perennialize, pigeonpea can drop 1.6 dry t/ha/yr of litter in the first year (Sheldrake and Narayanan 1979). It is used in folk medicine in West Africa and has been proposed as a nurse crop in India (Purseglove 1968).

CROPPING SYSTEMS: Pigeonpea is used in a great variety of cropping systems throughout the tropics. Although average grain yield (650 kg/ha) and harvest index (20-25%) are low, its hardiness and ability to grow on residual soil moisture make it attractive to small farmers (Sheldrake and Narayanan 1979). Early growth is slow,

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making it an ideal, noncompetitive intercrop with cereals such as sorghum and millet. Such systems give full sorghum yields and over 70% of the pigeon pea grain harvest that could be obtained if the two crops were grown separately (Willey et al. 1981). Pigeonpea is a short-day plant, and its maturation period is related to daylength sensitivity of particular cultivars (Sheldrake and Narayanan 1979). Farmers in India, where pigeonpea is usually grown as an annual, exploit this trait. In the north, it is planted as a late-maturing crop (9-11 mos.) at relatively wide spacings (50,000/ha) during the longest summer days. In the peninsula, medium duration varieties (6-8 mos.). which flower as days grow shorter, are planted solely or intercropped with cereals (Willy et al. 1981; Sheldrake 1984). Early varieties, which are usually determinate (flowers borne on terminal racemes) and photoperiod insensitive, are sown densely (100,000 plants/ha) as sole crops during the rainy season or the post rainy season, when they use stored soil moisture and benefit from fewer pests and diseases (Sheldrake 1984).

In Africa, greater use is made of its perennial nature. In East Africa, long duration pigeonpea is sown with cereals or short duration grain legumes such as cowpea. After the grain crop is harvested, pigeonpea grows to its full height and pods are used as a green vegetable or pulse. In the next year, pigeonpea is either ratooned and the cereals are planted, or it is allowed to dominate the field for pod production (Omanga and Matala 1987). Cereals are rarely planted among unratooned pigeonpea in the second year, because it is too competitive. Animals allowed to graze fields after cereals are removed eagerly browse the pigeonpea (Omanga and Matala 1987).

Ongoing work at ICRISAT suggests it can be used as a semipermanent, perennial component in alley cropping. Its traditional uses as a rotational/fallow crop in East Africa and as a part of shifting agriculture in SE Asia deserves more attention. It has been used as food and fodder- bearing windbreaks and live fences. It is widely planted as a backyard plant for shade and as a green vegetable.

ICRISAT (India) will help cooperators establish provenance trials, such as this 4-month-old trial Hawaii.

ESTABLISHMENT: Pigeonpea is best established by direct seeding in a well-prepared field. Gaps should be filled with seedlings grown -in pots. No pre-germination treatment of seeds is needed.

BREEDING SYSTEMS: Pigeonpea (2n=22) is mostly self-pollinating, but a range of 3 - 95% outcrossing has been reported. This is probably a function of environment and populations of pollinating insects (Sheldrake 1984). When pure lines need to be maintained, it may be necessary to cover plants with muslin bags to exclude insects. The "wrapped flower" character, with overlapping petal lobes, delays flower opening and has been used to increase the degree of selfing (Sheldrake 1984). Male sterile lines have been developed and are used in hybridization programs. One ICRISAT hybrid, ICPH8, consistently yielded 25% more grain than the best control in 15 trials in India (Wallis et al. 1986). Interspecific hybrids with species of the congeneric genus *Atylosia* have shown promise as fodder and cover crops.

PESTS AND DISEASES: In India, wilt (*Fusariun udum*) and sterility mosaic (mite-borne virus?) are the most important diseases (ICRISAT 1986). Wilt and leaf spot (*Mycovellosiella cajani*) are important in East Africa (Omana and Matala 1987). Rust (*Uredo cajani*) is the major disease in the Caribbean (Reed 1987). Root rot (*Phytophthora dreschsleri*) can be a problem in poorly drained fields. Resistance to these diseases, notably wilt and sterility mosaic, exists and should be exploited when pigeonpea is used as a perennial or grown in areas of heavy rainfall. Important insect pests include the pod borer, (*Heliothis armigera)*, and the podfly, *Melanagromyza obtusa*, (Reed 1987). Scale insects (*Coccus* spp.) can build up rapidly and severely damage perennial stands. Insect resistant lines are not yet widely available.

OBTAINING SEEDS: Small seed packets of a perennial variety are available from NFTA. For other seeds, contact ICRISAT, Patancheru, Andhra Pradesh 502324, India.

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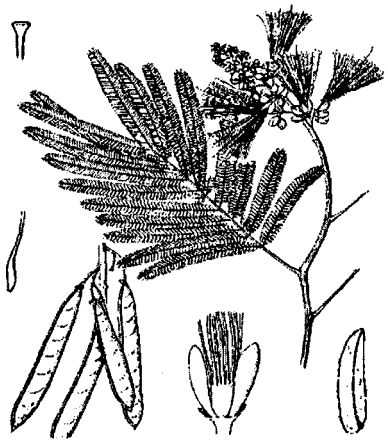
FACT Sheet

FACT 99-02
A quick guide to multipurpose trees from around the world January 1999

Calliandra calothyrsus : An Indonesian Discovery For Humid Tropical Regions



From Macqueen 1993

Calliandra calothyrsus is easy to establish and manage, grows quickly, and provides multiple products and services. Introduced to Indonesia in 1936 as a shade tree, it proved unsuitable for that purpose, but was adopted by Javanese farmers for fuelwood production and land reclamation. It has since been planted for green manure, animal fodder, bee forage, and pulpwood. The successful use of *C. calothyrsus* in Indonesia stimulated global interest in the species, and it is now cultivated for agroforestry throughout the tropics.

Botany[1]

Calliandra calothyrsus Meissner is a small, branching tree growing to a maximum height of 12 m and a maximum basal stem diameter of 20 cm. The stems have red or pale gray bark covered with small, pale, oval lenticels. Toward the tip, the stems tend to be ridged, and in trees with red-brown bark the final stem portion may be tinged with red.

The species has soft leaves divided into many straight leaflets. The leaves may reach 20 cm long and 15 cm wide, and they fold against the stem at night. The leaf stalks are ridged with a groove on the upper surface, but they do not have glands between the pairs of secondary axes.

In the species' native range, flowering occurs throughout the year, but it tends to peak between July and March. The inflorescences develop at the branch terminals. Several clusters of flowers develop around nodes below the axis. The flowers mature over a period of many months, beginning at the base of the in-florescence and progressing to its tip. Each flower opens for a single night to display showy filaments, which usually are white at the very base and red at the tip (although, exceptionally, they may be pink). By the next day, the filaments have wilted, and unfertilized flowers drop.

Pods take from two to four months to develop, and when mature they may be 14 cm long and almost 2 cm wide. They are straight, medium-brown, and contain 8-12 ovules, which may develop into flat, hard, oval seeds up to 8 mm long. In its native range, seed set peaks between November and April. As the pods dry, tensions created in the thickened pod margins cause an explosive splitting from the pod tip to the base that ejects seeds with a spinning motion, dispersing them as much as 10 m away. The species has several common names in its native range, the most frequently used being "cabello de angel" (meaning "angel's hair") and "barbe sol" ("the sun's beard"). In Indonesia, the species is referred to as "calliandra merah" ("red calliandra").

Taxonomy[1]

Calliandra calothyrsus can be distinguished from species of similar appearance by a unique combination of features. The species' almost straight leaflets do not tend to overlap, and they do not have a glossy upper surface. The leaves are soft and tend to fold after a branch is cut. The stems, flowers, and pods are almost always glabrous (without hairs). The petals are never thick or woody nor covered in hairs of any length or color.

Ecology and Native Range[1]

Calliandra calothyrsus occurs naturally along riverbanks but will rapidly colonize any area of disturbed vegetation (roadsides, for example). It is not particularly tolerant of shade and may soon be out-competed in secondary vegetation. It inhabits a range of sites within Mexico and Central America from sea level to an elevation of 1900 m. It primarily occurs in areas with a mean annual rainfall of between 1000 and 4000 mm, although exceptional populations occur in areas with only 800 mm annual rainfall. It principally occurs in areas with 2-4-month dry seasons (< 50 mm/month rainfall), although it has been found in areas with a dry season as long as 6 months. It occupies areas with a mean annual minimum temperature of 18-22°C. It is not frost tolerant. Within its natural distribution, it occurs on a variety of soils and appears to be tolerant of acidic soils with pH values around 4.5. It does not tolerate soils with poor drainage or that are regularly inundated.

Uses

Fodder.[2] Because of its fast growth and ability to resprout after repeated cutting, calliandra is a useful component of animal production systems. The edible fraction (leaves, flowers, and twigs) contains 20-25% crude protein, which makes it a good supple-ment for basal diets of grass or other low-quality roughages. The leaves contain high levels of tannin, which may account for its low digestibility of 30-60%. Calliandra should compose no more than 30% of a ration (dry-matter basis). The fodder should be used fresh, because animals respond poorly when it has dried. Small ruminants readily consume calliandra. Cattle may need an adjustment period when this fodder is introduced to their

diet. Rabbits and chickens can eat calliandra in small quantities as part of a mixed diet (up to 5% on an as-fed basis). Calliandra is reportedly used as fish feed in Vietnam.

Calliandra may be used in both cut-and-carry and direct grazing systems. For fodder banks, it is often planted at 1 x 1 m, or in hedgerows 2 m apart with trees 50 cm apart within the rows. In either system, planting distances may be adjusted to permit the use of machinery. Depending on the environmental conditions, calliandra may be harvested 4-6 times each year. Trees should be cut again after about 1 m of regrowth. Lopping should not be lower than 30 cm above ground. Under this management, fodder dry matter yields can be 3-8 tons/ha/year.

Wood and pulp.[3] Calliandra is widely used as a fuelwood. In Indonesia, over 30,000 hectares of fuelwood plantations are established on Java alone. The wood has a specific gravity of 0.5-0.8, dries rapidly, and burns well, producing 4600 kcal/kg (7200 kcal/kg as charcoal). It is burned to produce palm sugar, smoke sheet rubber, dry copra, and heat brick and tile ovens. Fuelwood plantations are normally planted at 1 x 1 m or 1 x 2 m spacing. The recommended cutting height is 30-50 cm. Annual yields are 5-20 m^3/ha for one-year-old plantations and 30-65 m^3/ha for 20-year-old plantations. With a cellulose content of 44-51%, *Calliandra calothyrsus* is suitable for paper pulp, but it should comprise no more than 10% of a pulp. In Indonesia, pulpwood plantations are planted at 2 x 2 m spacing.

Agriculture Systems.[3] In agriculture systems, calliandra is used to reduce weed growth, conserve soil moisture, and improve soil structure and fertility. It is used as an understory component in coconut plantations, a shade tree in coffee and tea plantations, and a nurse tree in timber plantations. To reduce competition with crops, calliandra is pruned when necessary, commonly 3-4 times a year, to a height of 0.5-1 m. Tree density varies from 160 to 2500 per hectare. Calliandra is also used in hedgerow systems, often on steep slopes, with corn, rice, groundnuts or other crops. Hedges are usually planted 1.5-2 m apart, with trees 1-2.5 m apart within rows. *Calliandra calothyrsus* is also becoming an important source of forage for honeybees in Indonesia.

Reclamation and rehabilitation.[3] Calliandra is used to reduce fallow periods and improve soil fertility at densities of 5000-10,000 trees per hectare. It is planted in contour hedge-rows to decrease erosion on steep slopes, with in-row spacing as close as 5 cm. Calliandra has been successfully used to rehabilitate imperata grasslands in Indonesia. Spacing varies from 1.5 x 1.5 m to 5 x 5 m.

Silviculture

Propagation.[4] To achieve rapid and uniform germination, calliandra seed (18,000-20,000/kg) should be scarified before sowing. For small quantities of seed, the seed coat may be cut or scraped opposite the thin micropyle or hilum and soaked in cool water for 12-24 hours before sowing. For large quantities, soak in cool water for a minimum of 24 hours. Soaking in hot water for 2-5 minutes before the cool-water treatment may increase germination, although hot water may also kill the seed. Careful testing of the chosen technique is recommended.

Seed generally should be sown at a depth equal to its width. Germination should occur in 4-10 days. The choice of nursery container depends on the desired seedling size. For large seedlings, use large containers. Large seedlings compete better and need less care after transplanting. However, small seedlings are easier and less expensive to grow and transport. Seedlings are normally ready for field planting after 6-12 weeks in the nursery when 15-50 cm tall. Standard nursery management and seedling hardening-off procedures should be followed.

Calliandra may be established by directly sowing scarified seed at the planting site. Sowing should be done at the beginning of the rainy season. Stump sprouts of 4-12-month-old seedlings, or vegetative cuttings from succulent stems or roots (cultivated in propagation boxes), can also be used to produce suitable planting material. All calliandra planting material is susceptible to early competition. Intensive weed control should be practiced until calliandra is well established, particularly in grass ecosystems.

Seed production and collection.[5] Compared to other leguminous tree species, calliandra is known to be a "shy" seed producer outside its native range. One reason for this is that the primary pollinator, bats, may require a few years to identify new stands of calliandra as feed resources. Trees flower through-out the year but have a peak flowering period 3 months before the dry season. Individual flowers are receptive to pollination for only one night. Individual trees may produce receptive flowers over a 4-6 week period. Demand for high-quality calliandra seed is growing and exceeds supply. The Oxford Forestry Institute is currently working on seed orchard guidelines.

Calliandra seed is sensitive to improper handling—only fully mature seed should be collected, before pods open. Dried seed can be stored in air-tight containers at 4°C for up to 5 years. Bulk seed should be stored in sacks in a shaded, cool, dry area, protected from insects, rats, and mice.

Symbiosis.[4] Calliandra root systems form symbiotic relationships with both *Rhizobium* bacteria and vesicular-arbuscular mychorrhizal fungi (VAM).

Pests and Diseases.[6] Information is available on pests and diseases of the genus *Calliandra*, but there has been little systematic study of pests or diseases of *C. calothyrsus*. However, it does not appear to suffer serious damage from pests or diseases in its native range or in areas where it has been introduced.

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NFT Highlights

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Casuarina : Difficult Sites Are Home to Casuarina

Sand, sun and salt spray are part of home to the *Casuarina* spp. that thrive on beaches from the tropics to temperate zones. The ability to tolerate diverse and difficult niches such as seashores characterize the genus. Casuarinas also have been grown on limestone quarries and infertile tin mine tailings.

C. equisetifolia, which occurs naturally on coastlines from India to Australia, is the most widely used species. A 3000 km shelterbelt was built mainly with *C. equisetifolia* along the People's Republic of China's southern coast to stop encroachment of sand dunes and to decrease strong winds. A similar shelterbelt in Taiwan reduced downwind salt deposition by 60 percent (Kpki, 1978).

C. equisetifolia In Egypt, C. *glauca* and *C. cunninghamiana* shelterbelts protect farms, highways and irrigation canals from clogging by sandstorms.

Casuarina has been called the best firewood in the world. Its wood is very dense, splits easily, burns when green, has low ash content and makes excellent charcoal (NRC, 1984). It is the main plantation species in peninsular India, where 7-15 year rotations yield 100-200 tons of fuelwood per ha (NRC, 1984) and even the roots are sometimes harvested for charcoal. Yields of 7.5- year-old stands in Florida were up to 17 dry t/ha/yr (Rockwood, et al.; 1985).

In Thailand, hybrids of *C. equisetifolia* and *C. cunninghamiana* grow on heavy acid soils and are harvested five years after planting for posts, firewood and other products. Villagers in southern China gather four tons/ha/yr of Casuarina litter from shelter- belts and use it for domestic fuel (NRC, 1984).

Most Casuarina wood is hard, heavy and difficult to saw. It also tends to split, crack and warp as it dries. However, the wood is used for fencing, pilings, beams, rafters, ship masts, scaffolding, flooring, particle board, roof shingles and pulp.

C. oligodon shades coffee trees and is a fallow-improvement crop in Papua New Guinea. Soil samples collected after five years of such a fallow show substantial increases in soil nitrogen and

organic matter (NRC, 1984). Casuarina roots are modulated by the nitrogen-fixing actinomycete, *Frankia*. Annual nitrogen fixing rates for established

C. equisetifolia stands has been estimated near 60 kg/ha (Dommergues, 1963). Inoculating seedlings with Frankia and mycorrhizal fungi promotes faster growth and survival, and seedlings are ready for planting in six months or less.

Suitable growing conditions for *C. equisetifolia* in the tropics and subtropics include: temperatures of 10-300 C with no frost, 200 to 5000 mm annual rainfall, 6-8 month dry season, sea level to 1500 m, and sandy, calcareous soils. *C. cunninghamiana* tolerates about 50 light frosts annually and survives periodic inundation in fresh water. C. *glauca* survives tidal inundation and is very drought tolerant. *C. oligodon* grows well in humid highlands up to 2500 meters above sea level, and C,, iunghuhniana grows in drier highlands up to 3000 meters.

Casuarinas normally are propagated by seeds. *C. equisetifolia* produces seed prolifically by the age of 5 years. Most species have separate male and female trees, but some species have both flowers on one tree, and *C. equisetifolia* is reported as fitting into both of these categories. Seeds of different species vary greatly in size. *C. equisetifolia* has between 300,000 to 450,000 seeds/lb. Germination generally takes 2-3 weeks. Germination rates for *C. equisetifolia* range from 75 percent for fresh seed to 30 and 40 percent for stored seeds.

A male clone presumed to be a hybrid of *C. equisetifolia* and *C. junghuhniana* is reproduced by young, short cuttings in Thailand and India. Vegetative propagation efforts with *C. equisetifolia* have not been very successful, although rooting of properly treated young lateral shoots has been as high as 90 percent (Somasundaram and Jagadees, 1977). Trees coppice poorly or not at all. The root-derived shoots of some species allow for a type of "coppice" management, however (NRC, 1984).

Pest problems on casuarinas have been minor. Root rot in Florida and a blister disease in India have occurred. Many species survive fires well, but even light fires kill *C. equisetifolia.* Some casuarinas can become pests. *C. glauca's* vigorous root suckering has created problems in Hawaiian pastures and in Florida, where some counties have banned its planting. Additionally, leaf litter of some species may be toxic to some plants and increase soil acidity or salinity.