NFT Highlights

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Casuarina cunninghamiana : The River She-Oak

DESCRIPTION : *Casuarina cuninghamiana* Miq. (river oak, river she-oak) is one of the largest species of the genus *Casuarina*, attaining a height of 20-35 m and diameter of 0.5- 1.5 m. The foliage consists of deciduous, jointed needle-like branchlets known as cladodes with reduced scale-like leaves in whorls of 8-10, commonly 9. Young trees typically have a pyramidal crown with ascending branches; the crown becomes more open with maturity. *C. cunninghamiana*, with a haploid chromosome number of 9, is dioecious and wind pollinated. Male flower spikes are borne at the tips of shoots and small rounded female flowers occur in clusters along the branches. Fertilized female flowers develop into rounded cones (6-10 mm diameter) which ripen in the autumn and shed seed rapidly at maturity (Boland et al. 1984, Turnbull et al. 1986).

Native distribution of river she-oak.

The native range of the species mends from southern New South Wales, where it is a protected species to north Queensland, Australia (15-37° S latitude). It typically occurs in pure stands along freshwater streams and rivers, extending to adjacent valley flats and rarely hillsides. A distinct subspecies, *C cunninghamiana* subsp. *miodon*, occurs in the Northern Territory (Wilson and Johnson 1989). The altitudinal range of the main occurrence is 100-500 m while the range is 20-1000 m. It may hybridize with the closely- related species *C. glauca* (Turnbull et at. 1986).

SOILS AND CLIMATE: In the native range, the river she-oak occurs primarily on well-drained, light-textured sandy or gravelly soils and, less frequently, on clay soils. In cultivation, *C. cunninghamiana* also performs better on sandy loam rather than heavy clay soils (El-Lakany et al. 1982.) Soil pH is generally acidic to neutral. The species is only moderately salt tolerant, and reportedly becomes chlorotic on highly calcareous soils (Turnbull et al. 1986).

Precipitation in the native range varies from 600-1100 mm per annum (50 percentile). Some populations occur in areas receiving as little as 375 mm, but they would have access to groundwater due to their riverine habitat (Turnbull et al. 1986). As a planted exotic, the river she-oak appears only moderately drought tolerant (Bulloch 1986). Once established it will survive drought periods, but growth will be reduced without access to groundwater.

Maximum temperatures in parts of the native distribution exceed 32°C while southern populations at higher elevations may experience up to 50 frosts per annum and temperatures down to -8°C (Turnbull et al. 1986). Certain individuals within a high elevation provenance showed slight or no injury five months after exposure to mid-winter minimum temperatures of -12°C and heavy snow in a two-year-old field planting in California, USA (Casuarina Improvement Association, unpublished data).

USES: *C. cunninghamiana* has been successfully introduced to several countries, including Argentina, China, Egypt, Israel, Kenya, Southern Africa, USA and Zimbabwe (NRC 1984). Its principal uses are for shelterbelts, erosion control and fuelwood.

Shelter: Its fast growth, moderately dense canopy and retention of lower branches close to ground level when young make the species well-suited for use in windbreaks to protect field and horticultural crops (NRC 1984). Side trimming of single-row shelterbelts is recommended to maintain form and foliage density. Older trees may tend to open out at the base if trimming is infrequent or too severe (Bulloch 1986).

Erosion Control: Native stands of the species are protected due to their value in streambank stabilization (Boland et al. 1984). In Egypt, it has been planted along irrigation canals to stabilize batiks and prevent excessive wind deposition of sand in the canals (El-Lakany 1983).

Fuelwood: *C. cunninghamiana*, like other casuarina species, is recognized as an excellent source of fuelwood. Wood density ranges from 800-900 kg/m^3 (Turnbull et al. 1986). The wood is very easily split, can be burned either green or dried, and bums slowly leaving little ash (NRC 1984). In a sample evaluation of biomass properties, *C. cunninghamiana* wood with a specific gravity of 0.72 composed 73% of total biomass and yielded 4544 cal/g upon combustion (Rockwood et al. 1980).

Wood Products: The timber is moderately strong, tough, durable and straight-grained. However, excessive splitting and warping during seasoning limit its utility for posts, poles and sawn lumber. The wood has been used in small dimensions for products such as furniture, turnery, shingles, flooring, packing cases, tool handles and barrel staves (Turnbull et al. 1986).

Other Uses: The foliage is palatable to sheep and cattle, but is considered useful only as emergency drought fodder (Bulloch 1986, Turnbull et al. 1986). It is also used in ornamental landscaping and as windbreak plantings along highways.

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ACTINORHIZAL SYMBIOSIS: In its native range, root hairs of *C. cunninghamiana* commonly become infected with the symbiotic actinomycete *Frankia*, thereby forming root nodules which are the site of N_2 fixation (NRC 1984). Artificial inoculation prior to outplanting with an effective strain of *Frankia* greatly enhances tree growth, particularly on sites low in N. Inoculation can be accomplished by applying an aqueous suspension of crushed root nodules to young seedlings in containers or nursery beds. Pure cultures of *Frankia* isolated from root nodules of *C. cunninghamiana* have also been used for artificial inoculation (NRC 1984).

PROPAGATION AND ESTABLISHMENT: The species is readily propagated from seed (average 1.8 million/kg) and rapid germination is achieved at about 30°C. It can be vegetatively propagated by rooting young softwood cuttings using an IBA hormone treatment (Turnbull et al. 1986).

Seedlings are generally grown in containers in the nursery before outplanting in the field. Recommended spacing for single-row horticultural shelter are 1-1.5 m and for multi-row farm shelter or plantations 2-3 m (Bulloch 1986). *C. cunninghamiana* develops a deep fibrous root system, except in waterlogged soils where it is more shallow and spreading (El-Lakany et al. 1982).

In arid and semiarid areas, *C. cunninghamiana* is successfully grown under irrigation using furrow, flood or drip methods (NRC 1984). It has also been irrigated using municipal and industrial wastewater effluent. The species' dense fibrous root system is very effective at intercepting and absorbing nutrients such as N, P and Ca in wastewater compared to other tree species (Stewart et al. 1988).

Poorly modulated seedlings show a response to applications of N fertilizer. On sites deficient in P, addition of P fertilizer is required before a growth response to N fertilizer or *Frankia* inoculation is observed (Reddell et al. 1988).

Weed control during establishment is vital for good stand survival since *C. cunninghamiana* is intolerant of competition when young (Bulloch 1986). After canopy closure, weeds are suppressed by shading and the self-mulching effect of fallen branchlets.

PESTS, DISEASES AND LIMITATIONS: Protection from grazing animals, rabbits and hares is important in young plantings (Bulloch 1986). Grasshoppers can be damaging particularly when the trees are young. Basal trunk damage and girdling may also be infected by rodents, requiring tree guards and weed control to reduce cover. *C. cunninghamiana* is susceptible to *Phytophthora* and *Clitocybe*root rots (Bulloch 1986).

In Florida, USA, *C. cunninghamiana* has naturalized in wild areas as a result of seed spread along watercourses (NRC 1984). Therefore care should be taken with plantings along canals or watercourses to prevent unwanted escapes. Although root suckering in older trees has been reported, it is less common than with *C. glauca* (Turnbull et al. 1986).

OBTAINING SEED: Seed is available in small quantities from NFTA. The Australian Tree Seed Centre maintains a large collection of seed sources of *Casuarina cunninghamiana* collected from native stands, and seed for research purposes is available for purchase (up to 10 g per lot); direct inquiries to the Officer in Charge, Australian Tree Seed Centre, CSIRO Division of Forestry and Forest Products, P.O. Box 4008, Caberra ACT 2600 Australia. The Australian Tree Seed Centre can also provide a list of commercial seed dealers in Australia able to supply larger quantities of seed.

Three-year-old **Casuarina cunninghamiana** *planted as a windbreak around crop fields and orchards in the Sacramento Valley, California, USA.*

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NFT Highlights

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

Casuarina equisetifolia : An Old Timer With A New Future

Casuarina equisetifolia Forst. & Forst. (syn. C. litorea L.), is the most widespread and well-known member of the family Casuarinaceae, and has many names: Casuarina, ironwood, coast she-oak, horsetail, Australian pine, whistling pine, beefwood, agoho (Philippines), ru (Malaysia), filao (Vietnam, West Africa, West Indies) and nokonoko (Fiji). All the casuarinas are nitrogen fixing. Casuarinas support an actinorhiza symbiont in their root nodules, as opposed to the rhizobium symbiont found in the root nodules of leguminous trees that fix N_2.

C. equisetifolia has two variants. *C. equisetifolia* var. *incana* is a small (6-10 m) tree that grows exclusively along the coast of Queensland and northern New South Wales. Var. *equisetifolia* is a tall (10-40 m) tree found on seacoasts from Malaysia to subtropical Australia, Melanesia, Micronesia, the Philippines and Polynesia.

Botany

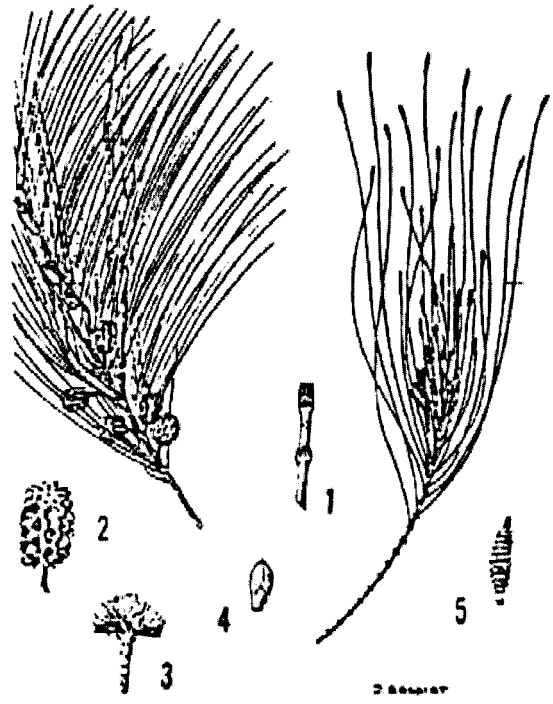
Like other Casuarinaceae, *C. equisetifolia* as a conifer-like appearance which is increased by hanging green branchlets and cone-like fruits. Casuarinas are actually typical angiosperms with simplified and reduced unisexual flowers. They are dioecious or monoecious, the proportion of male, female and monoecious trees varying widely from one site to another. The stem of Casuarinaceae is composed of two parts: indeterminate persistent branches which, after secondary thickening, form the permanent above-ground plant body-, and determinate deciduous branchlets (incorrectly called cladodes), about 1.5-2.5 mm in diameter. These branchlets are the major photosynthetic organs of the plant (Torrey and Berg 1988). The leaves are reduced to white or brown scales fused laterally at the base in whorls that define nodes on the branchlets.

Individual plants have striking phenotypic variations in the crown shape, branch angle, length of branchlets, and size and shape of cones. *C. equisetifolia* is known to hybridize with other casuarinas, such as *C. junghuhniana* and *C. glauca.*

Ecology

Casuarina equisetifolia is intolerant of frost. Var. *incana* thrives in the warm subhumid zone while var. *equisetifolia* is a heat-loving plant of the hot subhumid zone. Although *C. equisetifolia* is generally a lowland tree, it grows at altitudes up to about 600 m in Hawaii.

C. equisetifolia tolerates a wide range of moisture availability. *C. equisetifolia* grows best along the coast, where sea spray supplements moisture from the water



Casuarina equisetifolia *structures including 1) photosynthetic green branchlets, 2) fruit, 3) female flower, 4) seed and 5) male flower*

table in arid and semi-arid climates with average annual rainfall <300 mm.*C. equisetifolia*'s N_2-fixing ability seems to depend wholly on the availability of adequate soil moisture.

C. equisetifolia tolerates both calcareous and slightly alkaline soils, but withstands salinity less well than *C. glauca* and *C. obesa.* It thrives in sandy soils and grows poorly on clay soils, with some exceptions. It cannot stand to be waterlogged long.

USES. The wood of *C. equisetifolia* is dark brown, very hard (density 1000 kg/m^3), and resistant to decomposition in soil or saltwater. It is often used as round wood for making piles, poles and fences, but splits too severely during drying to be popular as lumber; although in areas with acute wood shortages, such as southeastern China, *C. equisetifolia* is used for house beams and simple furniture (Midgley et al. 1983).

Because of its high calorific value (ca. 5000 kcal/kg), C equisetifolia wood is an excellent source of fuel and charcoal. People in China and India use stumps and even litter for fuel, use which also draws heavily on soil phosphorus and potassium reserves.

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Because of its resistance to salt-laden winds, *C. equisetifolia* is widely used to stabilize coastal sand dunes. It is also extensively planted as windbreaks to protect crops. In some tropical lowland agroforestry systems it is associated with crops such as coffee, cashew nut, coconut, groundnut, sesame and various grain legumes.

C. equisetifolia and its hybrids are often used as ornamental plants for urban beautification, parks and seaside resorts. There is also potential for incorporating *C. equisetifolia* into mixed-species tree plantations.

ROOT SYMBIOSES. Root nodules are prolific on *C. equisetifolia* when they occur. Effective strains of *Frankia* are now available to inoculate *C. equisetifolia* on sites where the same *Frankia*-compatible group of trees (in principle any species of the *Casuarina* genus) have not been previously planted.

When there are no limiting factors, the response to inoculation is spectacular. Inoculation with *Frankia* entrapped in alginate beads is the most convenient system (Sougoufara et al. 1989). Inoculation with crushed nodules, which is sometimes practiced, should be discouraged because of the risk of introducing non-nodulating or poorly effective strains and disseminating soil-borne pathogens *Pseudomonas salanacearum*, a bacterium that causes casuarina wilt. Prolonged waterlogging inhibits nodule development.

As in other actinorhizal plants, spontaneous endomycorrhizal (VAM) infection occurs easily in *C. equisetifolia*. True ectomycorrhizae have, however, been seldom reported, except in certain coastal areas of northern Australia where a wide range of fungi are involved (Paul Reddell, pers. comm.). Proteoid roots have also been observed on their root systems. These are unique structures made of tightly packed rows of rootlets which may increase the ability of the host plant to absorb nutrients and thereby better tolerate nutrient deficient soils.

SILVICULTURE. Ripe green cones are collected from branches lopped from mature trees and dried in the sun. One kg of green cones yields 20-60 g of seeds. There are 300,000-700,000 cleaned seeds/kg. The seeds have a relatively low viability of 80-90% for fresh seeds and 30-40% for seeds after 3 years storage. Germination is usually complete within 2 weeks after planting.

At 6-10 weeks the 10-15 cm high seedlings are transplanted into containers where they are grown for 5-8 months to a height of 50-70 cm, at which time they are transplanted to the field. Another procedure is to transplant the 10-15 cm seedlings into a new bed at a 10 x 10 cm spacing to obtain plants ready to be planted bare rooted in the field. Cuttings and microcuttings can be used when working with clones.

C. equisetifolia does not sucker as vigorously as *C. glauca*. Plantation planting density is usually around 2,000 plants/ha, but private farmers can plant up to 8,000 to 10,000 trees/ha (Midgley et al. 1983).

C. equisetifolia can be improved by exploiting the large phenotypic variation of its populations. There are essentially two approaches to increase both wood production and N_2-fixation potential: conventional plant breeding and screening of elite individuals followed by vegetative propagation.

The N_2-fixing potential of *C. equisetifolia* can be greatly enhanced through the use of selected clones inoculated with effective *Frankia* strains. Clone beta of *C. equisetifolia*, inoculated with strain ORS021001 and irrigated throughout the dry season in Senegal, fixed 45 g N_2/yr/tree during the two first years of growth (Dommergues, unpublished data). Extrapolating this result gives a figure of 90 kg of N_2 fixed annually/ha at a planting density of 2,000 trees/ha.

YIELD. Compared to some of the other casuarinas, *C. equisetifolia* is relatively short-lived, surviving only 40-50 years. Its growth is rapid during the first 7 years (1.5-2.5 m/yr), then gradually declines. In general, the volume yield reaches a maximum at age 15-20 years (7-10 m^3 /ha yr^{-1}). The yield could probably be greatly increased by using selected clones and applying proper management practices, including irrigation and inoculation with effective *Frankia* strains. *C. equisetifolia* plantations are generally managed on a rotation of 7-15 years.

PESTS AND DISEASES: *C. equisetifolia* is not prone to any serious pest and diseases, except when grown in unfavorable conditions. Pests that attack the tree include crickets and grasshoppers (*Chondracis rosea, Schistocera gregaria*), defoliators (*Lymantria xylina*), stem borers (*Apate momachus*) and sap feeders (*Icerya* spp.). The major root diseases are caused by, *Pseudomonas solanacearum*, *Trichosporium vesiculorum* and *Rhizoctonia* spp.

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NFT Highlights

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Casuarina glauca : A Hardy Tree With Many Attributes

Known as swamp she-oak in its native Australia, *Casuarina glauca* grows in difficult, saline sites inhospitable to many other trees. This *Casuarina* has been planted in agroforestry systems primarily as a windbreak but also in woodlots for fuelwood and reserve fodder.

BOTANY. *Casuarina glauca* Sieb. ex Spreng. (family Casuarinaceae) is a medium-sized tree 10-15 m tall, occasionally reaching 25 m, with an often buttressed and fluted main stem. The dense crowns of plantation- grown trees become sparse to narrow in free-growing trees (Midgley et al. 1983). The jointed, green, cylindrical branchlets, which serve as leaves for casuarinas, are much coarser, thicker, and longer (1 diameter, 30-60 cm long) than those of *C. equisetifolia* or *C. cunninghamiana*. The length of the internodes on branchlets averages 15 mm. The reduced, true leaves appear as teeth at the nodes and vary in number from 12-16, occasionally to 20.

C. glauca is dioecious; male and female trees occur in approximately 1:1 ratios in natural stands. Male flowers appear as 4-7 cm long, light-green spikes. Female flowers are sma dark red, and inconspicuous. Males trees flower at 2-3 years of age and female trees produce fruits one year later. Trees fruit mainly in autumn, except in plantations (for example, in Egypt), where trees produce crops in both autumn and spring.

The cone-like woody fruits vary in size with provenance, ranging from 12 to 16 mm long and 11.5 to 14 mm wide (El-Lakany and Youness 1985). Fruit bracteoles are relatively thin compared to other casuarinas. *C. glauca* is a prolific cone producer and averages 70 seeds/cone and 1,300,000 seeds/kg (El-Lakany et al. 1989). Closed cones may persist on the tree for more than a year.

Casuarina glauca hybridizes with other casuarina species through open, wind pollination. A hybrid with *C. cunningharniana* has been reported in Australia and identified in Egypt (Badran et al. 1976), and a hybrid with *C. equisetifolia* is recognized in USA and Egypt.

ECOLOGY. Natural distribution is limited to a narrow coastal belt of southeast Australia (23-37° S latitude) with an insular occurrence on Fraser Island. Trees occasionally extend 50-80 km inland. Trees often occur along the edges of tidal reaches and estuaries, intermediary between mangrove swamps and open woodland, and sometimes on or near beach fronts. On swampy sites water tables may be only 30 cm from the surface. Trees usually occur close to sea level but are also found on seasonally moist hillsides near the sea, and up to 900 m elevation in Hawaii. In its native range annual precipitation averages 500 mm; in Hawaii rainfall is as much as 4,000 mm (NAS 1984). Annual temperatures range from 5 to 33°C.

C. glauca is more salt tolerant than other casuarinas (El-Lakany and Luard 1983). Seedlings outgrew eight species in nutrient solutions containing increasing concentrations of NaCl. In these tests both *C. glauca* and the closely related *C. obesa* survived 500 mM/1 NaCl--a level close to 3/4 the total salinity of seawater.

C. glauca has proven widely adaptable. In Egypt, trees grow on clay to coarse sand and saline to calcareous and dry to water-logged soils. Trees grow on very dry sites with saline soils in Israel and flowish on limestone soils in Florida, USA. In Hawaii, trees have been planted on parent basalt. *C. glauca* has also been successfully planted in Kenya, India, Malawi and South Africa.

A five-year-old stand of* Casuarina glauca *growing near Alexandria, Egypt.

Written by M. H. El-Lakany, Managing Director, Desert Development Center, The American University in Cairo, 113, Sharia Kasr el Aini, Cairo, Egypt, and NFTA staff.

SILVICULTURE: No seed pretreatment is required. Turnbull and Martensz (1982) recommend temperatures of 20-25°C and El-Lakany and Shepherd (1983) recommend 30°C to germinate *C. glauca* seed. Seed stores well up to eight months at room temperature (El-Lakany et al. 1990). Seed for experimental purposes is available from the Australian Tree Seed Centre, (Div. Forestry and Forest Products, CSIRO, Canberra, Australia), the Desert Development Center (AUC, P.O. Box 2511, Cairo, Egypt), and NITA.

Wide intraspecific variation for certain characteristics has been reported for *C. glauca* (El-Lakany and Shepherd 1983). Early results of provenance trials in Egypt and elsewhere suggest substantial growth gains are possible through use of proper seed sources. In an irrigated plantation on the desert fringes in Egypt, height growth varied by a factor of two among nine provenances (El-Lakany and Youness 1985). Biomass productivity of 12-year-old irrigated plantations was estimated at 496 t/ha of which wood volume was 294 m^3/ha (Megahed and El-Lakany 1986). Provenance testing is underway in California, USA for frost tolerance (Merwin 1990). Irrigation is required to establish trees in desert areas.

SYMBIOSIS. *C. glauca* forms a symbiosis with actinomyeetes of the genus *Frankia*.. Spherical woody nodules, some exceeding 20 cm in diameter, are found in large masses near the base of the trunk and as deep as 10 m. Root nodules have been observed on trees in natural stands and on trees in plantations growing on very saline or water-logged sites. The greatest number of nodules are found in soils with pH ranging from 6-8.

For *Casuarina* species, N-fixation is greatest when species are inoculated and when inoculated with nodules from the same species (Reddell and Bowen 1985, Reddell 1990). Crushed nodules or soil from beneath mature trees can be used to inoculate nursery seedlings. Under conditions of high soil salinity, drought or water-logging, *C. glauca* exhibited more efficient N-fixation than *C. cunninghamiana* (El-Lakany 1987). Inoculum is available from CSIRO, Davies Lab, PMB, Aikenvale, QLD 4814, Australia.

USES. Shelterbelts: *C. glauca* finds its best use in shelterbelts, windbreaks, and amenity plantings around settlements. The trees are wind-firm and show rapid early growth. In parts of North Africa and the Middle Fast, especially in water-scarce areas, they are preferred to eucalypts for plantings. Windbreaks are planted 2-3 rows wide. Like other casuarinas, trees can be coppiced to form dense hedges. The low branching habit and extensive litter production help reduce soil erosion. Trees have also been used successfully to stabilize stream banks and shifting sand dunes.

Wood: The most universal use of casuarina is for fuel. The wood has a high calorific value (about 5,000 Kcal/kg) and tends to burn slowly with little smoke or ash. Branches, branchlets, and other litter also burn well. Casuarina wood makes excellent charcoal. Wood is reddish-brown, tough, and fissile with a density ranging from 662 (El-Lakany 1983) to 980 (Midgley et al. 1983) kg/m^3. Timber is used for handles, fence raus, rafters, shingles, stakes, small sea-water piles, for flooring and turnery, and in Egypt, with some technical difficulty, for particle board. The timber does not season readily and has a tendency to warp.

Other Uses: Cattle, sheep and goats will graze *C. glauca* seedlings, suckers, and branchiets. The ground foliage has been included as an ingredient in chicken feed (El-Deek et al. 1988). Foliage contains 9% crude protein, 37% crude fiber, and 37% total digestible nutrients (Omran and Nour 1980).

C. glauca has potential for use in wide-row intercropping and, contrary to common belief, has been found to increase yields of crops sheltered (El-Sayed et al. 1983). Farmers usually dig a ditch between the crop and trees to minimize competition for water and nutrients. An excellent shade tree, it is planted along streets in many and zone cities. Like other casuarinas, the dense canopy and slow-to-decompose litter severely inhibit understory plant growth.

PROBLEMS AND PESTS. Prolific production of root suckers lends *C. glauca* a serious potential for weediness, especially in humid areas. It is considered a pest in Florida and the Hawaiian isles (NAS 1984). In arid areas such as Egypt it has generally not become a weed, although it can spread along water courses. The tree itself is almost pest-free, except for *Stromatium fulvum*, a wood borer which makes the stem susceptible to wind-damage and rot.

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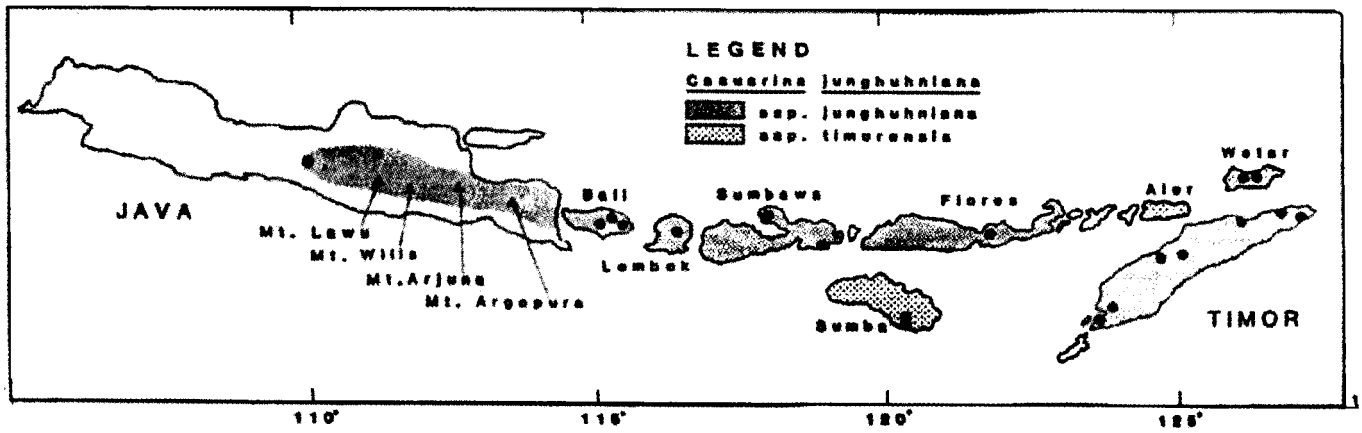
Casuarina junghuhniana : A Highly Adaptable Tropical Casuarina

Casuarina junghuhniana Miq. occurs naturally in Indonesia where its common names are jemara or cemara (Java), and adjaob and kasuari (Timor). It is an environmentally important nitrogen fixing tree, hosting the actinorhiza *Frankia*. *C. junghuhniana* is a fall forest tree 15-25 m tall and 30-50 cm diameter, that can grow up to 35 m in height and 1 m in diameter. A putative hybrid with *C. equiselifolia* is commercially cultivated in Thailand (Chittachumnonk 1983). *C. junghuhniana* is locally important in Indonesia for fuelwood, poles and soU conservation. With domestication its utility could be enhanced.

BOTANY: The crown of jemara is reasonably open and consists of numerous long deciduous branchiets bearing reduced scale leaves. It is dioecious; individual trees are carry either male or female flowers. Male flowers are borne on the tips of deciduous branchlets and female "cones" in the axils of scale "leaves" on permanent shoots. This species grows rapidly with a strong apical dominance. It has the capacity to produce vigorous root suckers and female trees seed abundantly.

DISTRIBUTION: The taxonomy of *C. junghuhniana* is very confused and requires revision. Currently the species is considered to consist of two subspecies. Subspecies *junghuhniana* is found on the islands of Java, Bali, Lombok, Sumbawa and Flores. A subspecies tentatively called *timorensis* occurs on Timor, Wetar, Sumba and perhaps Sumbawa, Indonesia. Variation within each subspecies further complicates the subgroupings. The subspecies *junghuhniana* consists of discrete populations having coarse, fine, and intermediate textured deciduous branchlets but the patterns of variation are currently unresolved. The coarse forms may be related to tree growth on exposed sites. The coarse form is notable for its rugged, deeply furrowed corky bark which is unusual for a *Casuarina*. Subspecies *timorensis* on Timor is also thought to consist of two forms which the locals term 'white' and "black' casuarinas. The hillside form has long, robust deciduous branchlets which in the riverine form are short and thin. Provenance trials of this *Casuarina* have not been conducted. Environmental variation in natural habitat, however, suggests that considerable genetic variation is present.

ECOLOGY: *Casuarina junghuhniana* is wholely tropical in distribution, and is a native of highlands in Indonesia where it pioneers deforested lands such as screes (rocky slopes) and grasslands, and in disturbed areas it replaces mixed mountain forest plant communities (NAS 1984). Subspecies *junghuhniana* typically grows in extensive pure stands on volcanic slopes between altitudes of 1500 to 3100 m but can also occur below 100 m. Subspecies *timorensis* is normally found at lower altitudes, especially in Timor where it grows from near sea level to 300 m. Rainfall in its natural habitat is monsoonal with a well-defined summer maximum and a range of 700-1500 mm (NAS 1984). *C. junghuhniana* often forms pure stands in dry and periodically burned-over areas. It is also found along gravelly stream beds in Timor. Once trees reach a few meters in height they are fire resistant and have good sprouting ability if fire damaged. *C. junghuhniana* grows



The generalized range of the natural distribution of Casuarina junghuhniana *in Indonesia. The map was constructed using herbarium records and the locations of the original collections are indicated by the black dots and triangles.*

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in a wide range of soils from volcanic, sandy to compact clay sod and including very acidic sites, pH 2.8 (Chittachumnonk 1983). It also appears well-adapted to growmg on alkaline soils in Timor (Turnbull 1989 pers. comm.). It can tolerate waterlogging up to 104 days (Verhoef 1943). It is considered moderate (NAS 1984) to very (Djogo 1989) drought resistant and is especially good as a pioneer on landslide-prone soils (Diogo 1989). In Timor it commonly grows on limestone-derived soils.

USES: As with other casuarinas, wood of *C junghuhniana* is highly suitable for fuelwood and charcoal production. Its calorific value in charcoal form is 7180 kcal/kg, among the highest for a firewood species. Its wood is very heavy having an air-dry density of 900 kg/m^3 (Chomcharn et al. 1986).

C. junghuhniana is especially suitable for wind breaks and for ornamental plantings. It is not used as fodder. In Timor *C. junghuhniana* is used for soil improvement, live fencing, building material and firewood and branches and foliage are burnt and the ashes spread in village gardens (Djogo 1989). It has been used in revegetation and land rehabilitation projects in Java for nearly a century. In Thailand its straight-stemmed character makes it a popular underground pile for construction work as well as for fish-trap stakes. It is grown on farm boundaries for pole production in Kenya and Tanzania.

SILVICULTURE: Seed from *C. junghuhniana* is small with approximately 1-1.6 million seeds per kg. No special pre-treatment is needed to germinate seed. Like most casuarinars, seed probably loses viability quickly unless kept in dry, cold storage.

In Indonesia, Kenya and Tanzania all *C. junghuhniana* are raised from seed. In Thailand and India planting stock is raised by vegetative propagation because only male trees were originally introduced. Airlayering has been tried but with little success. The most successful method for production on a large scale was developed in Thailand. Stem cuttings of young shoots are placed in small pots filled with soil and river sand. Several pots are enclosed in polyethylene bags with tops supported by a stake. Rooting hormone (IBA) is necessary to promote rooting. The rooting process takes 3-4 weeks under 70% shade. Mahmood and Possuswam (1980) also report successful root cuttings of shoots and root suckers of this *Casuarina* in India.

YIELD: *C. junghuhniana* has the potential to grow very quickly. In irrigated plantations in Thailand it can attain 21 m height and 15 cm diameter at 5 years. Growth is normally slower without irrigation. In Markhanam, Madras, India trees reach 5 m tall at 20 months after planting (Thirawat 1953). Well-maintained plantations can produce 30-35 m^3/ha/y (Boontawee and Wasuwanich 1980).

PESTS AND DISEASES: There appear to be no serious insect pests of *C. junghuhniana.* In East Java forests of *C. junghuhniana* have been attacked by caterpillars but the trees recovered even after repeated defoliations. Defoliation of *C. junghuhniana* plantations by a locust (*Aulaches miliaris*) during rainy season has also been reported in Thailand. Young trees died but older trees suffered only a temporary setback. Also reported from Thailand was minor damage to young shoots by an insect identified as *Aristobia approximator* in plantations (Chittachumnonk 1983). In dry areas subterranean termites can destroy young plants by attacking their roots.

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NFT Highlights

NFTA 93-03

A quick guide to useful nitrogen fixing trees from around the world June 1993

Chamaecytisus palmensis : Hardy, Productive Fodder Shrub

Chamaecytisus palmensis is a fast-growing shrub or small tree adapted to temperate regions with winter rains and prolonged, dry summers. In addition to producing high yields of palatable, nutritious fodder, the shrubs provide welcome shelter for livestock, help control soil erosion and salinization, increase soil fertility through nitrogen fixation, and produce nectar for bees. If allowed to develop, thick branches provide fuelwood that burns with intense heat.

Called "tagasaste" on the island of La Palma in the Canaries, where it originates, the species was formerly known as *Cytisus proliferus*. After its introduction to Australia, it was given the misleading common name of "tree lucerne" (Webb, 1982).

Botany

Chamaecytisus palmensis is a member of the Papilionoideae subfamily of legumes. If managed as a single-stemmed tree, it reaches heights of 7 to 8 m, but its common growth form is a multi-stemmed, spreading shrub of 5 to 7 m. The branches droop, the leaves are on short petioles, and the single lanceolate leaflets are pubescent below. Seed pods are 4 to 5 cm long. They become black on ripening, and contain 8 to 12 black seeds. About 35,000 to 40,000 seeds weigh 1 kg.

The shrubs have no thorns and produce profuse masses of fragrant white pea-like flowers in early spring, making them attractive ornamental plants. The white flowers distinguish *C. palmensis* from related, unpalatable species that have yellow flowers.

Ecology

To date, successful growth has been restricted to temperate regions with wet winters and dry summers, with annual rainfall ranging from 350 to 1600 mm (Douglas, 1987). The shrubs tolerate a wide range of temperatures. They grow vigorously to the southern tip of New Zealand (46°S) and are naturalized in Australia as far north as Toowoomba (27°S). They are found from sea level to elevations of 1000 m and are reported to survive at 3000 m in Ethiopia (ILCA, 1987).

Cultivars develop that are suited for specific environments. In Australia, seedlings proliferate vigorously along roadsides near Orange, New South Wales, despite annual frosts down to -15°C. Seedlings survive with equal vigor in deep coastal sands in the hot and arid climate of Geraldton, Western Australia.

Chamaecytisus palmensis establishes most easily on sandy-surfaced soils, but tolerates a wide range of soil types including gravels, loams, acid laterites and limestones. The shrubs tolerate a pH range of 5.0 to 7.0, but require soils that are free draining. Under waterlogged conditions, they are susceptible to root rot and mortality is high.

Seedlings are remarkably drought resistant and can survive six months of hot weather without rain or irrigation. Of more importance, established shrubs have a remarkable capacity to recover from defoliation. Regrowth occurs even in the prolonged absence of rain.

Distribution

Chamaecytisus palmensis is endemic to the arid volcanic slopes of La Palma in the Canary Islands. The shrub was introduced to Australia in 1879. It is now also common in New Zealand and has been introduced to parts of Africa.

Uses: fodder

For centuries, farmers in the Canaries depended on *C. palmensis* to maintain their livestock through the long dry summers. However, the species did not gain international recognition until the 1980s.

In Australia, the apparent need for manual or mechanical harvesting was initially a serious deterrent to farmers. Subsequently, the demonstration that sheep and cattle can browse the shrubs directly without detriment to the plants has led to greatly increased use. Well-managed plantations remain fully productive without irrigation for many years (Snook, 1952; 1982). They require little attention beyond annual application of fertilizer and periodic lopping.

A well-managed three-year-old plantation of *C. palmensis* in Western Australia, growing on deep sand otherwise useless for crop or pasture production. The shrubs have been grazed by sheep and mown regularly to keep them low and bushy.

This issue was prepared by Laurence C. Snook, retired agricultural scientist and farmer, Box 54, Margaret River, WA 6285, Australia. Material was added by NFTA staff.

Composition. The foliage has a composition similar to best-quality alfalfa. Material eaten by grazing animals can be expected to contain 17 to 22% crude protein, depending on the stage of growth and severity of grazing. The leaves and fine stems of fresh regrowth may contain 25 to 29% crude protein (dry matter) and only 16 to 19% crude fiber. The foliage is free from toxic substances.

Nutrient composition varies according to soil fertility. In particular, minerals such as calcium and phosphorus are reduced in foliage grown on mineral-deficient soils. Leaves have high *in-vitro* dry-matter digestibility (0.77 to 0.82). Stem digestibility is lower (0.59), but still adequate for feeding (Borens and Poppi, 1986).The fodder contains protein, vitamins and minerals that are lacking in poor-quality roughage. Used as a supplement, it increases consumption of dry mature grass and improves roughage utilization. Normally *C. palmensis* foliage is readily consumed by all grazing animals--including rabbits, pigs and poultry--but there may be some hesitation when it is first introduced.

Yield. In regions with annual winter rains of 600 to 1000 mm, established shrubs planted in rows 5m apart can produce 15 to 20 kg of edible dry matter/plant when harvested once a year. In-row spacing can vary from 25 cm to 2 m. At a planting density of 1,000 trees/ha, annual yields of 15 to 20 t/ha can be expected (Snook, 1986). Under current systems of dryland farming in Western Australia, plantations should produce at least 10 t/ha of edible dry matter from a single annual grazing or cutting. This is equivalent to 1.5 kg each for 18 sheep every day of the year. If plantations are harvested three or four times a year, or subjected to rotational or continuous grazing, yields can be even higher.

Silviculture

Establishment. The small black seeds are extremely hard and must be scarified or treated with boiling water to ensure quick germination. Hot-water treatment consists of dropping the seeds into boiling water and immediately lifting them out. They should not remain in the water for more than one minute.

In Australia, most plantations are established by direct seeding. Contractors have developed special machinery to do this in one operation. A blade or "scalper" removes a strip of surface soil to clear away weed growth. This is followed by a ripper which opens the soil so that fertilizer and seed can be placed in lines. Finally, a following wheel compacts the soil over the seeds.

In most situations, *C. palmensis* readily makes use of rhizobia present in the soil. However, to insure nodulation, seed should be treated with cowpea inoculum or an inoculum specific for the species.

It is important to apply adequate fertilizer with the seed. This will encourage deep rooting and the development of robust plants that can withstand the first summer. Fertilizer should be applied as recommended for other legumes at each specific site. In most cases soluble phosphate will be the main requirement, but if additional essential plant minerals are lacking, these must be supplied. In Western Australia, for example, superphosphate with copper and zinc should be applied at seeding at a rate of 200 kg/ha.

Seedlings transplant very well and are commonly used for establishment in small areas, on steep slopes or where stones prevent the use of machinery. Animal-proof fences are essential for the first two to three years to protect young seedlings from grazing animals. Rabbits and hares are particularly fond of the seedlings and must be excluded. Mature plants recover remarkably well, even from severe overgrazing, if early regrowth is protected.

Most plantations consist of shrubs planted in parallel rows about 5 m apart, although distance between rows can be varied. Interplanted crops grow well because the shrubs provide protection from cold and drying winds.

Management. Experience shows that shrubs in plantations must be kept short and bushy. When seedlings are about 10 months old, they should be cut with a mower or grazed. This encourages the formation of bushes with multiple stems. The time and frequency of further harvests or grazing will be determined by the rate of growth. Until recently, the common practice was to graze or cut the shrubs once a year. Even when grazing is severe, vigorous leaders remain, and it is essential to lop these annually.

The need for annual lopping can be reduced or eliminated by grazing the shrubs three or four times a year or on a continuous basis. Under such management, vigorous, upright shoots are eaten before they become too robust.

Obviously, the shrubs must not be overgrazed to the extent that regrowth is eaten before root vigor is restored. When grazing pressure is too high, the animals may inflict serious damage by eating the bark. This problem is rare with good management. It is difficult for the animals to tear off bark from shrubs with a bushy growth habit and multiple stems.

Fertilizer. For continued high yields of nutritious fodder, regular application of the appropriate fertilizer is essential. In Western Australia, superphosphate and potash (3:2) should be applied annually at a rate of 200 kg/ha. Application of micronutrients, such as calcium, may also be necessary. The shrubs may continue to grow despite a lack of essential minerals but the quality and palatability of the foliage will decline steadily.

Limitations

In Australia, *C. palmensis* is remarkably free of pests and there is no evidence of viral infection. Slugs, cutworms and grasshoppers eat emerging seedlings, but one application of insecticide at seeding appears to give adequate protection. Mature shrubs are the last crop plants to be attacked by grasshoppers or locusts, and even when all the foliage is eaten, the plants make a rapid recovery when the swarms pass on. The species' requirement for fertilization to maintain high levels of productivity and nutrient content poses a management limitation for resource-poor farmers.

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NFT Highlights

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

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Dalbergia latifolia : The High-Valued Indian Rosewood

Dalbergia latifolia is a premium-quality timber species internationally known as "Indian Rosewood". It is used to manufacture furniture, paneling, and other ornamental products. Medicines and an appetizer are made from tannins in the bark. The tree is commonly called sitsal, beete, shisham or Bombay blackwood in India, and sonokeling or sonobrits in Indonesia.

Botany

Dalbergia latifolia Roxb. (Leguminosae, subfamily Papilionoideae) is predominantly a single-stem deciduous tree with a dome shaped crown of lush green foliage. On wet sites it may remain evergreen. The trees reach a height of 20-40 meters with a girth of 1.5 - 2.0 meters (Prasad et al, 1993). Leaves are alternate, odd-pinnate with 5-7 unequal-sized leaflets originating from the same rachis. Leaflets are broadly obtuse, dark green above and pale below. Flowers are white in axillary panicles, 0.5-1.0 cm long. The brown pods are oblong-lanceolate and pointed at both ends. They contain 1-4 smooth brown seeds and do not open at maturity. The bark is grey, thin with irregular short cracks, exfoliating in fibrous longitudinal flakes (Troup, 1921; Kadambi, 1954). The root system is well developed, consisting of deep tap roots and long lateral roots. When near the soil surface, roots produce suckers.

Ecology

The annual rainfall in *D. latifolia's* native habitat ranges from 750-5000 mm. As a seedling *D. latifolia* is shade tolerant but sensitive to drought and fire. In maturity, it is tolerant of drought and ground fire, but susceptible to crown fire. It is classified as a moderate light demander (Troup, 1921). Establishment is restricted by frost. It survives maximum temperatures of 37°-50° C, minimum temperature of 15° - 0° C, and relative humidity of 40-100 percent. *Dalbergia latifolia* occurs from the low plains to roughly 1500 m (Kadambi, 1954). It commonly grows with *Tectona grandis*, *Terminalia* sp., *Anogeissus latifolia* and bamboos.

This species grows on a variety of soil formations including; gneiss, trap, laterite, alluvial, and boulder deposits. It grows best on well-drained, deep, moist soils. *Dalbergia latifolia* is common on deep loams or clays containing lime. It also grows well on black cotton soils. Shallow dry soils and poor drainage stunt tree growth.

DISTRIBUTION. The natural range of *Dalbergia latifolia* stretches from the sub-Himalayan tract to the southern tip of India and the island of Java in Indonesia (Kadambi, 1954). Its best growth occurs in the Western Ghat forests of Karnataka, Kerala, and Tamil Nadu. It has been introduced to Burma, Sri Lanka, Nepal, Nigeria, and Kenya (Kadambi, 1954).

USES. Wood. The sapwood of *D. latifolia* is pale yellowish-white often with a tinge of purple. Heartwood varies in color from light golden brown to shades of light purple with dark streaks, or deep purple with distant black lines. The heartwood darkens with age and weighs about 850 kg per cubic meter. The wood is very hard with no distinct annual rings. It is difficult to work because of its high density. The wood is fragrant and commands a high price. It is used to make premium-grade furniture, panelling, veneers, and interior and exterior joinery. Secondary uses of the wood include; knife handles, musical instrument calico-printing blocks, mathematical instruments, agricultural implements, and boats keels and screws.

Agroforestry. *Dalbergia latifolia* is a popular agroforestry species in Indonesia. Trees are spaced widely, 3 x 1 to 6 x 2 m, with intercrops of upland rice, maize, beans, or cassava during the first three years. In other systems *D. latifolia* is planted with mango, annona, jackfruit, and guava. When the tree canopies begin to close, shade tolerant crops, like turmeric and ginger, are underplanted (Sukandi, 1993). Farmers use the nitrogen-rich foliage of *D. latifolia* as a green manure and fodder.

Leaves, flowers and pods of Dalbergia latifolia.

Written by AG Devi Prasad, Department of Applied Botany, University of Mysore, India; and Taulana Sukandi, Forest Research and Development Center, Bogor, Indonesia.

Medicinal uses. Tannins from the bark are used to produce medicines for the treatment of diarrhoea, worms, indigestion, and leprosy. These tannins also produce an appetizer.

SILVICULTURE. Propagation. Under natural conditions, *D. latifolia* reproduces by seed, root sucker or coppice. Artificial reproduction is common by seed, root cutting, and stump sprout. Direct seeding is possible under moist conditions with good weed control. Root cuttings can be planted directly in the field or raised in a nursery for future transplanting.

Fresh seed germinates at 50-75% within 7-21 days of sowing. Stored in gunny sacks or earthen pots, seed remains viable for six months (Kadambi, 1954). Seed viability can be extended to 9-12 months by drying seeds to 8% moisture content and storing them in airtight containers, however, germination will decrease to 30-40%. One kilogram contains 21,000 seeds (DITSI, 1980).

Although no seed treatment is necessary, soaking seed in cool water for 12-24 hours will hasten germination. Nursery grown seedlings are transplanted to the field after 6 months in Java (DITSI, 1980) or 12 months in India (Kadambi, 1954).

Root cuttings should be taken from trees that are at least 5 years old. Recommended length of cuttings is 20 cm with a diameter of 1-2 cm. Keep cuttings at room temperature for three days before planting them in either nursery beds or polyethylene bags (Soekeri, 1979). Eighteen cm of the cutting should be planted below the soil surface with 2 cm above. Transplant cuttings to the field after 6 months in the nursery (DMI, 1980).

Dalbergia latifolia can be quickly established by stump sprouts. Stumps are made from seedlings of seed or cutting origin. Stump roots and shoots should be 4.5 cm and 2.5-4.0 cm long, respectively. Root-collar diameter should be 0.5-1.5 cm (Deshmukh, 1975). Planting must coincide with heavy rains or survival will be low.

Management As pure stands, *D. latifolia* is spaced at 1.2 x 1.2 to 1.8 x 1.8 m (Deshmukh, 1975) or 2 x 1 to 2.5 x 1 m (Japing, 1936 in Kadambi, 1954). Wider spacing may produce crooked stems. For agroforestry systems spacings of 3 x 1 to 6 x 2 m are common (Sukandi, 1993). Trees are usually harvested in 30-40 years. In Java, to obtain 30 cm of heartwood a 50 year cutting cycle is recommended (DMI, 1980). *Dalbergia latifolia* is generally managed by clear felling followed by artificial regeneration. After planting or direct sowing, regular weeding is necessary until trees dominate weed competition. Loosening soil around seedlings also improves growth. Weeding and soil loosening should be done before weeds become dense. The sudden removal of heavy weed growth from around seedlings may cause death from exposure (Kadambi, 1954).

Growth and Yield. Fertilization, soil moisture conservation and weed control enhance the typically slow growth of this species. In a 25 year old plantation in Purwakarta, West Java average diameter breast at height (1.30 m above the ground) was 26.1 cm and tree height 20.3 m (Sukandi, 1993). A maximum diameter growth of 3 meters has been reported in Karnataka, India (Prasad et al., 1993).

SYMBIOSIS. *Dalbergia latifolia* is known to be a nitrogen fixing tree. However, studies on the symbiosis of this species with *Rhizobium* bacteria have not been made.

VARIETIES. In Java, two varieties of *D. latifolia* are recognized. The native variety, called sonokeling, seldom produces seeds. The naturalized variety of Indian-origin, called sonobrits, produces seed yearly.

LIMITATIONS. *Dalbergia latifolia* is very susceptible to crown fires, a common danger throughout the dry ecosystems it occupies. Trees are commonly attacked by fungi (*Fusarium* spp.) termites and browsing wild animals (Kadambi, 1954; Suharti and Hadi, 1974). Unfortunately, little is known concerning management options for these pests.

TREE IMPROVEMENT. Tree improvement programs for *D. latifolia* should involve the selection and breeding of specimens with excellent timber/furniture characteristics. Selection of superior genotypes have been made and an experimental seed orchard established in Karnataka. *In-situ* conservation has been initiated at Nagarahole, Coorg, India. For more information contact the lead author.

RELATED SPECIES. *Dalbergia sissoides*, another endemic species to the western Ghats of India, is closely related to *D. latifolia*. Its wood is not distinguished from that of *D. latifolia* in trade; but it is stronger, harder, and lighter in color with more streaks. The wood of *D. sissoides* does not take as high a polish as the wood of *D. latifolia*, but it commands a high market price for use in premium-grade furniture and cabinets (Prasad and Shilalingadaradhya, 1988).

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NFT Highlights

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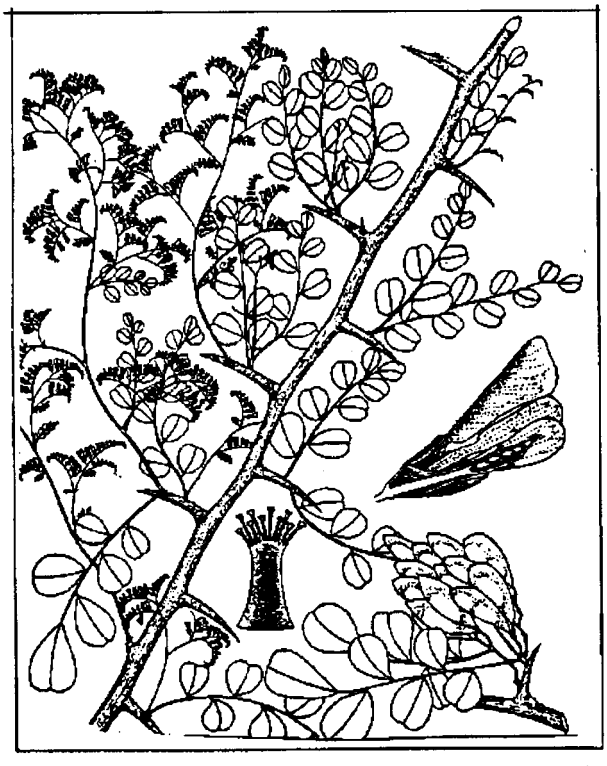
A quick guide to useful nitrogen fixing trees from around the world September 1993

Dalbergia melanoxylon : Valuable Wood From A Neglected Tree

Dalbergia melanoxylon produces one of the finest timbers in the world. Known in Tanzania as African ironwood, African ebony, *mpingo*, *poyi* or *mugembe* (Brenan and Greenway, 1949; Gillet et al., 1971; Noad and Birnie, 1989), round logs of this species fetch up to US$18,000/m^3. Yet the trees are seldom planted and little is known about their silviculture.

Botany *Dalbergia melanoxylon* Guill. & Perr. (Leguminosae subfamily Papilionoidae) is a small, heavily branched tree, typically 4.5 to 7.5 m tall but occasionally reaching 15 m. The bole is fluted with high narrow ribs separated by deep indentations. Bole length occasionally reaches up to 3.6 m, but normally ranges from 1.2 to 1.8 m. Average diameter at breast height (dbh) at maturity is less than 38 cm, although trees have been found with a dbh of more than 60 cm. The bark is pale gray to grayish-brown, papery, fairly smooth, and flaking in long narrow strips (Bryce, 1967). The stems are often crooked.



Dalbergia melanoxylon Guill. and Perr., from I.R Dale and P.J. Greenway. 1961. *Kenya trees and shrubs*. Nairobi: Buchanan's Kenya Estates Ltd, p. 361.

Branchlets are clustered at the nodes. Some grow out, while others are short and spine tipped. They are covered at first with short crisp hairs, and are usually glabrous. Leaves are alternate, pinnately compound and 6 to 22 cm long. The fragrant white flowers are 6 to 9 cm long, occurring in dense clusters. There are usually nine stamens, united or variously divided. Pods are elliptic oblong or irregularly oblong, bluntly pointed, flat and thin. They range from 3 to 7 cm long and 0.8 to 1.4 cm wide. They tend to be papery, glabrous, and laxly and rather diffusely veined, with one or two seeds.

Ecology *Dalbergia melanoxylon* grows under a wide range of conditions including semi-arid, subhumid and tropical lowland areas. It is often found on dry, rocky sites at elevations from sea level to 1200 m, but is most frequent in the mixed deciduous forests and savannas of the coastal region. The mean minimum temperature in its native range is 18°C and the maximum is 35°C, with no frost. Annual rainfall averages 700 to 1200 mm, often distributed in a bimodal pattern of three to six months. Soils vary from loamy sands to clayey vertisols ("black cotton soils"). The species is water and light demanding; it is common near water and will not regenerate under heavy cover. Mature trees are fire tolerant.

Distribution *Dalbergia melanoxylon* is widely distributed in Africa, from Senegal across to Sudan, Eritrea and northern Ethiopia, Uganda and Kenya. To the south, it ranges from Angola to Zambia, Tanzania and Mozambique, as far south as the Transvaal (Gillett et al., 1971; Redhead and Temu, 1981).

Uses Traditional uses include fuelwood and charcoal, as well as pestles, combs, knife shafts, cups and farming implements.

Timber. The sapwood is white or yellowish-white, often 12 cm wide, and sharply differentiated. The heartwood is purplish black, sometimes darker towards the outside, with light streaks and not always uniform in color. The timber is slightly oily, exceptionally hard and heavy, brittle and somewhat fissile. The heartwood is extremely durable (specific gravity not yet determined) and resistant to all forms of bio-deterioration. The sapwood, however, is susceptible to fungal or insect attack (Bryce, 1967). The dry wood is difficult to saw or plane. It blunts saws and cutters and cannot be nailed or screwed without drilling. It is, however, the finest of all turnery timbers, cutting exactly and finishing to a brilliantly polished, lustrous surface, dry and cold to the touch.

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Fuelwood. The calorific value of the sapwood and heartwood is more than 49,000 Kcal/kg. Heat generation is so high that fires of *D. melanoxylon* have been reported to melt cooking utensils.

Specialized uses. The wood of *D. melanoxylon* is used in carving, turnery and marquetry to produce sculptures, musical instruments, ornaments, inlays, chess pieces, walking sticks, bearings and many other products. The main industrial use, long supporting an export trade from East Africa and Mozambique, is the manufacture of musical instruments, especially woodwinds. With its high density and fine texture, *D. melanoxylon* wood produces a beautiful musical tone. It is stable, stands up to metal-working processes, and takes an excellent finish (Bryce, 1967).

The roots are used in traditional medicines to treat abdominal pain, diarrhea and syphilis. The smoke is inhaled to treat headaches and bronchitis. The pods and leaves can be used as animal fodder.

Silviculture

Seed treatment. Seeds (about 42,000/kg) generally remain viable for only a few months, although viability could probably be increased by storage in sealed containers. Seed extracted from pods germinates readily without treatment. However, few seedlings attain maturity under natural conditions due to fire and drought (Mugasha, 1978).

Establishment. In Tanzania, *D. melanoxylon* has not yet been planted extensively. Experimental work suggests that survival and growth are improved by planting two-year-old stumps that are 14 cm long, comprising 12 cm of root and 2 cm of shoot. These should be planted in the early or middle rainy season, followed by intensive weeding. Potted seedlings may also be used, but they tend to grow more slowly (Mugasha, 1983). When seedlings are raised in pots, frequent root pruning is mandatory. Delayed pruning leads to seedling shock. Advanced plant-production techniques, such as tissue culture or use of growth hormones, have not been tested.

Management. Field trials are currently exploring suitable spacing for *D. melanoxylon* plantations. An initial spacing of 2 x 2 m results in good branching characteristics, while later thinning improves growth. Stem form is improved by raising the trees under medium shade provided by *Pinus caribaea* Morelet (Nshubemuki, 1983).

Thorough weeding is important at the initial phase of establishment. After 7.5 years, trees planted early in the rainy season on thoroughly weeded plots averaged about 30% taller than trees planted at the same time but only lightly weeded. Trees planted in the middle of the rainy season and thoroughly weeded were taller still--about 45% taller than those planted at the beginning of the rains and lightly weeded (Mugasha, 1983). Intensive weeding is crucial until root-collar diameters measure about 5 cm. Alternatively, the area around the trees should be slashed until root-collar diameters measure 8 to 10 cm. The species is extremely slow growing: trees obtain timber size in 70 to 100 years. Studies on mycorrhizal associations have not been initiated.

Pests and diseases. Heart rot is observed on some logs, apparently associated with fungal infection following fire damage. Small game may feed on young shoots and leaves.

Limitations *Dalbergia melanoxylon* is not gregarious and may be difficult to establish in pure plantations. Rapid loss of seed viability might also make it difficult to establish plantations in new areas. Difficulties in working the wood call for specialized techniques, perhaps not feasible for cottage industries.

Logs are almost invariably defective and the wastage is considerable in conversion to top-grade dimension stock. End checks appear soon after felling and star shakes develop unless end coatings are applied immediately. Seasoning may take as long as two to three years after pieces are rough sawn.

Future research needs *Dalbergia melanoxylon* occurs in three of the four drainag basins found in Tanzania. Observed differences in growth habits suggest the existence of clinal variation resulting from genetic, topographic and ecological influences. Selections for characters such as fast growth, wood quality, volume production and stem straightness have considerable potential. Studies of provenance variation related to end use should form the basis for *in-situ* and *ex-situ* conservation.

Research would be useful on improved methods to increase seed viability and shorten the seasoning period. Symbiotic relationships also need to be explored and quantified. Hybridization with related species, such as *D. sissoo*, should be initiated.

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NFT Highlights

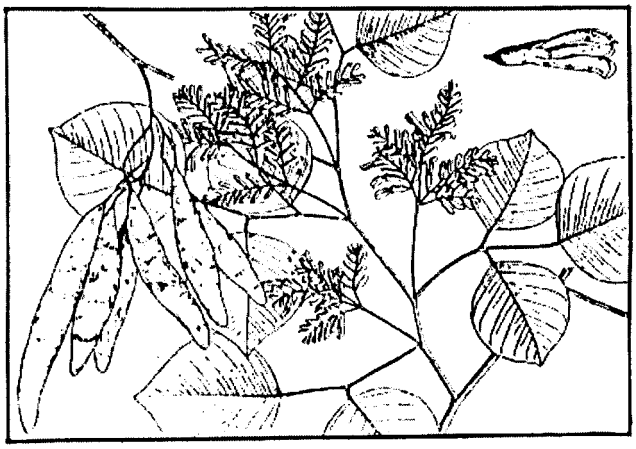
NFTA 89-07

A quick guide to useful nitrogen fixing trees from around the world December 1989

Dalbergia sissoo : The Versatile Rosewood

Dalbergia sissoo is best known internationally as a premier timber species of the rosewood genus. However, sissoo is also an important fuelwood, shade, shelter and fodder tree. With its multiple products, tolerance of light frosts and long dry seasons, species deserves greater consideration for agroforestry applications.

BOTANY. *Dalbergia sissoo* Roxb. (Leguminosae, subfamily Papilionoideae) is a medium to large deciduous tree with a light crown. It can grow to 30 m in height and 80 cm in diameter, but is usually smaller. Trunks are often crooked when grown in the open. Leaves are alternate, pinnately compound and about 15 cm long. Flowers are whitish to pink, 1 cm long and in dense clusters 5-10 cm in length. Pods are oblong, flat, thin, 3-7 cm long 10-12 mm wide, and light brown. They contain 1-5 flat bean-shaped seeds 7-9 mm long. Sissoo and shisham are common names for *Dalbergia sissoo.*



ECOLOGY. Sissoo is native to the foothills of the Himalayas of India, Pakistan and Nepal. It is primarily found growing along river banks below 900 m elevation, but can ranges naturally up to 1500 m. The temperature in its native range averages 12-22°C, but varies from just below freezing to nearly 50°C. An average annual rainfall of 500 to 2000 mm is distributed in a monsoonal pattern with droughts of 3-4 months. Soils range from pure sand and gravel to rich alluvium of river banks; sissoo can grow in slightly saline soils. Seedlings are intolerant of shade.

TIMBER. Sissoo is among the finest cabinet, furniture and veneer timbers. The heartwood is golden to dark brown, and sapwood white to pale brownish white. The heartwood is extremely durable (Specific Gravity = 0.7-0.8), and is very resistant to dry-wood termites; but the sapwood is readily attacked by fungi and borers.

FUELWOOD. The calorific value of the sapwood and heartwood of excellent fuelwood is reported to be 4908 kcal/kg and 5181 kcal/kg, respectively (Anon. 1952). As a fuelwood, it is grown on a 10 to 15-year rotation (NAS 1983). The tree has excellent coppicing ability, although a loss of vigor after two or three rotations has been reported in Nigeria (NAS 1983). Sissoo wood makes excellent charcoal for heating and cooking.

FODDER. Leaves and young shoots of sissoo are an important winter fodder in some areas and an emergency fodder in others. They are eaten readily by many animals, including monkeys. On a dry weight basis, leaves contain 12.6-24.1% crude protein, with young leaves having the higher values, and 12.5-26.1% crude fiber. Dry matter digestibility is about 56% (Jackson 1987). The trees are deciduous, dropping leaves in the winter. Young leaves appear about the end of February and leafing is complete by early April, making April to May the best time of the year for the production of high-quality fodder (Jackson 1987). Although the material has no known toxic compounds, feeding green leaves sometimes causes digestive disorders which can be prevented by making silage (Jackson 1987). Sissoo silage contained 14% crude protein and 30% crude fiber (Anon. 1952).

BIOMASS PRODUCTION. A study of 40 natural riverine sites showed that growth for 20, 30 and 50-year-old stands was 5, 7 and 7m^3 /ha/year (CSIR 1976). A 10-year-old irrigated plantation in Peshawar, Pakistan, spaced at 2 x 2, 3 x 3 and 4 x 4 m produced a total wet weight biomass (main stem, branches, leaves and roots) of 510, 231 and 244 tonnes/ha, respectively (Sheikh 1988a). In Nepal a 9.5-year-old stand thinned to 867 trees/ha at 6.5 years produced an annual increment of 18.1 m^3 (Jackson 1987). A permanent water table 7 m below the surface made the site very favorable. Species trials have indicated that total biomass yields for sissoo are usually lower than that of other species (NAS 1983, Sheikh and Haq 1982, Sheikh 1988b). Sissoo should therefore be used in areas where a high-value timber market is available, or on sites unfavorable for other species.

SEED TREATMENT. Seeds (50,000/kg) remain viable for only a few months when exposed to air, but can be stored for up to 4 years in sealed containers (Jackson 1987). It is not necessary to extract seeds from pods, which can be broken into one-seeded segments and sown.

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Seeds should be soaked in water for 48 hours before sowing, and 60-80% germination can be expected in 1-3 weeks (Jackson 1987).

ESTABLISHMENT. Stump cuttings are commonly used for establishment. Plants are grown for 6 months to 1 year in beds, pulled up carefully and cut to leave 5-10 cm of stem and 20-25 cm of root. Stumps thicker than 2.5 cm and thinner than 1.5 cm in diameter are rejected in Pakistan, although in Nepal stumps average 1 cm in diameter at the root collar (Jackson 1987).

Container-grown seedlings also are used but outplanting survival averages only 50%. Regular root pruning is necessary in the nursery, as seedlings develop strong taproots. Direct seeding has been a common practice in taungya plantings in India. Rows are planted 3 m apart and saplings are thinned to a 1 m spacing within rows after one year. It is also possible to raise plants from stem cuttings. The age of the tree and time of planting are very important. Rooting success of hardwood cuttings from 1-year-old and 4-year-old trees ranged from 34-73% and 18-38%, respectively. Wood cuttings planted in May and June failed completely, while those planted in August achieved up to 20% success (Vidaeovic 1968); May and June are hot and dry and monsoons occur in August in the study area. Pain and Roy (1981) reported 100, 80 and 60% rooting success with IBA, NAA and IPA treatment for 30 seconds, respectively, when summer planted. There has been some success with tissue culture (Jackson 1987).

SILVICULTURE: At spacings of 4 x 4 in, 3 x 3 in and 2 x 2 in, height and diameter after 6 years were 8.4 in and 11.3 cm, 8.7 in and 10.1 cm, and 8.7 in and 8.6 cm, respectively (Sheikh 1984). Differences were not significant, but the 2 x 2 in spacings produced trees with fewer branches and more fuelwood. After 9 years, height and DBH for the three spacings were 15.1 m and 18.9 cm, 13.4 m and 15.6 cm, and 13.9 m and 14.2 cm.

Thorough weeding is important during the first 2-3 years. In a trial at Adabhar, Nepal, mean height at 18 months was 3.8 m in fully cultivated plots and 1.3 in when weeding was confined to a 50 cm diameter circle around the plants (Jackson 1987). Protection against browsing animals and fire also is essential if the plant is to become a tree. Irrigation is very important for establishment of sissoo in and even semi-arid areas; it is through canal irrigation that the species has spread throughout much of the Indus valley. Sissoo should be able to tap subsoil water within a couple of years if irrigated properly (Anon. 1952). Shallow and frequent irrigation or constant flooding induces superficial root formation.

Fertilization with various combinations and amounts of NPK did not show significant effects on DBU or height over 5-6 years on a rich soil (Sheikh and Cheema 1986). Phosphate would normally be expected to promote early growth on poor sous.

PROVENANCES: Selections for fast growth and tree form have been made in Pakistan and India and experimental seed orchards established. In a trial at Adabhar, Nepal, relatively small differences in height growth in two years were observed for seven Nepal provenances, but two Pakistan provenances showed inferior growth to the Nepalese provenances.

OTHER USES: Some ethnic groups in Cameroon are said to relish eating fresh young leaves of sissoo (Anon. 1987). Sissoo is a desirable shade tree in tropical and subtropical regions. Many medicinal uses for its fresh leaves, dried bark, and wood raspings are reported from its native region. Sissoo is reported to be a stimulant used in folk medicine and remedies (Nadkarni 1954). Its habit of developing root suckers and runners make it useful for erosion control in gullies (NAS 1983).

PESTS AND DISEASES: *Plecoptera reflexa,* a leaf defoliator, *Dichomeria eridantis,* a leaf roller, *Stromartium barbatum,* a wood borer, and *Sinoxylon anale* and *Lyctus africanus,* powder post beetles, have been reported as having caused considerable damage. The fungus, *Ganoderma lucidum,* which causes root and butt rot, is common. *Fusarium solani* and *Polyporus gilvus* cause similar diseases. Sissoo suffers minor damage from two foliage rusts and a powdery mildew (Jackson 1987).

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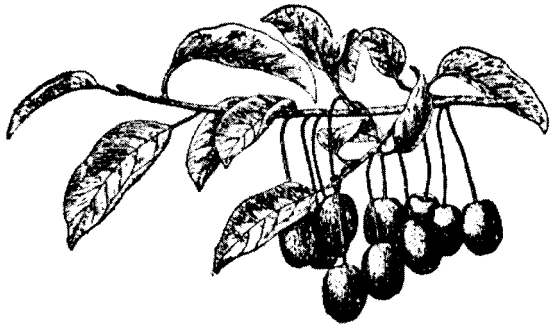
NFT Highlights

NFTA 92-07

A quick guide to useful nitrogen fixing trees from around the world December 1992

Elaeagnus : A Widely Distributed Temperate Nitrogen Fixer

Elaeagnus are temperate nitrogen fixing species commonly used for land reclamation, and as nurse crops. They are distinctive because of their peltate brownish scales which give the foliage a silvery appearance. The general appearance of the trees, leaves, and fruits are reminiscent of the olive. Hence the common names applied to the species often include the word olive (e.g. Russian olive, autumn olive).



Elaeagnus multiflora, *from The Standard Cyclopedia of Horticulture (1939).*

BOTANY. *Elaeagnus* is the major genus within the family *Elaeagnaceae.* Approximately 25 species have been identified as well as numerous varieties. The other two genera within the *Elaeagnaceae, Hippophae* and *Shepherdia* are also nitrogen fixing, and are very similar to *Elaeagnus* in general appearance and growth habits. Species of *Elaeagnus* may have spines, may be deciduous or evergreen, and generally never reach heights greater than 6-7 meters. Leaves are simple, alternate, and entire. Flowers are small and inconspicuous, but are commonly very fragrant. The deciduous species usually flower in the spring; the evergreen species flower in the fall. Flowers are borne in the axils of leaves.

Fruits are a drupe with a single stony seed, and are usually brightly colored and fleshy with a sweet tart taste. Fruits of *E. angustifolia* are creamy yellow in color and may be 1-2 cm in length, whereas those of *E. umbellate* are generally smaller and bright orange-red.

ECOLOGY. Elaeagnus is distributed in temperate and subtropical climates around the world. The deciduous species (*E. umbellate, E. angustifolia and E. commutata*) tolerate the very cold winters of the higher northern latitudes. For example, *E. angustifolia* survives in the high plains of Wyoming and Utah, USA where temperatures can reach -34°C. The evergreen species (*E. pungens*) are hardy only in moderately cool subtropical zones. *Elaeagnus* grows readily in almost any soil type although it thrives in calcareous soils.

Like other actinorhizal plants, they are pioneer species and prefer open sunlight. Their ability to grow well an degraded soils has made them popular for conservation and reclamation planting (Fessenden 1979). Distribution of seed by fruit-eating birds is the most common method of dissemination.

DISTRIBUTION. The native range of *Elaeagnus* is very wide. They occur from southern Europe through all of continental Asia. One species, *Elaeagnus commit*, is native to North America. Their center of origin is probably Asia. The most popular species are those originating from Japan. Human activity has made the current range worldwide.

USES. *Elaeagnus* species are not utilized for wood nor timber. Rather they are valued for their ability to reclaim degraded soils, and as soil-improving nurse trees (Dawson 1990). The genus makes good windbreaks. *Elaeagnus angustifolia* was introduced to the plain states of the western United States for this reason.

Within North America, *Elaeagnus* has been one of the major genera provided by government agencies for soil. conservation (Fessenden 1979). The bright red fruits of *E. umbellate* attract numerous songbirds, and it is desirable for increasing wildlife habitat. Most of the species also make suitable shade for animals.

The fruits of *E. umbellate* and *E. multiflora* are edible and have been used in ways similar to other small soft-fleshed fruits. Their flavor is pleasant yet tart. They are used for preparation of jams, jellies or even desserts. These foods are a favorite in Korea.

SILVICULTURE. Fruits of *Elaeagnus* are collected when ripe and the pulpy flesh removed by maceration. Stratification of the seed in peat moss or sand at 1-10°C for 30-90 days gives best germination of new seed. Removal of the hard seed coat, or treatment with plant hormones also overcomes seed dormancy. The seed coat contains a dormancy factor which inhibits immediate germination even when the seed imbibes moisture. There is tremendous seed size variability in all *Elaeagnus* species.

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Direct seeding of *Elaeagnus* in the field is practical although fall planting may be required to overcome the dormancy factors (Beloit and Berry 1990). Young plants of *Elaeagnus* grow quickly and branch profusely. No single dominant main stem develops. If an arborescent architecture is desired, frequent pruning and training will be required. Pruning is also used to maintain plants as hedges. *Elaeagnus* make handsome ornamentals. When *Elaeagnus* are used as nurse trees for timber crops, they are usually planted in alternate rows with the main species. Because of their short stature and slower growth, they usually do not compete significantly with the main crop.

A flowering branch of Elacagnus umbellata (photo D. Baker)

When used as a nurse tree in temperate North America, Elaeagnus are competitively removed from the plantation over a period of 15-20 years (Dawson 1990). However, during the period of their growth and nitrogen fixation, they improve soil fertility, provide shading, increase moisture retention, and reduce soil-borne disease (Friedrich and Dawson 1984).

ACTINORHIZAL SYMBIOSIS. Root nodules are common and numerous on all species of *Elaeagnus* growing in moist soils. On semiarid sites, nodulation is limited in upper soil layers but nodules will likely form well below the soil surface where moisture is available on a continuous basis. Root nodules are formed by direct penetration of young roots by the actinomycete bacterium *Frankia*. Root hairs are not required for infection (Miller and Baker 1985), a situation unlike most actinorhizal plants or many legume trees.

Root nodules are perennial and increase in size as the tree continues to grow. Young active nodules are snow-white in surface coloration, although older interior parts of nodules are light or dark brown and woody.

Elaeagnus is nodulated by *Frankia* strains that also nodulate *Hippophae* and *Shepherdia*, but not by strains that colonize other actinorhizal plants such as *Casuarina* and *Alnus*. Inocula is available for *Elaeagnus* species, although inoculation may not be necessary since most plants spontaneously nodulate in the nursery or upon planting in the field. Unlike *Rhizobium*, *Frankia* survive in the soil for long period without the presence of host plants. However, if *Elaeagnus* is to be used for reclaiming severely degraded soils or mine sites, it is appropriate to inoculate in the nursery.

Estimates of nitrogen fixation by *Elaeagnus* species have not been carefully made, but it probably does not fix as much nitrogen as other actinorhizal species like *Alnus* or *Casuarina*. Paschke et al. (1989) estimated from nitrogen mineralization studies that *Elaeagnus umbellate* interplanted with *Juglans nigra* might contribute as much as 90 kg nitrogen per hectare per year.

LIMITATIONS. The ability of these species to grow on almost any site combined with their prolific seeding habit can make them a serious weed. Their introduction is prohibited in some places.

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NFT Highlights

NFTA 90-05

A quick guide to useful nitrogen fixing trees from around the world November 1990

Enterolobium cyclocarpum : The Ear Pod Tree For Pasture, Fodder and Wood

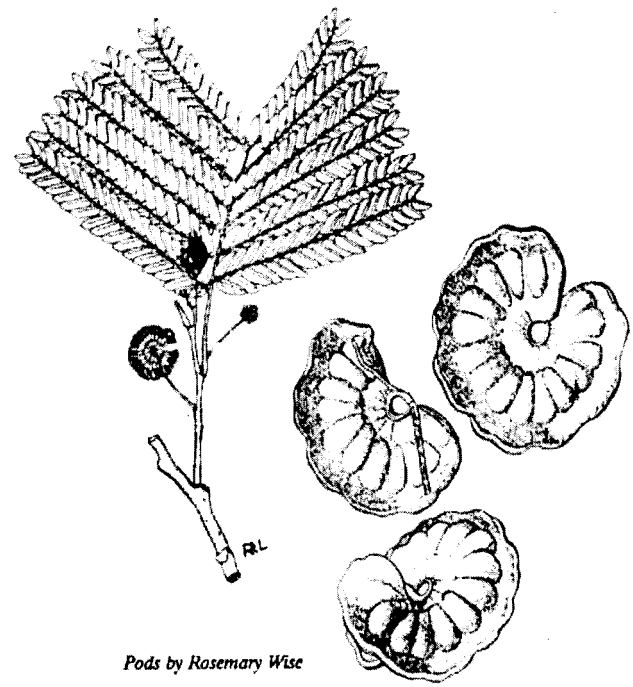
Enterolobium cyclocarpum (Jacq.) Griseb. is one of the largest trees in the dry forest formation of Mexico and Central America, reaching up to 3 m diameter and 40 m in height with a huge spreading crown. It is a conspicuous and well-known tree in its native range. Large crowned trees scattered in pastures are a common sight and a distinctive feature of the landscape in many parts of Central America. Such is its fame that *Enterolobium* has been adopted as the national tree of Costa Rica. The province of Guanacaste in Costa Rica is named after *Enterolobium* which occurs abundantly in that area.

Enterolobiumn cyclocarpum is also well-known for its distinctive, thickened, contorted, indehiscent pods which resemble an ear in form. Most of the common names for *Enterolobium* refer to this resemblance, including ear fruit, ear pod, *orejoni* (from Spanish *oreja,* an ear) and *guanacaste (conacaste,* a Nahuatl derivation signifying ear tree).

BOTANY: The nitrogen fixing tree *Enterolobium cyclocarpum* belongs to the subfamily Mimosoideae of the Leguminosae and is placed in the tribe Ingeae. The genus *Enterolobium* is closely related to *Albizia* and *Samanea* and is probably only maintained as a separate genus due to its widespread cultivation. *Enterolobium* contains only five species, all from Central and South America, and only *E. cyclocarpum* is widely cultivated. Closely related species, such as *E. schoinburgkii* Benth., remain untested to date.

Enterolobium leaves are bipinnately compound with opposite leaflets. Small white flowers occur in compact round heads. In Central America *E. cyclocarpum* is sometimes confused with *Albizia niopoides* (Guanacaste blanco) due to similarity in tree form but may be readily distinguished by the different bark which is pale golden yellow in *A. niopoides.*

ECOLOGY: *Enterolobium cyclocarpum* occurs from latitude 23°N in central Mexico, south through Central America, to 7°N in northern South America. It has been widely introduced throughout the tropics where it is cultivated mainly as a roadside or garden tree. In its native range, *Enterolobium* occurs in a wide range of different forest types from tropical, dry deciduous forest to tropical moist forest. It becomes a climax tree only in the dry forest, being restricted to disturbed areas in wetter forest types. *Enterolobium cyclocarpum* is a lowland species occurring from sea level to 1200 m elevation and has only very limited tolerance of frost.



Pods by Rosemary Wise

Annual rainfall varies between 750-2500 mm through most of its native range with a dry season that lasts 1-7 months. Trees are generally deciduous, losing their leaves during the dry season and flushing out again about two months before the onset of the rainy season. Flowering starts while the trees are leafless (March-April in Central America), and the pods take a year to mature, ripening in April-May.

USES: The wide spreading canopy of a mature *Enterolobium* makes it an ideal shade tree, whether for livestock in pasture lands, for perennial crops such as coffee, or in roadside and urban plantings. Its value to livestock is further enhanced by production of large quantities of highly palatable and nutritious pods containing a sugary dry pulp. Pods are generally shed at the end of the dry season in Central America when livestock feed is particularly short. Pods fall from the trees gradually over a period of two months thus spreading the availability of pods for livestock. Data from Puerto Rico suggests that pod production may be delayed as much as 25 years after planting. The foliage is also palatable, though to a lesser extent than the pods, which results in high mortality of natural regeneration in pasture lands and may explain why the tree occurs naturally only as scattered individuals.

Written by C. E. Hughes and J. L. Stewart, Oxford Forestry Institute, South Parks Road, Oxford OXI 3RB, UK.

Enterolobium heartwood is reddish-brown, coarse-textured and moderately durable, with a straight interlocking grain and an appearance somewhat similar to walnut. Specific gravity is variable, ranging from 0.4- 0.6. The wood is resistant to attack by dry-wood termites and *Lyctus,* and can be used in house construction as well as for nonstructural interior elements including panelling. The white sapwood, by contrast, is highly susceptible to insect attack. *Enterolobium* wood may also be used for boat-building because of its durability in water; it has been used in the past for water-troughs and dug-out canoes. The dust from sawmilling can produce allergic reactions in workers.

Other uses include food (the immature pods as a cooked vegetable, or the seeds toasted and ground), soap-making (using tannins from the pods and bark), and medicinal use of bark extracts against colds and bronchitis. The ability of *Enterolobium* to fix nitrogen, and to resprout vigorously when coppiced, suggest it could also have a role in alley-cropping systems as a hedgerow species, though this is an area requiring further research.

SILVICULTURE: *Enterolobium* is a light-demanding species at all stages in its development. It is susceptible to weed competition during early growth. *Enterolobium* resprouts vigorously after coppicing or lopping; indeed, it is difficult to kill *Enterolobium* by girdling because of its tendency to resprout below the girdle line. Little information is available, however, on its response to repeated cutting. With no silviculture intervention it usually occurs as a single, large, open-grown tree, though pruning can improve the length and form of the bole.

Enterolobium can tolerate a wide range of soil types, from alkaline and calcareous to somewhat acidic (pH as - low as 5), provided that aluminum saturation is not a problem. Best growth is on deep, medium-textured soils but sandy and clay soils also allow good development provided drainage is unimpeded. The trees will not thrive on sites prone to waterlogging.

PROPAGATION: The combination of large nutritious pods and seeds with hard coats is ideal for seed dispersal of *Enterolobium* by animals. Seeds are most easily collected by waiting for pods to fall. An adult tree produces an average of 2000 pods, each with 10-16 seeds (900-1200/kg). Trees produce seed crops in most years in Central America. Seed extraction from the indehiscent pods is usually carried out by manual threshing, milling or maceration of the pods followed by winnowing and screening.

Enterolobium seed is naturally scarified by passage through the gut of large herbivores. It is likely that the original consumers of *Enterolobium* pods are now extinct and their role as seed dispersal agents has been assumed by horses and cattle. Collected seed requires pretreatment before sowing to allow water to penetrate the seed coat. Manual scarification is effective, as is treatment with hot water or concentrated sulfuric acid. A suitable hot water treatment is a brief (30 second) soak in water close to boiling point, followed by 24 hours in water at room temperature. *Enterolobium* seeds remain viable for several years under cool, dry conditions and can be easily stored under normal conditions.

Seed supplies are currently dependent on collections from natural populations in Latin America and scattered cultivated trees in areas where *Enterolobium* has been introduced. Most early introductions of *E. cyclocarpum* were undocumented, casual and collected from a narrow genetic base. A broader range of representative germplasm should be tested to evaluate the potential of the species. Seed is available from OFI and NFTA for the establishment of field trials.

The seed should be sown 1-2 cm deep with the micropyle pointing downwards; the emerging root is not strongly geotropic and may come up out of the soil if the seed is planted upside down. Early seedling growth is rapid and vigorous. This early advantage over smaller-seeded species can continue several months after outplanting, but thereafter growth rate, though still vigorous, is no longer exceptional relative to other fast growing species.

PESTS AND DISEASES: *Enterolobium* has no serious or widespread disease and insect problems, although attack by a *Fusarium* fungus, with associated damage by wood-boring insects, can cause affected limbs to fall from mature trees. Branches may also be broken off by storm damage. Both factors reduce the desirability of *Enterolobium* for urban and roadside planting. Although no bruchid seed predators are found on *E. cyclocarpum*, the green pods are often preyed upon by parrots and fruiting may be further disrupted by the gall forming moth *Asphondylia enterolobii.*

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NFT Highlights

NFTA 94-01

A quick guide to useful nitrogen fixing trees from around the world January 1994

Erythrina edulis : Multipurpose Tree For Tropical Highlands

Cultivated for centuries, *Erythrina edulis* is an important food source for humans and animals in the tropical highlands of South America. The seed is a component of many diets,and the trees also provide shade in coffee and cacao plantations, support for vine crops, green manure, live fenceposts, wood for construction and fuel, and medicinal preparations.

Botany

Erythrina edulis Triana ex M. Micheli is one of about 115 *Erythrina* species in the subfamily Papilionoideae of the Leguminosae (syn. Fabaceae) family. Over a normal life span of 30 to 40 years, the leafy trees grow up to 14 m tall with stem diameters up to 37 cm and crown diameters up to 7 m. The stem and branches are covered with stout prickles. The alternate leaves are trifoliate with long petioles and two nectar-producing glands at the base of each leaflet. The flower cluster (raceme), supported on a stout stalk, consists of 180 to 200 short-stalked flowers arranged in threes around the axis. The flowers have a reddish-green calyx and a crimson corolla with an upper petal (standard) and two lateral petals forming the keel. The pistil is surrounded by 10 stamens. The two-petaled flowers face upward, forming a large cup in which nectar gathers (Ruskin, 1989).

Erythrina edulis is cross pollinated by sucking insects, bees, wasps and birds. Seeds mature 65 days after flowering. Fruits hang in bunches of 9 and 18 cylindrical pods. Pod size varies widely, but averages 32 cm long and 3 cm in diameter with six seeds. The seed coat is generally brownish-red but is sometimes yellow or black (Acero, 1989).

Distribution

Erythrina edulis is distributed from Mérida in Venezuela, to the mountain ranges of Colombia and the Andes mountains of Ecuador, Peru and Bolivia. It is commonly known as *chachafruto*, *balú*, *basul* or *sachaporoto* in Colombia, *guato* in Ecuador, and *pashuro*, *pajuro*, *basul sachaporoto* or *sacha purutu* in Argentina and Bolivia (Ruskin, 1989).

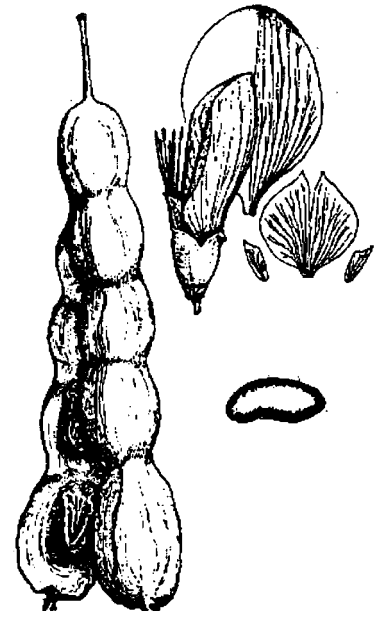
Ecology

Erythrina edulis is a pioneer species that grows best in full sunlight, but trees can tolerate some shade in the early stages of growth. In Colombia, the species occurs from elevations of 1200 to 2600 m, with an optimum range from 1600 to 2200 m. In Peru, *E. edulis* grows from 900 to 3200 m (Martel, 1989). In the species' native range, annual rainfall varies from 450 to 1800 mm and temperatures are between 5° and 25°C. The trees grow well in loose-textured sandy loams and in heavy clay soils. They do not tolerate frequent frosts.

Uses

Human food. The seeds contain 23% protein, 1% fat, 8% crude fiber and 84% moisture. They have a good balance of amino aci ds and a digestibility after cooking of about 50%. Seeds must be boiled at least 45 minutes or fried thoroughly before being eaten. As a paste, they provide a nutritious base for tortillas, desserts, pies, soups and food for infants. They are also boiled, sun dried, ground and added to flour. Research indicates that uncooked *E. edulis* seeds can be toxic if consumed over a long period (Pérez et al., 1979). Seeds of all other *Erythrina* species are highly toxic.

Forage. The leaves and tender branches can be fed to cattle, goats, horses, pigs, guinea pigs and rabbits. Leaves contain 24% protein, 29% crude fiber (dry weight) and 21% total carbohydrates. They are rich in potassium but low in calcium (Surco, 1987). Seeds and pods can be fed fresh to cattle and goats, but should be cooked before feeding to pigs, chickens, rabbits or fish. The pods contain 21% protein, 23% crude fiber (dry weight), 24% carbohydrates and 91% moisture. Cooked seed can replace up to 60% of the concentrate fed to chickens and fish (Martín and Falla, 1991).



Erythrina edulis pod, flower and seed. Not to scale. From Krukoff and Barneby (1974) and Martel (1989).

Written by Nancy Barrera, Universidad Nacional de Colombia-Palmira, A.A. 237 Palmira, Valle, Colombia.

For maximum fodder production, the trees can be planted in protein banks at a close spacing (1.0 x 0.5 m). They are first pruned at 10 months and then at six- or four-month intervals. A two-year-old protein bank can produce up to 80 tons of leaves and tender branches per ha, or the leaves can be dried and ground to produce 6 tons of chicken feed rich in carotene (Vargas and Ocampo, 1991).

Shade and support. *Erythrina edulis* is widely used as a shade tree for coffee or as a support for vine crops such as pepper, betel and grape. In Colombia, trees are spaced at 6 x 6 to 8 x 8 m in coffee plantations or 5 x 5 m with vine crops (Vargas and Ocampo, 1991). Annual pod production from three- to four-year-old trees at a 6 x 6 m spacing can average 30 kg/tree or 8 tons/ha (green weight); annual pod production from 20-year-old trees can average 177 to 211 kg/tree.

Live fenceposts. In Colombia, live fenceposts are established from stakes at 2-m intervals and allowed to grow for 30 months before pruning or attaching barbed wire. Stakes should be at least 4 to 6 cm in diameter and 2 m long. Pruned at four-month intervals, leafy branches from 1 km of fencing can provide up to 30 tons of fodder per year; unpruned, the same fenceposts can provide up to 85 tons of fruit (Vargas and Ocampo, 1991).

Medicine. In Colombia, a soap made from the bark, branches and leaves of *E. edulis* is used to wash dogs with skin disease. In Peru, the seed is mixed in a liquid concoction to treat inflammation of the bladder. The flowers are used to treat eye irritations (Acero, 1989).

Silviculture

Seed treatment. *Erythrina edulis* is easily propagated from seed or cuttings, but seedlings tend to root deeper and live longer than cuttings. Seed should be removed from pods immediately and stored in paper bags in a cool, dark place. They lose viability quickly and should be planted within eight days of harvesting. Viability can be extended up to 20 days by dipping seeds for a moment in molten paraffin so that a thin layer of paraffin coats the entire seed. Seed size varies widely: Acero (1989) reports 60 fresh seeds per kg in Colombia, while Martel (1989) reports 146 fresh seeds per kg in Peru.

Establishment. Larger seeds tend to produce more vigorous seedlings. Plant seeds in 1-kg polyethylene bags with the convex side facing upwards and slightly exposed. Leave room between planting bags to allow space for leaf development (Vargas and Ocampo, 1991). Germination begins in 5 to10 days. Shade the seedlings in the nursery and reduce shade partially in the last two weeks before outplanting. At 60 days, seedlings may be planted out in holes 30 cm deep.

Erythrina edulis can also be direct seeded. Cultivate the soil thoroughly to a depth of 30 cm and plant two seeds per hole. Thin to one seedling after four or five weeks. Weed periodically in a 1-m circle around the plants. Seedlings grow rapidly (2.5 m in the first year) and begin producing fruit in approximately 24 to 27 months.

Cuttings of 4 to 6 cm diameter, and usually 1 m in length, should be planted to a depth of 30 to 50 cm within three days of harvesting (Vargas and Ocampo, 1991). Cuts should be made with well-sharpened tools to avoid damage that can lead to rotting; the top cut should be at a 45° angle. Sealing the cuts with paraffin, plastic, mud or other material can increase survival rates. Cuttings begin producing fruit about 18 months after planting.

Erythrina edulis forms a nitrogen-fixing symbiosis with *Rhizobium* in the cowpea miscellany (Acero, 1989). Large nodules form in the upper soil surface and decrease in size with increasing soil depth.

Limitations

Erythrina edulis does not tolerate long periods of drought, especially during early stages of establishment. It does not grow well in strongly acidic soils (pH below 4.5). Stem borers damage terminal shoots and cause lateral branching. Butterfly larvae (*Terastia meticulosalis*) bore into seeds. Trees are also susceptible to nematodes (*Helicotylenchus* sp., *Hoplotylus* sp. and *Meloidogyne* sp.) (Francia Varon de Agudelo, personal communication).

Future research needs

The large differences observed in seed size suggest the existence of genetic variation. Rangewide provenance collection and testing is needed to determine differences in fruit yield, biomass production, nutrient content and adaptability. Research would also be useful on improved methods to increase seed viability. Symbiotic relationships need to be explored and quantified. Finally, traditional agroforestry uses of *E. edulis* and pest and disease management need further documentation.

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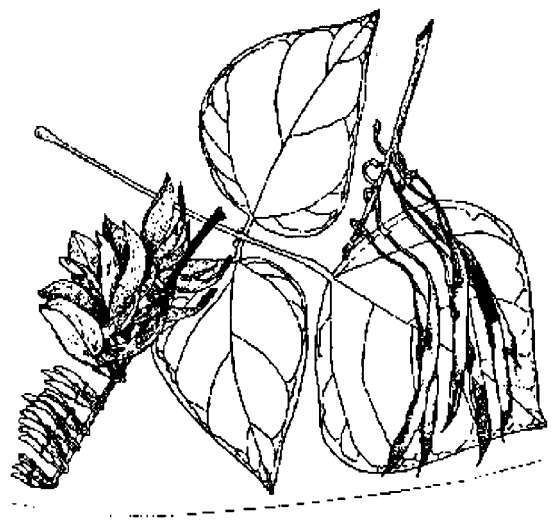
FACT Sheet

FACT 96-06
A quick guide to multipurpose trees from around the world September 1996

Erythrina poeppigiana : Shade Tree Gains New Perspectives

Erythrina poeppigiana (Walpers) O.F. Cook is a leguminous tree used in several agroforestry systems in Tropical America including shade for coffee, cacao and pastures, living fence posts, forage and fuel wood. It is also a promising species for alley cropping and mulching. Ease of management, high biomass production, nitrogen fixation and multiple uses make *E. poeppigiana* a suitable tree for farm and community forestry. It is known as "cámbulo" or "barbatusco" in Colombia, "bucare" or "cachimbo" in Venezuela, "amasisa" in Peru, "poró gigante", "poró de sombra" or simply "poró" in Costa Rica, "pito" in Guatemala and Honduras, and "immortelle" or "mountain immortelle" in the West Indies; the more formal English name is "coral tree". (Holdridge and Poveda 1975; Russo 1993).



Source: Little and Wadsworth, 1964

Botany

Erythrina poeppigiana belongs to the family Leguminosae, subfamily Papilionoideae, tribe Phaseoleae (Neill 1993). It is a large tree, growing to 35 m in height and 2 m in diameter. The crown is moderately spreading and the bole of large trees tends to be branchless below 10 - 20 m. The bark is grayish brown or gray, with thorn-like protuberances. Leaves are alternate, trifoliolate. The rhomboid-oval or oval folioles are 15 - 25 cm long and generally larger in saplings than in big trees. Glandular stiples below the paired lateral folioles are large and cup-shaped. Orange or reddish flowers are produced in racimes. The upper petal is wide and open. *Erythrina poeppigiana* is pollinated by perching passerine birds. The pods are 10-25 cm long. Seeds are brown, about 2 cm long and slightly curved. There are about 4,500 seeds per kg.

Ecology

Erythrina poeppigiana is native to humid and subhumid tropical lowlands, but cultivated and naturalized trees now are found to 2,000 m elevation (Holdridge and Poveda 1975). The average annual rainfall in its native and naturalized range is between 1,000 and 4,000 mm. In subhumid areas, it tolerates a 5-6 month dry season. *Erythrina poeppigiana* tolerates low soil fertility and relatively high acidity (down to pH 4.3), however tolerance varies by genotype (Pérez Castellón 1990).

In Costa Rica, the phenology of unpruned *E. poeppigiana* shifts from evergreen to deciduous along a rainfall gradient from the humid lowlands to the sub-humid mountains. The leafless period is quite short, and possibly caused by flowering rather than drought (Borchert 1980). A visible reduction of foliage during the flowering (December - January) also occurs under humid conditions. Pruning trees periodically will prevent complete leaf fall, and pruning trees once-a-year is enough to impede flowering (P. Nygren, pers. obs.).

Distribution

Erythrina poeppigiana is native to riverine and upland forests of the Amazon and Orinoco basins from Venezuela to Bolivia, and the moist Pacific forests of Ecuador and Colombia. It was introduced to Central America and a number of Caribbean Islands in the 19th century, and it has been widely naturalized in some areas like Costa Rica and Trinidad (Neill 1993).

Uses

Shade. Planted as a shade tree in cacao plantations in the humid tropics, *E. poeppigiana* conserves soil and contributes to high and sustainable cacao yields (Beer et al. 1990). Shade trees are partially pruned or not pruned at all. Production of N-rich litter (2.3 - 2.6%, Nygren 1995) is abundant, and the N supply in litterfall exceeds several times the export of N in the cacao harvest (Escalante et al. 1984).

In coffee plantations in Costa Rica, *E. poeppigiana* is usually pruned completely and lopped to a height of 2-3 m twice-a-year to promote coffee flowering and ripening of berries. The N supplied through pruning residues left on the ground fulfills the recommended N application rate for coffee in Costa Rica (Beer 1988). Farmers plant *E. poeppigiana* at spacings of 8 x 8 m and 6 x 6 m for unpruned and pruned trees, respectively.

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Mulching and alley cropping. The green leaves of *E. poeppigiana* contain 4.1 - 4.9% nitrogen (Pérez Castellón 1990), which makes it an excellent species for green manure production. A ten-year experiment in Costa Rica measured the effects of cut-and-carry mulching with 20 tons/ha of *E. poeppigiana* fresh matter on maize and bean yields in a sequential cropping system. Crops were harvested once-a-year and production was good compared to local on-farm production. Crop production also increased each year of the experiment. The same experiment in Costa Rica evaluated alley cropping *E. poeppigiana* with maize and beans. Although satisfactory and sustainable for 10 years, the maize yield in this experiment was lower than the maize yield in the mulching experiment. The bean yield in the alley cropping system was both high and sustainable (Haggar et al. 1993). In a separate experiment in Costa Rica, *E. poeppigiana* alley cropping also sustained two maize crops per year over eight years without fertilization. Soil carbon and nitrogen pools decreased, but 50% less than in fertilized control plots (Dominique 1994).

For alley cropping, *E. poeppigiana* should be planted in dense hedgerows (1 - 2 m between trees), with wide alley (6 - 8 m) between tree rows (Kass et al. 1993a; Nygren and Jiménez 1993).

Forage. The green leaves of *E. poeppigiana* have a good nutritive value (20 - 22% of dry matter), are high in crude protein (27 - 34%) and have a good range of in vitro digestibility (49 - 57%). However, due to the high cell wall content (55 - 58%), they should be supplemented with energy sources, e.g. tropical grass, which are readily degradable in the rumen (Kass et al. 1993b). The presence of potentially toxic alkaloids in the leaves of *E. poeppigiana* has not affected the health of cattle or goats, but feeding leaves to non-ruminants may be risky (Kass 1994).

Other uses. The wood is light, with low calorific value but it is sometimes used as fuel wood (Russo 1993).

Silviculture

Propagation. The seeds of *E. poeppigiana* may be stored for several years in tightly closed containers in a cool, dry place (ca. 5 °C, 30 - 40% relative humidity). Immersion in water at room temperature for 24 h enhances germination. The germination rate is about 70%. Germination takes 5-15 days. The seedlings may be planted in the field when they are 20-30 cm high (3 - 4 months), preferably at the beginning of rainy season. The seedling survival is generally good, but weed control may be necessary during the first year to enhance growth (Víquez and Camacho 1993; P. Nygren pers. obs.).

Air-layering to establish rooted cuttings yields a survival rate of 83% in vegetative propagation of *E. poeppigiana*. The roots appear about 6 weeks after air-layering. The leaves must be removed before planting, and the top cut made at a 45° angle and sealed with paraffin. Unrooted cuttings should be long (> 1.5 m). Stakes from lower and middle sections of one-and two-year-old branches give best results. Cuttings are planted at a depth of 30 cm. Inoculation of seeds or cuttings with *Bradyrhizobium* bacteria is not generally required in areas where *E. poeppigiana* is native or naturalized (Víquez and Camacho 1993; P. Nygren pers. obs.). However, inoculation is recommended when introducing the species to new areas.

Management. A formation pruning is recommended about 4-6 months after planting to remove the lowest branches. Normal pruning management may start 9-12 months after planting. Tall crops should not be associated with *E. poeppigiana* before the first complete pruning, but low crops may be planted at the time of the formation pruning. Coffee and cacao may be planted together with the trees. Due to the slow recovery of carbohydrate reserves, pruning of *E. poeppigiana* more often than twice-a-year causes the risk of debilitation and turnover of trees within a few years (Nygren et al. 1996).

Symbioses

E. poeppigiana nodulates abundantly with nitrogen fixing bacteria of genus *Bradyrhizobium*; peak values exceeding 1,000 kg/ha of nodules were reported for unpruned cacao shade trees, but during the driest season nodulation dropped to nil (Escalante et al. 1984). Globular nodules are formed in the site of lateral root emergence, and they have never been observed deeper than 10 cm. (Holdridge and Poveda 1975; Neill 1993; Víquez and Camacho 1993; P. Nygren, pers. obs.). Soil acidity does not impede nodulation, but differences in the efficiency of bacterial strains were detected in a soil with 50% aluminum saturation (Gross et al. 1993). Pruning causes a complete turnover of nodules, and renodulation initiates about 2.5 months after pruning. After initiation, 66-180 kg/ha of nodules may be produced in a month (Nygren and Ramírez 1995).

Vesicular-arbuscular mycorrhizae improve nitrate uptake efficiency of unnodulated seedlings (Cuenca and Azcón 1994).

Limitations

Adult June beetles (*Phyllophaga menetriesi,* Coleoptera: Scarabaeidae) feed on young leaves of *E. poeppigiana.* Because June beetles lay eggs close to foraging areas, the root-eating larvae are a potential risk for associated crops (Hilje et al. 1993). Only minor damage to maize alley cropped with *E. poeppigiana* has been observed (D. Kass, pers. obs.), but the pest problem requires further investigation.

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For a complete set of references contact the authors or FACT Net

NFT Highlights

NFTA 92-06

A quick guide to useful nitrogen fixing trees from around the world October 1992

Erythrina sandwicensis : Unique Hawaiian NFT

Erythrina sandwicensis, commonly known as wiliwili, is the only *Erythrina* endemic to the Hawaiian Islands. The wood, seed and flowers were traditionally used in Hawaii, and the tree is integral to many Hawaiian legends and proverbs. A unique characteristic of the species is the flower color variation within natural populations. Wiliwili is adapted to and lowland environments and has potential for revegetation of degraded sites.

BOTANY *Erythrina sandwicensis* Degener (syn. *E. monosperma* Gaud) is closely related to both the *E. tahitensis* and *E. velutina* (Neill 1990). *Erythrina sandwicensis* is a small deciduous tree 5-15 m tall with a short, stout, crooked or gnarled trunk 30-90 cm in diameter. Spreading branches are stiff, and the broad thin crown is wider than it is high. A champion tree measured on the Island of Hawaii in 1968 was 16.8 m tall with a trunk circumference (cbh) of 3.8 m.

The bark is smooth, light to reddish brown, and has scattered stout grey or black spines up to 1 cm long. With age, it becomes slightly fissured and thin. Twigs are stout, green with yellow hairs when young and have scattered blackish spines. Leaves are alternate, compound, 13-30 cm long, with a long slender leafstalk. The three leaflets are short-stalked. The end leaflet is larger than the other two. Leaflets are 4-10 cm long and 6-15 cm wide (Little and Skolmen 1989).

Flower clusters (racemes) are on hairy yellow stalks of 7.4 cm or less. Flowers are crowded in a mass and are 7.5-15 cm long and short stalked. Flower color within natural populations can include orange, yellow, salmon, green and white (Little and Skolmen 1989). This striking color variation is probably unique within the genus (Neill 1990).

Reports vary on flowering and leaf fall. Rock (1913) reported that wiliwili loses its leaves in the late summer or early fall (August to October), and leaves appear again during early spring to mid-summer (March to July), usually after flowering has occurred. Observations on Maui indicate that leaves drop during the dry periods of late spring or early summer (May to June). The tree flowers during the fall (September to November). Leaves reappear after the first southerly storms in the late fall (November) (B. Hobdy, Hawaii Department of Land and Natural Resources, personal observation). Differences in observations may be tied to variation of annual soil moisture, and the considerable heterogeneity of flowering, leaf loss, and seed set within a single stand.

Fruits (pods) are approximately 10 cm long and 13 cm broad, flattened, and pointed at both ends. They are blackish and slightly narrowed between seeds. Mature pods are found on the trees during winter months (December to February). Pods contain 1-4 elliptical, shiny red orange seeds 13-15 mm long (Little and Skolmen 1989).

Erythrina sandwicensis leaf, seed, fruit, and flowers (Little and Skolmen 1989).

ECOLOGY. Wiliwili occurs near sea level to 610 m altitude in and regions (Little and Skolmen 1989). Annual rainfall in these areas ranges from 500 to 1250 mm and is usually concentrated between November and March. Once an important component of ancient endemic Hawaiian dryland forests (Rock 1913), wiliwili has been replaced by *Prosopis pallida* in many areas (Little and Skolmen 1989). However, the species is not in danger of extinction.

DISTRIBUTION. Wiliwili is endemic to the leeward side of the Hawaiian Islands (Little and Skolmen 1989). It is not known to have been introduced elsewhere.

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USES. Wood: The wood is reported to be the lightest of Hawaiian wood. It was used for surfboards (Neal 1965), canoe outriggers, and fish net floats, (Degener 1973, Neal 1965). Degener (1973) reports that the practice of using wiliwili wood for outriggers was abandoned because Hawaiians believed that sharks followed such canoes. They also believed that trees bearing orange-red flowers possessed more durable wood than those bearing lighter colored flowers (Degener 1940).

Other uses: The bright red seeds were used for making leis (Rock 1913). Captain Cook was reportedly given a lei made of wiliwili seed when he visited the islands in 1778 (Little and Skolmen 1989). Wiliwili has been planted as living fences (Degener 1940). The species is strongly linked to Hawaiian culture through legends and proverbs. One legend refers to the different appearances of this species in the transformation of three sisters into wiliwili trees. A bald sister becomes a tree with no leaves, a sister with wind-tossed hair becomes a tree with fluttering leaves, and a hunchbacked sister becomes a gnarled tree (Neal 1965).

Land rehabilitation: Wiliwili is now being used in revegetation programs using endemic species to rehabilitate highly eroded areas in Hawaii. It survives extended drought and high winds, but growth is slow under such harsh conditions.

SILVICULTURE. Propagation: Wiliwili can be easily propagated by seed or vegetative cuttings. To improve germination, the seeds should be mechanically scarified by nicking the seed coat, and soaked in water (at room temperature) overnight. For nursery propagation 1 liter containers with a 1:1:1 mixture of perlite, vermiculite, and potting soil are suggested. A small amount of 14-14-14 N-P-K slow release fertilizer can be added to the potting mix (Chapin 1990). If vesicular arbuscular mycorrhizal (VAM) inoculant is available, it should be mixed in the potting media as well. Plant seeds 4 cm deep. Inoculate with rhizobia by irrigating the seedings with a suspension of peat inoculant in water. Keep seedlings in a shady area until the first 2 or 4 true leaves appear. Water as needed. Overwatering may cause damping-off. After two weeks, place plants in the full sun. Water with a liquid fertilizer solution containing N- P-K plus micro-nutrients. Moderate fertilizer use will not adversely affect the microsymbionts.

Methods for vegetative propagation of *Erythrina variegata* (Rotar *et al.* 1986) may be used for wiliwili. Rotar recommends that cuttings be a minimum of 2.5 cm in diameter and 30 cm long. Before planting, cuttings should air dry, or cure, for at least 24 hours. The base of the cuttings can be coated with rooting hormone. The cuttings should be placed in the ground to a depth of at least 15 cm, and the soil kept moist. Sealing the top surface of the cuttings with wax or tree-wound dressing will help to prevent drying out.

Establishment: Wiliwili should be planted on sites similar to its natural environment. Sites are recommended that have well-drained soil and receive full sun. Seedlings are ready for outplanting when stems are sturdy and well hardened, after approximately four months in the nursery. Planting holes should contain slow release fertilizers as recommended by soil nutrient analysis. If possible, water once a week for the first month. If watering is not possible or if conditions are particularly harsh, the leaves of the seedlings may be trimmed or the tops cut off entirely.

SYMBIOSES. Wiliwili forms a nitrogen fixing symbioses with *Bradyrhizobium* species. Highly effective strains have been identified (van Kessel *et al.* 1988). Rhizobial inoculants are available from NifTAL, 1000 Holomua Rd., Paia, HI, 96779 USA.

In highly eroded soils in Hawaii, inoculation of wiliwili with VAM species *Glomus fasciculatus* resulted in significantly increased plant growth and decreased requirements for phosphorus amendments. This indicates VAM symbioses is critical to plant success in phosphorus infertile soils.

LIMITATIONS. Wiliwili seedlings may be susceptible to damping-off problems. Powdery mildew fungi will attack the leaves in humid environments. Stem boring caterpillars have caused seedling mortality. Red spider mites are commonly associated with wiliwili. The tree is not suited for areas with high rainfall.

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NFT Highlights

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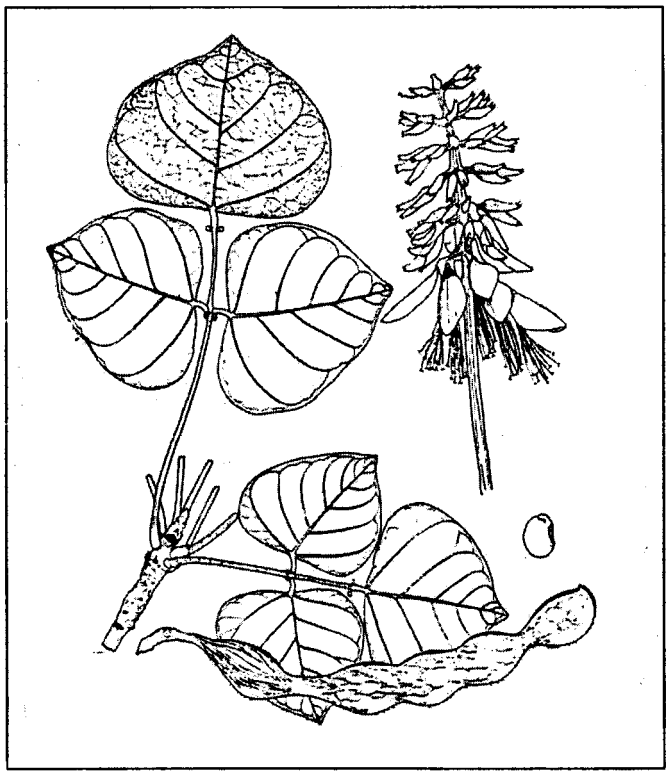
A quick guide to multipurpose trees from around the world January 1994

Erythrina variegata : More Than A Pretty Tree

Erythrina variegata is a showy, spreading tree legume with brilliant red blossoms. Commonly known as the 'Indian coral tree' in Asia or 'tropical coral' in the Pacific, this highly valued ornamental has been described as one of the gems of the floral world. It has also proven valuable for fodder production and as a sturdy component of windbreaks. It is a useful species for soil enrichment because it modulates readily and prolifically in both acid and alkaline soils. Farmers in India appreciate *E. variegata* as fodder, light timber and, more recently, pulp for the paper industry.

Botany

Erythrina variegata is a medium to large tree, commonly reaching 15 to 20 m in height in 20 to 25 years. It has an erect, spreading form, typically with several vertically oriented branches emerging from the lower stem. On favorable sites, the stem can reach a diameter at breast height (dbh) of 50 to 60 cm in just 15 to 20 years.



The smooth bark is streaked with vertical lines of green, buff, grey and white. Small black prickles cover the stem and branches. These become longer if the tree suffers moisture stress. They typically drop off as the girth of the stem expands (Hegde, 1993). The leaves are trifoliate. The leaflets are commonly variegated, medium to light green, heart shaped, 7 to 12 cm wide and 12 to 18 cm long. The trees are deciduous, typically losing their leaves before flowering except under very humid conditions.

Brilliant orange-red flowers emerge in dense, conical inflorescences 5 to 7 cm long and 2 to 3 cm wide, usually after the leaves have dropped. Flowering is normally followed by a lavish production of seed. The pods are thick and black-1.5 to 2 cm wide and 15 to 20 cm long. Each contains 5 to 10 egg-shaped seeds. These are glossy brown, red or purple and are 6 to 10 mm in diameter and 12 to 17 mm long.

A column-shaped cultivar, 'Tropic Coral' or 'Tall Erythrina', is used extensively in windbreaks and as an ornamental in parks and gardens. Through cultivation, it has spread from New Caledonia to Australia, Hawaii and southern Florida. Unlike other cultivars, the leaves of 'Tropic Coral' remain on the tree through flowering.

Ecology

Erythrina variegata is well adapted to the humid and semi-arid and tropics and subtropics, occurring in zones with annual rainfall of 800 to 1500 mm distributed over a five- to six- month rainy season. The species is most commonly found in warm coastal areas up to an elevation of 1500 m. The trees prefer a deep, well-drained, sandy loam, but they tolerate a wide range of soil conditions from sands to clays of pH 4.5 to 8.0. They can withstand waterlogging for up to two weeks and are fairly tolerant of fire. *Erythrina variegata* is bird pollinated, outcrossed and sometimes genetically incompatible.

Distribution

Erythrina variegata is native to the coast of India and Malaysia. It has been widely introduced in coastal areas of the Old World tropics, extending from East Africa and Madagascar through India, Indochina, Malaysia, northern Australia and Polynesia. The seeds can float on salt water for months, facilitating the spread of the species. Introduced to the Americas, it was so well established by 1825 that Candolle described two new species based on trees considered to be native to the New World (McClintock, 1982). It is now a very popular hedge species in southern Florida.

Uses

Support for vine crops. Farmers in India use *E. variegata* to support climbing plants such as betel (*Piper betle*), black pepper (*Piper nigrum*), vanilla (*Vanilla planifolia*) and yam (*Dioscorea* spp.) (Hegde, 1993). Trees established to support vines are usually planted at a spacing of 2 x 2 to 2 x 3 m. Vines are planted three to four months after establishment of the tree seedlings or during the following rainy season. During the hottest

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months, foliage from the closely spaced trees shades the vines and keeps them moist. When the days become cooler, the leaves fall and the vines receive more direct sunlight, which matches their requirements at this time.

Shade. Coffee and cacao growers establish *E. variegata* shade trees from large cuttings (2 to 3 m long and 2 to 5 cm in diameter) at a spacing of 8 x 10 m. The trees are pollarded once a year to a height of 2 to 3 m to produce a spreading crown. The pruned leaves are usually spread in the plantation as mulch. The branches may be used as fuelwood.

Windbreaks. *Erythrina variegata*, particularly the columnar variety, is widely used as a windbreak for soil and water conservation. The trees have a strong, vertical root system that does not seem to compete too severely with adjacent crops (Rotar et al., 1986). Windbreaks are normally established from large cuttings planted in lines at a spacing of about 2 m.

Live fenceposts. *Erythrina variegata* makes excellent live fenceposts. Farmers commonly establish fenceposts from three-year-old upright branches about 15 cm in diameter and 2.5 m long. These are normally stacked in the shade in an up-right position and left to cure for one week before planting.

Fodder. The foliage of *E. variegata* makes an excellent feed for most livestock. Leaves normally contain 16 to 18% crude protein and have an *in-vitro* dry-matter digestibility of 50%. A tree of average size, pruned three or four times a year, produces from 15 to 50 kg of green fodder annually depending on growing conditions. Trees maintained in coffee plantations benefit from associated cultivation practices they can produce up to 100 kg of fodder from one annual harvest. The leaves have no known toxicity to cattle.

Wood. The wood of *E. variegata* is light and soft, with a specific gravity of 0.2 to 0.3. Each shade tree in a coffee plantation can yield from 25 to 40 kg of wood from annual pollarding. The wood is used to construct floats, packing boxes, picture frames and toys, and, in India, it is increasingly used for pulp production. The timber requires careful seasoning, preferably kiln drying. It does not split on nailing, but holds nos poorly.

Medicinal. *Erythrina variegata* has a reputation for medicinal properties in India, China and Southeast Asia. The bark and leaves are used in many traditional medicines, including *paribhadra*, an Indian preparation said to destroy pathogenic parasites and relieve joint pain. Juice from the leaves is mixed with honey and ingested to kill tapeworm, roundworm and threadwonn (Hegde, 1993). Women take this juice to stimulate lactation and menstruation. It is also commonly mixed with castor oil to cure dysentery. A warm poultice of the leaves is applied externally to relieve rheumatic joints. The bark is used as a laxative, diuretic and expectorant.

Other uses. With their rapid growth and prolific modulation, all erythrinas are a good source of organic matter for green manure. The nitrogen rich litterfall decomposes rapidly, making nutrients available for plant uptake. The dry foliage of *E. variegata* normally contains from 1 to 3% nitrogen Aqueous leaf extracts of *E. variegata* have also proven highly toxic to certain nematodes (Mohanty and Das, 1988).

Silviculture

Establishment *Erythrina variegata* is successfully propagated from seed or large stem cuttings. Seed should be scarified by soaking in hot water (80°C) for 10 minutes and then in tepid water overnight. Treated seeds normally germinate within 8 to 10 days. Well-watered seedlings are normally ready for planting at 10 weeks.

Woody cuttings establish best under dry conditions. They should always be held for at least 24 hours before planting to prevent attack by soil fungi. Cuttings establish quickly, producing axillary shoots in three to four weeks and then rooting. To produce tall trees with straight stems, it is important to retain the terminal bud of branch cuttings. The column shaped form, 'Tropic Coral', may not reproduce true to form from seed and should thus be propagated from cuttings.

Management. *Erythrina variegata* generally requires little maintenance. Once established, seedlings grow rapidly, usually to 3 m in one year. Cuttings typically produce more and larger side branches than seedlings; they should be pruned when young if upward growth and a clear bole are desired.

Limitations

This species is a host to the fruit piercing moth *Othreis fullonia*, a destructive insect pest in the Pacific region. The larvae feed on the tree and the adults 'pierce' important commercial fruits such as oranges, guava, papaya, banana and grapes, causing serious economic losses (Muniappan, 1993). The light wood, with 60 to 65% moisture content, is not useful as a fuel. Even when dry, it produces smoke when burned.

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NFT Highlights

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Faidherbia albida : Inverted Phenology Supports Dryzone Agroforestry

The African winterthorn is famous for its unusual phenology. It sheds its leaves with the rains and is green during the dry season, favoring crop production beneath its canopy and reducing the need for a fallow period on poorer soils.

Botany

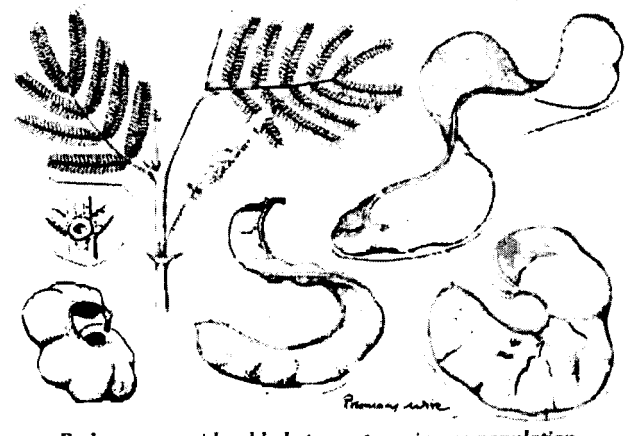
Faidherbia albida (Del.) A. Chev. (syn. *Acacia albida* Del.) is a monotypic genus in the legume subfamily Mimosoidae. Normally a deciduous tree to 15m it can reach 25m or more in southern Africa, with a large rounded crown and spreading branches, and trunk diameters of 1m or more. It is distinguished by its phenology whitish twigs and paired thorns, blue green bipinnate leaves lacking a petiolar gland, but with glands between nearly all its 2-12 pinnate pairs. The inverted phenology does not occur in seedlings until their tap roots are well into the water table.

Flower buds appear soon after leaves on current season's growth. About 100 creamy white flowers occur on spikes up to 16 cm long, but most abort and normally 5 or less mature into pods 3-4 months later (Zen-Nlo & Joly in Van Den Beldt 1992). Pods (11-30 cm long x 1.4-6.7 cm wide) are orange to reddish brown, often coiled or twisted, and contain up to 30 seeds. Seeds are dispersed by herbivores eating the indehiscent pods or by the pods floating down rivers. Populations in Cameroon show levels of outcrossing from 50-100%, with variation in a population throughout the flowering season. It is a diploid species (2n = 26) over most of its range; a poly ploid (2n = 52) has been recorded from Israel (Halevy 1971).

Distribution and Ecology

Its natural range extends throughout dry tropical Africa into the Middle East and Arabia, from 270 m below sea level in Palestine up to 2500 m in Sudan (Wickens 1969). It has been introduced into India, Pakistan, Nepal, Peru, Cyprus, Cape Verde and the Ascension Islands. It grows in a wide range of climates and habitats, either scattered or gregarious, in closed canopy woodland or open savanna and in cultivated lands. It is usually a pioneer on alluvial flats but can form part of a fire climax vegetation in the west African savannas, where optimal conditions are between 500-800 mm annual rainfall. In east Africa it grows well with 1800 to 8 mm or less, provided it taps underground water. It is susceptible to frost damage.

The species develops into large populations on deep sands and alluvia in the Sahelian belt, heavy vertisols in the Ethiopian highlands, and around many of the rift valley lakes or riverine and valley bottoms in east and southern Africa. It withstands flooding for a number of months along the Zambesi and Nile rivers and in paddy fields.



Pods vary considerably between trees in one population.

Uses

Agroforestry. The mulch created by falling leaf litter and the canopy shade at planting time creates as improved microclimate (better rainfall infiltration, reduced evapotranspiration and temperature extremes) resulting in increased crop yields (Charreau & Vidal 1965 and Poschen 1986 in CTFT 1988). Geiger et al. (in Vandenbelt 1992) argue that the fertility effect may in part be due to the tree developing on more fertile microsites rather than creating them. Animal dung and urine commonly accumulate under these shade trees.

In Zimbabwe, average leaf fall was calculated at 0.73 t/ha/yr at 11 trees/ha (Dunham 1989) compared with 0.58- 0.97 t/ha/yr at 10 trees/ha in Senegal. Small leaflets rapidly decompose and increase the soil organic matter. In sandy Senegalese soils, mineralized carbon increased by 73%, and total N and available P almost doubled under the canopy com pared with open fields (Charreau & Vidal 1965 in CTFT 1988). The species is well suited to subsistence farming when the crop is a cereal (millet, sorghum and maize). Groundnuts yields can be depressed under the canopy from increased vegetative growth due to excess N in relation to P & K. Trees also integrate well in the rice paddy fields and are used as shade for coffee. Analysis of economic returns from cereal cropping under *F. albida* in the eastern highlands of Ethiopia showed an income gain of 82% was possible where cropping was under 65 trees/ha compared to treeless fields (Poschen 1986 in CTFT 1988).

Fodder. The nutritional value of leaves and fruit is well documented. Pods fall towards the end of the dry season when fodder is scarce; leaves and branchlets are lopped around this time. Fruit production is highly variable be tweentrees and between years. Average pod production ranges from 6 to 135 kg/tree/yr in the Sudanian zone. In Zim babwe (Mana pools) 2 trees averaged 161 kg/tree/yr (Dunham 1990), and a single tree varied from 40-339 kg/yr. Average pod production in the Mana woodland

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was 590 kg/ha/yr at 11 tree/ha. The pods fall over a period of months. In west Africa pods are sometimes shaken down, collected, and fed to animals or sold in markets or at roadsides.

Trees are lopped in a number of countries for leaves and fuelwood, but this in turn affects the pod production and can extend foliage retention into the rainy season. Leaves, pods and seeds contain 200, 150 and 260 g total protein/kg of dry matter; 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. While the wood is used for fuel, it is lighter (specific gravity 0.6-0.7) and less suitable than many African acacias. Because of its size, the wood is locally used for dugout canoes, mortars, doors and some light carpentry but it is susceptible to borers. Cooked seeds are eaten as a human famine food both in Ghana, Nambia, Zambia and Zimbabwe. Flowering later than most plants, it is a useful source of pollen and nectar for honey bees, and log beehives are made from its bark. Widely used for local medicines, Ovambo Namibians use its bark for toothbrushes and is reputed to contain Fluorine. Thorny branches are used for fencing.

Establishment and Growth

Hard coated seeds store well under dry conditions, and are often extracted by pounding the pods in a mortar. Pretreatment is needed for rapid uniform germination. Mechanical scarification works best for small lots. Dipping seed for 5-15 minutes in conc. sulphuric acid or covering the seed with boiling water then allowing to cool for 24 hours are also effective. There are 7,000-20,000 seeds/kg, the seeds are smaller in west Africa than those from the east and south. Seeds can be sown directly or nursery planted, ideally using long poly tubes (30x8 cm), with regular watering and frequent mechanical root or air root pruning (CTFT 1988). Seedlings can be transplanted 3-6 months later. Spacing at 10x10 m is common, but varies with moisture availability and local farming traditions. Establishment in farmers' fields affords protection and weeding as the species is vulnerable to competition. Tractor ploughing between mature trees can promote coppicing from damaged roots.

Extremely variable growth rates have been recorded because of genetic and site variation. Isozyme studies at OFI & CIRAD-Fôret indicate a large genetic diversity within the species, distributed into 3 major areas, west, southern and north eastern Africa with the latter being a key area of diversity. Larger seeded east and southern African provenances initially grow faster than the west African provenances and have a higher shoot/root ratio, but can collapse after a couple of years in the more arid west Africa where water tables are deep. On average 1-1.5m annual height growth has been recorded on favourable sites in Africa. Clonal propagation from shoot and root cuttings and from callus has been developed although elite stock needs to be identified. Seed from a broad range of provenances is available from members of the African *Acacia* trials network (OFI, CIRAD-Fôret, DFSC,FAO).

Millet under leafless F. albida at Kokologo, Burkina Faso

(Photo: CW Fagg)

Symbiosis

Faidherbia albida nodulates with *Bradyrhizobium* bacteria, common in tropical soils, and has VA mycorrhizal associations. It develops both surface and deep tap roots and in sandy Sahelian soils the highest densities of *Bradyrhizobium* were found at the water table 30-35 m below the surface. In moister sites abundant nodules can be found near the surface (Dupuy & Dreyfus in Van Den Beldt 1992).

Limitations

Apart from damage from foraging animals and rodents, the principal pests and diseases are insects and nematodes. Bruchid beetles can destroy up to 50% of the seeds. Seedlings are attacked by sap sucking insects or cochineal bugs, and nematodes (*Meloidogyne javanica, M. icognita*) favored by the moist nursery conditions. Caterpillars of the moth *Crypsotidia conifera* can defoliate adult trees by up to 50% in Nigeria and Zimbabwe. For control methods see CTFT (1988).

Insect galls (leaf and flower) and parasitic plants occur sporadically in its native range. It is less susceptible to fungal diseases due to its inverted phenology, but leaf blight (*Rhizoctonia solani*) has been recorded on nursery plants in India. Felled timber is susceptible to a variety of wood borers. It is vulnerable to competition in establishment. The thorns can be deterrent to farmers not used to them.

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NFT Highlights

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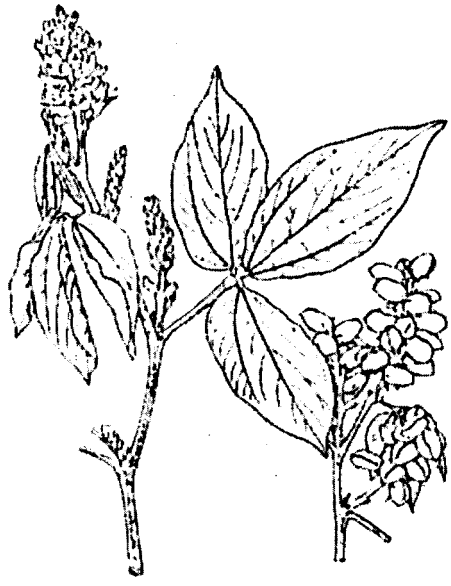
Flemingia macrophylla : A Valuable Species In Soil Conservation

The slow decomposition rate of its leaves, along with its dense growth, moderate drought tolerance, ability to withstand occasional flooding, and coppicing ability, make *Flemingia macrophylla* especially useful for mulching, weed control, and sod protection.

BOTANY: *Flemingia macrophylla* (Willd.) Merr., a member of the Papilionoideae sub-family of the Leguminosae is known under many aliases. The most important synonym is *F. congesta* and the genus also has been called *Moghania*. It is commonly called flemingia. The authors usually cited in connection to *F. macrophylla* (Prain, Kuntze) have not validly published the name (Gillet. 1971). Flemingia is a woody, leguminous, deep rooting, shrub, up to 2.5 m in height. Leaves are trifoliate. Leaflets are papery, with a glabrous upper surface. Flowers are in dense racemes with greenish standards with red blotches or stripes. Pods are small and turn brown when ripening, dehiscent, generally with two shiny black seeds in the vessel. Flemingia is native to Asia, but is considered naturalized in Sub-Saharan Africa (Asare *et al* 1984).



ECOLOGY: *F. macrophylla* can be found from sea level up to 2000 m. The minimum rainfall required is about 1100 mm, while the species has been found to thrive under equatorial rainfall conditions in the Cameroons (2850 mm). Flemingia is a hardy plant that can resist long dry spells, and it is capable of surviving on very poorly drained and occasionally water-logged soils. The species is naturally found growing along watercourses in secondary forest and on both clay and lateritic soils. Keoghan (1987) reports that in Indonesia it has outstanding adaptation to acid (pH 4.6) and infertile sods with high soluble aluminum (80% saturation) 1987). It grew well in a soil with a pH of 4.5 in Costa Rica (Bazill 1987). The plant is tolerant of light shade and is moderately able to survive fires.

WEED CONTROL: Probably the most interesting feature of the species is the relative resistance of its leaves to decomposition. Approximately 40% of a mulch layer made of flemingia leaves (4 tons DM per hectare), was still left after 7 weeks, compared to 20% for *Leucaena leucocephala* (Budelman, unpublished). The flemingia mulch formed a relatively solid layer that effectively prevented germination of weed seeds and/or stunted their early development for 100 days.

In experimental rubber plantations in Ghana, a flemingia mulch reduced the number of required weedings per year from six to two (Anon. 1964). Temperatures at a soil depth of 10 cm were 7-8 C lower in a mulched plot (5000 kg DM per ha) than under bare soil. Soil moisture under a flemingia mulch has been shown to be significantly higher than under mulches of *Gliricidia sepium* and *Leucaena leucocephala.*

An alley farming trial in Nigeria compared the ability of fallows and mulches of flemingia, *Cassia siamea* and *Gliricidia sepium* to control weeds. The trees/shrubs were not cut during a 2-year establishment period. In a 120-day test of the decomposition rate of foliage from the first cutbacks from these hedges, cassia lost 46% of its dry matter, flemingia 58%, and gliricidia 96% (Yamoah et al. 1986a). For later prunings over two maize cropping seasons, gliricidia prunings decayed completely in a 120-day period, cassia lost 85%, and flemingia 73%. However, cassia showed the greatest potential for controlling weeds during both the 2-year fallow and the two maize crops, primarily because of the greater shade cast by its canopy during the establishment period.

BIOMASS PRODUCTION: At 10,000 plants per hectare, flemingia produced a yearly average of 12.4 tons of leaf DM over 4 quarterly cutting intervals.

FODDER VALUE: Flemingia appears to have some value as a dry season browse (Skerman 1977), although its digestibility value is less than 40% (Brewbaker and Glover 1987). Palatability of immature herbage is considerably better than that of old, mature, herbage (Keoghan 1987). Reported crude protein values range from 17.9% (Laquihon, pers. comm.) and 14.5 to 18.3% (Asare 1985). A 14-week cutting interval and 35-cm cutting height produced the highest leaf DM yield in a fodder production trial in Ghana (Asare 1985). Increasing the cutting interval from 12-14 weeks decreased crude protein contents, however (Asare 1985).

A qualitative evaluation trial in a pine plantation in Costa Rica indicated that flemingia was one of several species worthy of further study as a shade tolerant forage legume for silvopastures (Bazill 1987). Shrubby legumes were considered especially useful toward the end of the tree rotation, when densely shaded grasses and herbaceous legumes are not vigorous enough to overcome grazing and trampling.

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Skerman (1977) reports that flemingia with centrosema was selected as the most promising for mixing with grasses for temporary pastures on arable land in Ghana, and that in Malaysia it is used to support creeping legumes.

ALLEY FARMING: Flemingia has lower leaf nutrient levels (especially & Ca and Mg) than *Leucaena leucocephala* and *Gliricidia sepium*, but the amounts are still substantial (N= 2.35 to 2.83%; P = 0.19 - 0.25%; K = 0.98 - 1.40%; Ca =0.65%; Mg = 0.20%). Maize yields in *Flemingia macrophylla* (F.m.) alleys compared to control plots and alleys of *Gliricidia sepium* (G.s.) and *Cassia siamea* (C.s.) in a trial at IITA, Nigeria, are compared in the following table (Yamoah *et al* 1986b):

Maize Grain Yield (kg/ha*)

Treatment	First Crop			Second Crop		
Control						
0 kg N	1509			704		
30 kg N	1644			1076		
60 kg N	1674			1408		
90 kg N	1887			1524		
Tree Alleys	F.m.	G.s.	C.s.	F.m.	G.s.	C.s.
Prunings Removed	2353	1977	2318	1772	1891	1329
Prunings Left	2384	2543	2863	2095	2177	1992
Prunings + 30 kg N	2872	2787	2965	2235	2434	2276
Prunings + 60 kg N	3064	2776	3095	2363	2707	2299
Prunings + 90 kg N	3324	3117	3239	2821	2302	2122

* Total area including maize and hedgerow.

The trees were planted 0.5 x 4 m, cut back two years after planting, and pruned three times during the subsequent two cropping periods. In Southeast Asia, the Mindanao Baptist Rural Life Center in Mindanao, Philippines, and World Neighbors report that flemingia has become popular with farmers practicing hedgerow intercropping (Laquihon and Fisher, personal communications).

OTHER USES: Although much of flemingia's biomass is not woody, fuelwood can be a secondary product. A 2-year-old stand with a spacing of 0.5 x 4 m produced 6.8 tons of dry woody stems/ha in Nigeria (Yamoah *et al* 1986b). The shrub is used in India as a host plant to the Lac insect, and is sometimes intercropped with food crops during its establishment period (Purkayastha et al. 1981). Glandular hairs from dried pods yield a powder that imparts a brilliant orange color to silks (Allen and Allen 1981). Hill tribes in India use the roots in external applications against ulcers and swellings (Bennet 1978). The species has been used a covercrop for coffee in the Ivory Coast and Cameroon, sisal plantations in Tanzania, cocoa plantations in Ghana and the Ivory Coast (experimental stations), and rubber in Sri Lanka and Malaysia.

ESTABLISHMENT: There are 45,000 to 97,000 seeds per kg. Tests at NFTA indicate that the standard hot water treatment ensures the best germination. Chandrasekera (1980) found that treatment in concentrated sulfuric acid for 15 minutes provided better germination than hot water. Young plants grow slowly and need care (weed control) during the first two to three months. NFTA has limited quantities of seed available for trials.

PESTS AND PROBLEMS: Flemingia is an off-season host for the podfly, *Melanagromyza obtusa*, an important pest of pigeonpea, especially in central and northern India (IPN 1985).

NOTE TO READERS: *Flemingia macrophylla* is a relatively unstudied species just beginning to be tested and used in many areas. Much remains unknown about its environmental requirements, uses and management. Anyone working with this species is urged to contribute information that could be included in a later edition of this NFT HIGHLIGHT or NFTRR.

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FACT Net

FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 97-04
June 1997

Gleditsia triacanthos : Honeylocust, Widdely Adapted Temperate Zone Fodder Tree

Well known as an ornamental street tree, honeylocust was widely advocated as a livestock feed early in the 20th century. Silvopastoral cultivar development began in the 1930's at the Tennessee Valley Authority in the United States. Because it can provide a source of fodder, protein, energy, and erosion control, honeylocust is being tested in many temperate, Mediterranean and highland tropic regions of the world.

Botany

Gleditsia triacanthos L., family Leguminosae (subfamily Caesalpinioideae), attains a normal height of 15-25 m and 0.5-1.0 m diameter (maximum height 50 m, diameter 1.8 m). Trees have a short bole and open, narrow or spreading crown with reddish brown to black scaly ridged bark, often covered in clusters of large, branched thorns. Leaves are 10-20 cm long, deciduous, pinnate or bi-pinnate with 15-30 leaflets, 1-3 cm long (Harlow et al, 1996). Flowers are a pale yellow to greenish yellow color and appear from early May in the southern United States to late June in the north. Seeds are 0.5 to 1.5 cm long, dark brown in color, smooth, with a hard, impermeable seedcoat. Seeds ripen from mid September to late October in the United States. Mature pods begin to drop by mid September and continue to drop throughout the winter.

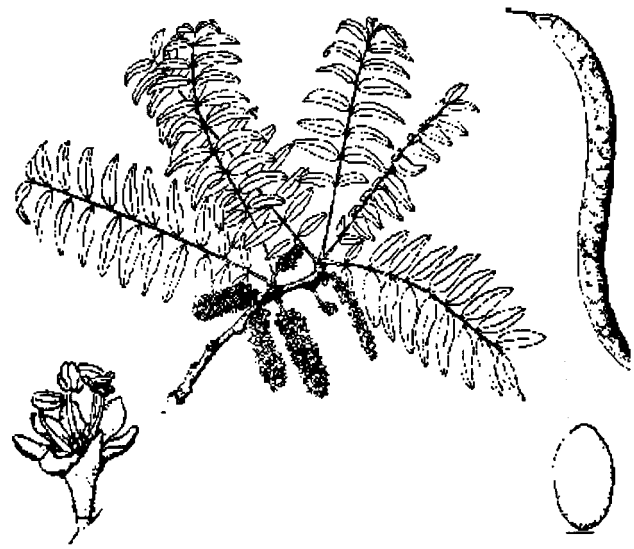
Ecology

Within the natural range, a large amount of variation exists in both climate and soil conditions. Honeylocust occurs naturally in humid and subhumid climate regions. Average annual precipitation varies from 510 mm to 1520 mm, the frost free period varies from a minimum of 150 to 300 days (Blair, 1990). Honeylocust grows naturally to 760 m but has been planted from sea level to 1,500 meters in temperate latitudes and will grow above 2,500 m in subtropical highlands.

Honeylocust is a shade intolerant tree, and will only become established in openings. It has a strong taproot and profusely branched root system. Its best growth in the United States is found on deep soils (pH 6.0 to 8.0) in moist, alluvial flood-plains between 35° and 40° N. latitude. It generally grows poorly on gravely or heavy clay soils and often fails on shallow soils (Blair, 1990). Honeylocust is resistant to both drought and salinity, and coppices vigorously when cut.

Distribution

Honeylocust grows naturally in the eastern half of the United States (Blair, 1990). It has become naturalized east of the Appalachian mountains from Georgia to New England in the East, and north to South Dakota in the West (Harlow et al, 1996). As a fodder tree, honeylocust is being tested in France, Spain, Germany, Greece, Algeria, New Zealand, Australia, South Africa, India, Bhutan, Nepal and Guatemala (Wilson, 1993).



Leaves, inflorescences, seed pod, seed and flower.
Source: M. A. Gold

Uses

Silvopastoral Agroforestry. Honeylocust pods have long been recognized for their animal fodder value in silvopastoral systems (Scanlon, 1980). Widely spaced overstory fodder trees (fodder orchard), can be planted for on-farm silvopastoral systems, providing light shade, soil enrichment and stabilization, and should be compatible with a variety of forage, grain, vegetable, woody perennials or animals in the understory. In addition to yields from understory enterprises, the pods function primarily as a late fall/winter animal feed supplement (Wilson, 1993). In France, results from sheep feeding trials using pods as a feed supplement indicate that selected grafted clones produce high quality fodder and good weight gain (Dupraz and Baldy, 1993). Sheep are able to digest the majority of seeds within the pods. However, for complete utilization by sheep, cattle, horses or swine, pods and seeds must be machine processed.

Leaf Fodder. Honeylocust leaves are an excellent source of fodder, contain 20 percent crude protein, low lignin and ensile well. Coppice regrowth retains high protein and low lignin levels (Baertsche et al, 1986). However, limited studies indicate very low biomass yield response when planted from seed and harvested with a forage harvester during the first year's growth (Gold, 1984) or when 1-year-old seedlings were coppiced (at age 2) after

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Wood. Strong, hard and durable, resistant to shock, with attractive figure and reddish-brown color, it is used locally for fence posts, pallets, crating, general construction, railroad ties (Panshin and De Zeeuw, 1970) and by woodworkers for making guitars (A. Wilson, pers. comm). Wood specific gravity is 0.60 green, 0.67 ovendry (Panshin and De Zeeuw, 1970), and is considered an excellent source of fuelwood.

Ornamental. It has been widely planted as an ornamental replacement for American elm in the United States and Canada with over fifty recognized cultivars (Santamour and McArdle, 1983). Thornless trees can be produced by budding with scionwood taken from the thornless upper branches of selected cultivars. However, seedlings from such trees are thorny. Thornless seedlings can be selected at a very early age (within ten weeks of germination) for use as ornamental cultivars.

Windbreaks. Honeylocust is hardy and drought tolerant, and can be grown in windbreaks with the added benefit of pod production.

Silviculture

Propagation. Mature pods can be collected after they drop off, by hitting branches to jar the pods loose, or by clipping pods from the branches. After harvest, pods should be stored at 0° C to prevent fermentation of the pods and, if bruchid seed weevils (*Amblycerus robiniae*) are present in the pods, it will prevent them from spreading within the pods. A good pod crop can exceed 20 kg of cleaned seed per tree. Results from a rangewide provenance/progeny test show that seed yield averages 5,200 seeds/kg (varying from 3,300 to 14,300 depending on the seed source) with high purity and soundness.

To prepare pods for mechanical seed extraction, place them in a convection/seed drying oven for at least 2 hours at 35° C. Honeylocust seed will remain viable for many years if stored dry at 1-4° C. Successful germination requires seed scarification via immersion in concentrated sulfuric acid (60-120 minutes followed by thorough rinsing), hot water (82°C), or by mechanical means. Germination of sound seed should be in the range of 75 95 percent. Seeds should be sown .5 to 1.5 cm deep and if properly scarified, complete germination will occur within 21 days of sowing.

Establishment

For successful propagation of honeylocust, chip budding with green wood in August works best, and June budding is also satisfactory. Dormant scionwood results in a low percentage of successful grafts (pers. comm. A. Wilson). One-year-old seedlings (or budded/grafted material) can be outplanted the following spring. Dormant, nursery grown seedlings can be stored, barerooted, at about 0° C for several weeks before outplanting. Due to large variation in pod production from different parent trees, and the presence of both male and female trees, only grafted seedlings are recommended for planting in order to secure consistently high production at an early age. Grafted seedlings begin to bear pods at age three and by age eight will produce 20-75 kg dry weight per tree (Wilson, 1993).

Management

Male trees (about 10%) must be included in or adjacent to fodder orchards to ensure pollination of female trees. When established in working pastures, young trees need protection via plastic tree shelters or electric fencing (Wilson, 1993). Appropriately managed, average annual pod production at age 10 of 40 kg/tree appears feasible. Planting 75 trees/ha (excluding male trees) would yield 3,000 kg/ha, sufficient to provide 100 sheep a 1.5 kg ration of pods for 20 days. Using conservative yield estimates from grafted trees, economic analyses indicate internal rates of return varied from 9 - 13% (Wilson, 1991).

Symbiosis

Typical of many caesalpinioid genera, *Gleditsia triacanthos* do not nodulate and lack an ability for symbiotic fixation of atmospheric nitrogen (Allen and Allen, 1981).

Limitations

Thorns on mature trees (twigs, branches and bark) are extremely dangerous as they can puncture tractor tires and injure livestock and increase the difficulty of orchard/windbreak management. Volunteer reproduction of thorny seedlings, usually derived from seeds eaten and not digested by wild and domestic animals, is also a concern.

The mimosa webworm, *Homadaula anisocentra* is a serious defoliant and heavy infestations of spider mites (*Eotetranychus multidigituli*) occur during dry weather and can also defoliate a tree (Blair, 1990).

Research

Research needs include additional production data from silvopastoral systems, development of consistent, heavy bearing, genetically thornless, high protein cultivars for a range of sites and end uses; and development of high sugar varieties for ethanol production (Gold and Hanover, 1993).

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A complete set of references is available from FACT Net

FACT Sheet

FACT 98-04
A quick guide to multipurpose trees from around the world June 1998
(updates NFTA 86-06)

Gliricidia sepium : The Quintessential Agroforestry Species

Gliricidia sepium is a versatile, fast-growing tree favored by farmers for living fences, fuel, fodder, green manure, shade, support for crops, and erosion control. Common names include madre de cacao, mata ratón, palo de hierro, cocoite (Central America), kakawati (Philippines), gamal (Indonesia), quick stick (Jamaica) and gliricidia. Gliricidia sepium is not synonymous with *G. maculata*, a closely related but much less useful species.

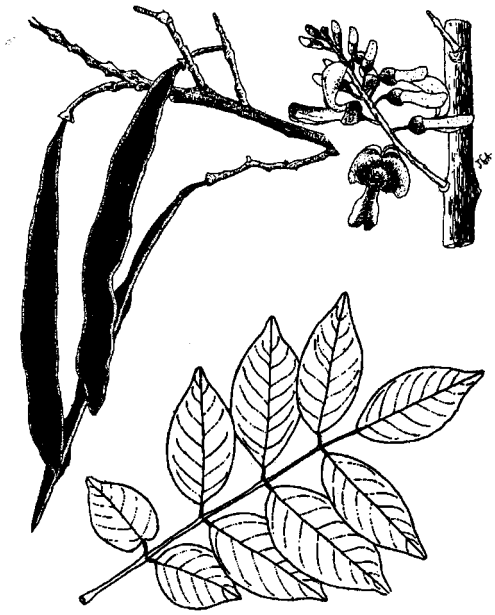
Botany

Gliricidia sepium (Jacquin) Steudel is a small to medium sized tree attaining heights of 2 to 15 meters. It may be either a single or multiple stem tree with trunk diameters reaching 30 cm. The bark is grayish-brown to whitish and may be deeply furrowed on old, large diameter trees. Leaves are pinnately compound, alternate in arrangement and 20 to 30 cm in length. Leaflets are generally opposite in arrangement, oblong in shape and pointed at the tip. On some specimens leaflets may be elliptical with rounded tips. There are 7 to 25 leaflets per leaf and size increases towards the tip. Leaflets are 40 to 80 mm long and 20 to 40 mm wide (Lavin 1996).

Flower development corresponds to the beginning of the dry season when trees have lost their leaves. In its native range flowering occurs November through March. In areas without a pronounced dry season, flowering may occur throughout the year but few pods form (Lavin 1996, Simons 1996). Flowers are pink to light pink in color, fading to white with brown spots or faint purple with age (Lavin 1996). The flowers are pollinated by the larger solitary bees *Xylocopa fimbriata* and *Centris* species in the tree's native range. Other potential pollinators have trouble accessing the flower due to the rigidity of the keel pedals (Simons 1996). A lack of effective pollinators will greatly hinder pod and seed production. Pods can reach full size, 10 to 20 cm, within 3 weeks of fertilization. The green succulent pods turn woody and yellow with maturity, which requires 35 to 60 days. Pods contain 3 to 10 seeds and are explosively dehiscent (Lavin 1996, Simons 1996). Seed collection is recommended prior to pods opening.

Ecology

Gliricidia sepium is native to the lowland dry forests from sea level to 1,200 m. It is uncommon above this elevation because of its sensitivity to cold. The temperature range is 20 to 30° C. It performs poorly below this range but will tolerate temperatures as high as 42° C (Glover 1989). Rainfall is generally from 900 to 1,500 mm/year, but may be as low as 600 mm or as high as 3,500 mm (Simons 1996). The dry season varies from3 to 8 months, however *Gliricidia sepium* survives dry seasons of 9 months in Indonesia.



Source : Little and Wadsworth, 1964

It grows well on many soil types; volcanic, sandy, stony, and heavy clays, including Vertisols. It is reported to tolerate some salinity and slightly alkaline soils. It will tolerate acid soils, but not severe acidity (pH less than 4.5) nor high aluminum saturation (greater than 60%). An aggressive pioneer, gliricidia readily colonizes infertile soils and reclaims *Imperata* grasslands (MacDicken et al 1997). Its name gamal means '*Imperata* killer'. It sprouts quickly after fire and thus may benefit from burning.

Distribution

The true native range of *G. sepium* is restricted to the dry and sub-humid lowlands of the Pacific coast of Mexico and Central America, and adjoining dry inland valleys (Simons 1996). Native Americans domesticated the species into other parts of Central America. The Spanish introduced it into the Caribbean and the Philippines. Over the last century gliricidia has become common throughout the tropics.

Uses

Living fence. *Gliricidia sepium* may be the most common living fence species in the tropics. Fence posts are established from large stakes (see **Propagation**). They may be planted at 1 to 2 m spacing and joined with barbed-wire or bamboo. Alternatively, they maybe planted 10 to 20 cm apart as a stockade and their branches interwoven (Stewart 1996). Fuelwood, stakes, fodder and green manure are harvested from fences.

Written by James M. Roshetko, Winrock International

Fuelwood. Hard and durable, the wood has a specific gravity of 0.5 to 0.8. It makes a good fuel, burning with little smoke and no sparks, and has a calorific value of 4,900 kcal/kg. Natural stands, secondary forests and woodlots of gliricidia have been managed for commercial fuel production (Glover 1989, Stewart 1996). The wood is also used for poles, timber, furniture and agricultural implements.

Fodder. Responding well to frequent cutting, gliricidia produces abundant amounts of nutritious fodder containing 18 to 30% crude protein. Livestock respond well to the fodder. Some animals are reluctant to eat gliricidia, but training may overcome this problem. Once gliricidia is accepted, subsequent offspring readily consume it. Toxicity problems are reported with non-ruminants. Pruning trees before the dry season enables coppice growth to be retained for use as dry season feed. Fodder plantings vary from hedgerows with 10 to 50 cm in-row spacing and 1 to 4 meter between row spacing, to block plantings of 50 x 50 cm to 1 x 3 m. Production varies from 2 to 20 t/ha (Glover 1989, Stewart 1996, Allison and Simons 1996). Pod peels are eaten by livestock as a dry season fodder in Bali.

Farming Systems. When used as mulch or green manure, the nitrogen-rich foliage improves crop production through the addition of nutrients, weed control, conservation of moisture and reduction of soil temperature. Leaf biomass is usually produced from hedgerows or fences around or in the cropping area. Companion crops include paddy and upland rice, corn, cassava and coconuts. Hedgerows are used on sloping farmland for erosion control and passive terrace formation. Hedgerow management should minimize competition with crops. Hedgerow systems can be labor intensive, which may limit their adoption. Gliricidia is used as a shade for tea, coffee and cacao; and as a support for cassava, yams, vanilla, pepper, and passionfruit. These crops also benefit from the soil improvement characteristic of gliricidia. The presence of gliricidia in fields reduces incidence of some fungal and insect attacks (Glover 1989, Stewart 1996).

Other uses. Flowers are bee forage. Cooked leaves and flowers are used as a human food. Gliricidia is used to make medicines, rodenticides and insecticides. It is also used as a windbreak and ornamental. Cut boles are used to propagate orchids.

Silviculture

Propagation. This species is easy to propagate by cutting or seed. Large sized cuttings, 1 to 2.5 m in length and 6 cm in diameter, are made from branches 1.5 to 2.0 years old. Small cuttings are 30 to 50 cm long and made from branches 6 to 12 months old. Branches used for cuttings should be straight and healthy, and without side branches. The top of the cutting should be cut on a slant to prevent water collection and subsequent rot. The bark on the lower portion of the cutting should be scarred through to the cambium with a sharp knife to encourage rooting. One-third of small cuttings can be buried. For large cuttings 50 cm is sufficient. Trees established from cuttings will have a shallow root system and a short bole. They are susceptible to uprooting by heavy winds.

Seed is yellow to brown in color with 4,500 to 11,000/kg. Under optimum storage conditions—6 to 10% moisture content at 4° C—seed remains viable for over 10 years (Allison & Simons 1996). At 50% moisture content and 17° C seed can be stored for a year (Hensleigh and Holaway 1988). Seed is sown without pre-treatment directly into nursery containers. Standard nursery management practices are recommended. Seedlings are ready for transplanting after 2 to 3 months in the nursery at a height of 30 cm. Direct sowing is possible with 2 to 3 seeds per planting position at a depth of 1 to 2 cm. Site preparation is required to reduce competition. Direct sowing and transplanting operations should coincide with the rainy season. Seedlings are sensitive to competition. Regular weed control should be practiced until trees are established.

Seed production. There is strong international demand for gliricidia seed. Depending on location and provenance, seed price varies from $2 to $120/kg. Seed shortages, particularly for superior provenances, indicate that seed production may be a profitable agricultural activity. In Southeast Asia, the International Centre for Research in Agroforestry (ICRAF), Winrock and local collaborators are developing seed production guidelines for farmers.

Pests

Gliricidia is relatively free from insect and disease problems. Boa and Lenné (1996) provide a list of reported problems.

Symbiosis

Gliricidia sepium fixes atmospheric nitrogen with *Rhizobium* soil bacteria. If gliricidia is being introduced to a new area or degraded site, seed or plants should be inoculated with the appropriate *Rhizobium* bacteria before planting. A list of *Rhizobium* suppliers is available from FACT Net.

Provenances

Growth and yield varies greatly among provenances. The Oxford Forestry Institute (OFI) has conducted extensive trials with 28 provenances. Provenance Retalhuleu (Guatemala) is superior for leaf and wood production, and stem length. Provenance Belan Rivas (Nicaragua) is consistently good for leaf and wood production. Other provenances are appropriate for specific sites or uses (Dunsdon and Simons 1996).

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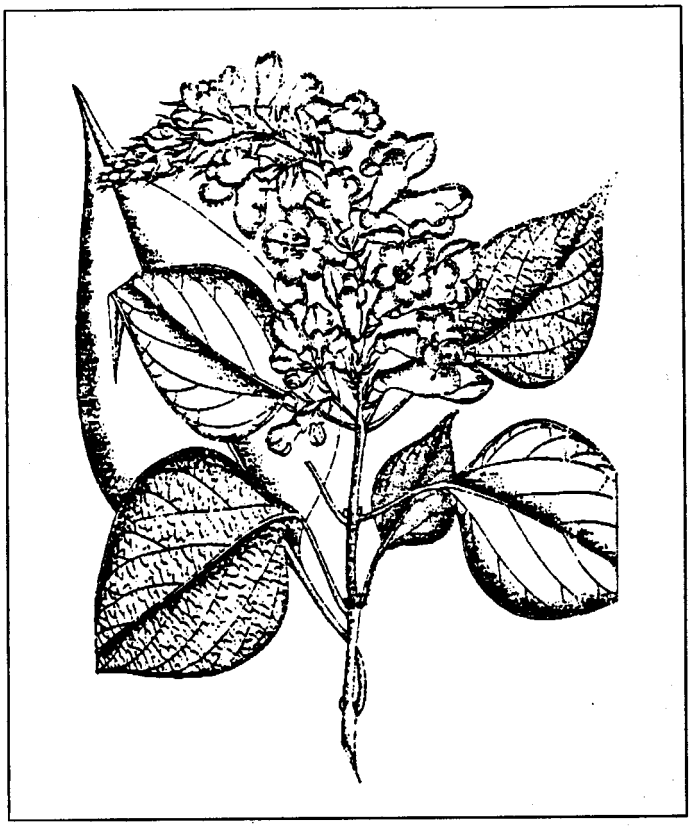
FACT 99-05

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

Gmelina arborea : A Popular Plantation Species in the Tropics

Gmelina arborea Roxb. (family Verbenaceae) is a fast growing tree frequently planted in plantations to produce wood for light construction, crafts, decorative veneers, pulp, fuel, and charcoal. The species is also planted in *taungya* systems with short-rotation crops and as a shade tree for coffee and cacao. It is commonly called gmelina and white beech (English), melina (Spanish), gamar in Bangladesh, melina/gambar in India, gemelina in Indonesia, yemane in Philippines and soh in Thailand, and it has many regional names (Brandis 1906, F/FRED 1994).



Botany

Gmelina arborea is a medium-sized deciduous tree up to 40 m tall and 140 cm in diameter, but usually smaller than this (Jensen 1995). The tree form is fair to good, with 6–9 m of branchless, often crooked trunk and a large, low-branched crown. The bark is thin and gray. Leaves are simple, opposite, more or less heart-shaped, 10–25 cm long, and 5–18 cm wide. The yellow or brown flowers are arranged in panicled cymes 15–30 cm long, which appear after leaf-fall. The trumpet-shaped flowers are 4 cm long and are hairy and short-stalked. The fruit is a drupe 2–2.5 cm long and contains 1–4 seeds (Khan and Alam 1996). The number of seeds per kilogram varies from 700–1400 (Evans 1982) to 2500 (Katoch 1992).

Ecology

Gmelina arborea is found in rainforest as well as dry deciduous forest and tolerates a wide range of conditions from sea level to 1200 m elevation and annual rainfall from 750 to 5000 mm. It grows best in climates with mean annual temperature of 21–28°C (Jensen 1995). Gmelina grows best on deep, well drained, base-rich soils with pH between 5.0 and 8.0. Growth is poor on thin, highly leached acid soils (F/FRED 1994).

Distribution

Gmelina arborea originated in an area of South and Southeast Asia from Pakistan and Sri Lanka to Myanmar. It has been widely planted in Southeast Asian countries including Bangladesh, Myanmar, Thailand, southern China, Vietnam, Indonesia and the Philippines (Jensen 1995). It has been planted less widely in tropical African and Latin American countries (Evans 1982).

Uses

Wood. The wood is yellowish or grayish-white, even-grained, and very useful for planking, paneling, carriages, furniture, and carpentry of all kinds (Khan and Alam 1996). The wood specific gravity is 0.42–0.64 (Davidson 1985). It is easily worked, readily takes paint or varnish, and is very durable under water (Gamble 1922). The wood is used for light construction and pulp as well as for fuelwood and charcoal. Fuelwood provides 4400–4800 Kcal/kg (Davidson 1985). The wood is used in Myanmar for carving images and canoes (Gamble 1922), and is excellent material for match manufacture, packing cases, and all ornamental work. It is also used for making quality toys and picture frames.

Other Uses. The leaves and fruits of gmelina are used as fodder in many parts of India (Mukherjee 1884, Benthal 1933, Laurie 1945). A number of the plant's parts have medicinal value. It also produces good quality honey.

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Silviculture

Propagation. The species can be propagated by seeds, cuttings, and stumps (Alam et al. 1985). Under natural conditions germination takes place in the rainy season soon after fruits fall from the tree. The germination rate for fresh seed is 65–80%. Fresh seed can be stored at room temperature for about 6 months. Seed stored at 4°C will remain viable for about three years. The seed should be soaked in cold water for 24 hours before planting. Seeds should be planted in germination beds with a mixture of sand and loam and covered with a thin layer of sand or compost. Seeds germinate in 2–3 weeks and are ready for transplanting to poybags when the first pair of leaves appears. A 10 x 15 cm polybag is widely used in Bangladesh. Root pruning and hardening off of the seedlings are beneficial for maximum field survival. The bare-root seedlings should have a minimum base diameter of 1 cm with a well balanced shoot-root ratio. Seedlings are ready for planting in the field when they reach a height of 30–45 cm, usually in 6 months.

For stump planting, seeds should be sown at the rate of 90 seeds per square meter. Seedlings are usually ready for stump preparation in 7–8 months and should have a root-collar diameter of at least 2.5 cm. The stem and roots of seedlings should be pruned back to 5 cm and 20 cm, respectively. Stump planting is not widely practiced due to high mortality (50% mortality is common).

Management. Outplanting starts at the onset of the rainy season and the spacing of the plantations depends on the objectives of the plantation and the end-uses. A spacing of 2 x 2 m is commonly used for plantation programs, and a spacing of 4.5 x 4.5 m is used for agroforestry. Under favorable conditions the growth of the seedlings is rapid, particularly from the second year onward. Because gmelina is shade-intolerant and sensitive to competition, 3–4 weedings are required during the first two years of growth. Rotations for pulpwood and sawnwood are usually 6 and 10 years, respectively. Rotations of 5–10 years are common for fuelwood. Stands on 10-year rotations are thinned to 50% at five years and another 50% at seven years. The second rotation is usually produced by coppicing. Seedlings and stumps are planted for a third rotation.

The growth of the species is remarkably fast and on good sites can reach 20 m height in 5 years. The tree attains more than 30 m in height with about 60 cm dbh at maturity. Form of the tree is fair to good, with 6–9 m of clear bole. Some trees can reach 3 m after a year from planting and 20 m after 4.5 years.

In Nigeria, the yield of gmelina is 84 m^3/ha at age 12 in poor sandy soils, 210 m^3/ha at age 12 in clay or lateritic soils, and 252 m^3/ha at age 10 in favorable alluvial soils—all volumes are underbark to 7.5 cm top diameter (Adegbehin et al. 1988). In Sabah, Malaysia, gmelina produces an average volume of about 25 m^3/ha/year on clayey loam soils with adequate moisture (Wong and Jones 1986).

Tree Improvement

In an evaluation of international trials containing 39 provenances of *Gmelina arborea* averaging 13 years of age, Lauridsen et al. (1995) concluded that in most regions the best results in terms of survival, health, and production can be achieved through selection from local landraces. An exception is Latin American landraces, which generally performed below average. The authors further recommend the inclusion of specific natural provenances from northern and northeast India. Some good provenances were identified in north, central-eastern, and southwest India, and Thailand-Malaysia. Provenances from central-north and central-west India are inferior.

Faster growing provenances have 2–3% lower wood density than average, corresponding to a weight decrease of approximately 12 kg/m^3 (Lauridsen et al. 1995).

Limitations

Armillaria mellea, *Ceratocystis fimbriata*, *Ganoderma colosum*, *Gnomonia* spp., and *Poria rhizomorpha* are some of the fungi that cause serious damage to gmelina. The species is heavily infested by mistletoe, *Scurrula gracilifolia*. The insect *Craspedonta leayana* causes serious defoliation in Bangladesh (Khan and Alam 1996).

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FACT 98-05

A quick guide to multipurpose trees from around the world September 1998

Grevillea robusta : A Versatile And Popular Tree For Farm Forestry

Grevillea robusta A. Cunn. ex R.Br., commonly known as Silky Oak or Silver Oak, has gained widespread popularity in warm temperate, subtropical and tropical highland regions of many countries, originally as a shade tree for tea and coffee and more recently as an agroforestry tree for small farms. It provides economically valuable products including timber, poles, firewood and leaf mulch; it is easy to propagate and establish and is relatively free of pests and diseases; its proteoid roots help it grow in low-fertility soils; it does not compete strongly with adjacent crops; and it tolerates heavy pruning of its roots and branches. With its fern-like pinnate leaves and prominent attractive orange flowering display, it is also popular as an ornamental.

Botany

Grevillea robusta is the largest species in the genus *Grevillea*, in the plant family Proteaceae. It has no recognized subspecies or varieties, and no hybrids with other species have been recorded (McGillivray and Makinson, 1993). It is an erect single-stemmed tree typically reaching an adult size of 20–30 m in height and 80 cm in diameter in its natural range. The crown is conical and symmetrical with major branches spaced at intervals of about 1 m and projecting upwards at an angle of 45°. Bark on the trunk is dark gray and furrowed into a lace-like pattern. The fern-like foliage of this species is very distinctive. Leaves are 10–34 cm long and 9–15 cm wide, variably pinnate to bipinnate, with a smooth green upper surface and hairy silvery undersurface. Petioles are 1.5–6.5 cm long.

The bright orange flowers, about 2 cm in length, are borne in numerous pairs along the flower spikes, on pedicels 1.5 cm long. Fruits are two-seeded follicles 2 cm in length, with a slender persistent style. Seeds are winged, 13–19 mm long x 8-10 mm wide and 0.8–0.9 mm thick, with a papery wing around the brown, ovate central seed body.

Distribution

The natural habitat of *G. robusta* is in northern New South Wales and southern Queensland, Australia, where it occurs from the east coast to as far west as the Bunya Mountains, Queensland, up to an altitude of 1120 m (Harwood, 1992a).

Grevillea robusta has been introduced to warm temperate, subtropical and tropical highland regions around the world commencing in the mid to late 19th century and is widely planted in India, Sri Lanka, Central and South America and many countries in Africa (Harwood, 1989).

Environmental amplitude.

The natural distribution is in the warm humid to warm sub-humid climatic zones. However, the species has performed well when introduced to a much wider range of climates. In its native range mean annual precipitation is 700-2000 mm and mean annual temperature is 15-20°C.

Towards the hotter extremes of the tolerated temperature range, the dry season should be no longer than 4 months for good growth. *Grevillea robusta* performs poorly in lowland tropical environments where mean annual temperature exceeds 23°C, and very wet locations where annual rainfall exceeds 2000 mm.

Grevillea robusta has some resistance to frost. During the winter months in temperate latitudes, it can survive temperatures down to minus 8°C with little or no damage, but milder frosts of only minus 2°C or so will cause damage during the growing season. Low-intensity ground fires will kill seedlings and young trees. It cannot withstand severe gales or persistent strong winds without damage to the branches.

Grevillea robusta prefers rather fertile soils such as those derived from river alluvia or basalts but will grow on shallower less fertile soils derived from sedimentary material. The pH range for good growth is around 4.5 to 7.5. Best growth is obtained on sandy loam, loam and clay loam textures. Heavy clay soils and prolonged waterlogging are not tolerated.

Uses

Wood. The air-dry density of heartwood is 550–650 kg m^{-3}, that of sapwood and branches is lower. The heartwood is pale pink on cutting, darkening to red-brown after drying, while the sapwood is cream colored. The sawn timber is of medium strength and is used for furniture, packing cases, flooring, paneling, plywood and the manufacture of small wooden items such as pencils (Bolza and Keating, 1972; Skolmen, 1974). The wood produces short-fiber pulp of acceptable quality (Ghosh, 1972) but has not been used for pulp production on a commercial scale. The branches and twigs are used for firewood and charcoal. Poles are used for house construction in rural areas, scaffolding and rafters (Spiers and Stewart, 1992).

Agroforestry. *Grevillea robusta* is one of the most important trees for agroforestry in the tropical highlands of Eastern and Central Africa. It is commonly planted as a boundary tree around the perimeter of small farms, in a single

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row at 2–2.5 m spacing. It is also planted in rows between small fields, and as scattered individuals over crops such as coffee and maize (Spiers and Stewart, 1992). Akyeampong *et al.* (1995) found that *G. robusta* produced the highest wood volume (18.1 m^3ha^{-1} at 3.5 years) of 9 tree species tested in agroforestry trials in Burundi when planted at 312 stems ha-1, intercropped with banana and beans. Yield of bananas was not affected to age 3.5 years, while bean yields were reduced by 29% in the 7th harvest at age 3.5 years.

In addition to their use as a soil mulch, the leaves of *G. robusta* are used by some farmers in the Embu district of Kenya as a fodder supplement for cattle in the dry season when other fodder sources are scarce (Spiers and Stewart, 1992). They are also used as bedding in livestock stalls.

Tea and coffee shade. From the late nineteenth century onwards, *G. robusta* has been planted extensively as high shade for tea and coffee plantations, and this use continues in many countries. The trees are often pollarded to produce a spreading crown, and have a typical working life of 40–50 years before they become senescent and must be replaced (Rao 1961). Shade trees of *G. robusta* provided effective protection against frost that caused extensive damage to open-grown coffee plants in southern Brazil at planting densities of 71 and 119 *G. robusta* trees per hectare, but not at 26, 34 and 48 trees per hectare (Baggio *et al.*, 1997). In this study, economic productivity of coffee and grevillea wood at 34, 48 and 71 trees per hectare was greater than that of coffee in unshaded plantations. Only at 119 trees per hectare was there a significant (15%) reduction of total coffee production to age 10 years, relative to unshaded stands. Its use as tea shade has been largely discontinued in Kenya and Rwanda because of the risk of *Armillaria* and other root pathogens spreading from dead *G. robusta* roots to those of the tea plants (Tea Research Institute of East Africa, 1969).

Silviculture

Silvicultural characteristics. *Grevillea robusta* grows well in row plantings and as scattered trees over food and cash crops in warm temperate and subtropical climates. Recent studies on root architecture and water uptake indicate that *G. robusta* is relatively deep-rooted and thus may compete less with crop roots than do other trees (Howard et al., 1996). It tolerates repeated heavy pruning and pollarding, enabling farmers to regulate the degree of competition with adjacent crops.

Propagation. Propagation is usually from seed. There are about 40,000 viable seeds/kg. Seed will retain viability for at least five years if dried to below 8% moisture content and stored in a dry, cool (20°C or lower) environment (Jones, 1967; B.V. Gunn, CSIRO Forestry and Forest Products, pers. comm. 1998). No pretreatment is required for germination. Seedlings are pricked out when their second leaf-pair starts to develop, into tubes or plastic bags filled with a fertile loamy potting mix. Seedlings are grown for around 4-6 months in the nursery until planting out at a height of 20–40 cm during the rainy season. Cuttings can be easily struck using shoots of seedlings or saplings (Swain, 1928), which can also be air-layered.

Establishment. As the species is usually planted in rows or small woodlots, or as scattered individual trees, mechanical site preparation is seldom used. Some control of competing vegetation is required for the first 1–2 years after planting. This is normally achieved by several rounds of manual weeding. Fertilizer is seldom applied: 50 g per tree of an NPK fertilizer (12:12:12) applied shortly after planting would be appropriate for infertile soils.

Management. When planted in woodlots (2.5 m x 2.5 m) and line plantings (2–2.5 m between trees), thinning of inferior trees is often carried out at age of around 4-5 years to yield poles and firewood for local use or sale. Farmers in the African highlands commonly harvest branches by high pruning and pollarding every 3–4 years from age 4–6 years onwards (Poulsen, 1983; Spiers and Stewart, 1992). Some African farmers prune the surface roots of *G. robusta* by digging with a hoe at a distance of around 30 cm around the trunks of trees growing in and around fields, to reduce competition with adjacent crops.

Growth and yield. When grown at close spacings in plantations and woodlots, the growth rate of the species is relatively modest. For example, the estimated mean annual wood yield in tropical highlands is only some 10–12 m^3ha^{-1} over 10–15-year rotations at recommended stocking of 800–1200 trees/ha (Pandey, 1987). *Grevillea robusta* is therefore not a high priority plantation timber species.

When it is planted singly or in lines, annual growth rates of 2 m (height) and 2 cm (diameter) over the first 5 years are commonly achieved in a number of countries where climate and soils are suitable.

Grevillea robusta coppices well after being cut back to ground level at ages of up to two years, but coppicing ability declines sharply thereafter, so management on a coppicing rotation is not feasible.

Symbiosis

The species does not form symbiotic associations with soil bacteria or mycorrhizal fungi, although it develops proteoid roots (sections of the secondary roots which develop as dense cylindrical clusters of rootlets, about 1 cm in diameter). These develop under conditions of low phosphorus availability are believed to enhance nutrient uptake. (Skene et al., 1996).

Limitations

In the humid tropical lowlands and other regions with high humidity, *G. robusta* is vulnerable to attack by fungal diseases such as *Botryosphaeria dothidea* (Guatemala; Schieber and Zentmeyer, 1978) and *Corticium salmonicolor* (Karnataka State, India; Nayar, 1987). In lowland environments in the Caribbean *G. robusta* is severely attacked by the scale insect *Asterolecanium pustulans* (Martorell, 1940) effectively precluding its use there. Attack by termites can be a problem when the species is planted on dry sites in Africa. *Grevillea robusta* is an effective colonizing species and, in some cases, threatens to be a noxious weed (e.g. in Hawaii, Nelson and Schubert, 1976).

Provenances and genetic improvement.

Provenance-progeny trials testing seed collections from across the natural range have recently been established in several countries including Australia, Kenya and Rwanda. These trials provide a good genetic base for breeding programs.

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A quick guide to multipurpose trees from around the world

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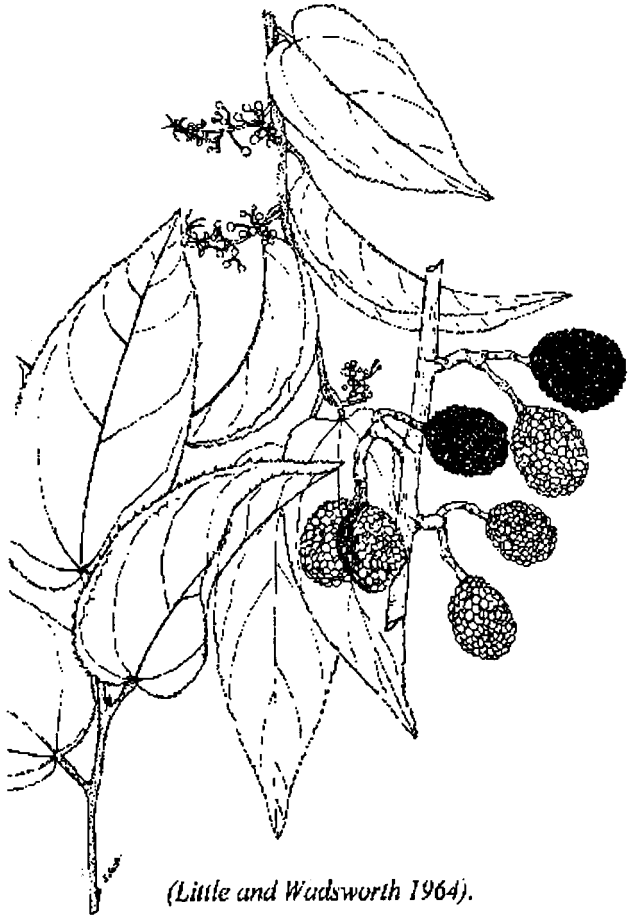
Guazuma ulnifolia : Widely Adapted Tree For Fodder And More



(Little and Wadsworth 1964).

A small to medium-sized tree, *Guazuma ulmifolia* is widely distributed throughout the Caribbean, Mexico, and Central and South America. The wood is used for posts, general carpentry, light construction and charcoal. It is an important source of livestock fodder in many areas, particularly during the dry season when pasture grasses are unavailable.

Common names include guácima, guácimo (Spanish); tablote, majagua de toro (Mexico); tapaculo (Guatemala, El Salvador); cualote (Guatemala, Honduras, El Salvador, Colombia); contamal (Guatemala); chicharrón (El Salvador); kamba aka guasa (Paraguay); iumanasi, papayillo (Peru); coco (Bolivia); cambá-acá, guazuma (Argentina); bacedar, bastard cedar (Jamaica, Trinidad); bois d'orme, West Indian Elm (Trinidad); pigeon wood (Tobago); bay cedar, caulote, pixoy (Belize); bois d'orme, orme d'Amérique (French); mutamba, fruta-de-macaco, embira, pojó (Brazil) (Little and Wadsworth 1964, Lopez et al. 1987, Lorenzi 1992).

Botany

Synonyms include *Guazuma guazuma* (L.) Cockerell, *G. tomentosa* H.B.K., *G. polybotrya* Cav., and *Theobroma guazuma* (L.) Poveda. *Guazuma ulmifolia* Lam, family Sterculiaceae, grows to 30 m in height and 30-40 cm in diameter with a round-shaped crown. The alternate, ovate to lance-shaped leaves are 5-7 cm long and 2-5 cm wide, with finely saw-toothed margins. The flowers are brownish-yellow and form in clusters at the base of the leaves. The seeds are black, round to elliptic, 1.5-3 cm long, and hard. Seed capsules contain 5 cells which open at the apex and contain many seeds, 3-5 mm in diameter (Little and Wadsworth 1964, Lopez et al. 1987). Young twigs are covered with rust-brown or light-gray star-shaped hairs. The bark is gray or gray-brown and becomes furrowed and rough or slightly shaggy (Little and Wadsworth 1964).

Ecology

Guazuma ulmifolia is widely adapted, growing in alluvial and clay soils, and in humid and dry climates. A pioneer species that grows best in full sunlight, it colonizes recently disturbed areas and is also found growing along stream banks and in pastures. It is a common species in secondary forest growth.

Guazuma ulmifolia grows mainly at elevations below 400 m with mean annual temperatures often above 24(C (Dunsdon et al. 1991). It is occasionally found growing up to 800 m in Brazil (Lorenzi 1992), 1000 m in Costa Rica (Vallejo and Oviedo 1994) and 1200 m in Guatemala (Witsberger et al. 1982). In its natural habitat annual rainfall is 600-1500 mm, but it grows well in areas with annual rainfall as high as 2500 mm (Dunsdon et al. 1991).

Leaves remain on the tree all year except in very dry areas where the leaves drop at the end of the dry season. In Puerto Rico, *G. ulmifolia* flowers from March to October and produces seed all year (Little and Wadsworth 1964). In Paraguay, it flowers in January and produces seed from July to August (Lopez et al. 1987). In Brazil, it flowers from January to September and produces seed in August and September (Lorenzi 1992).

Distribution

Guazuma ulmifolia is found in the Caribbean, Mexico, Central America and Colombia, Ecuador, Peru, Bolivia, Paraguay, Argentina, and Brazil. It has been cultivated in India for over 100 years. It has been introduced recently to Indonesia.

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Uses

Wood. The wood is used for posts, interior carpentry, light construction, boxes and crates, shoe horns, tool handles, fuelwood, and charcoal. The sapwood is light brown and the heartwood is pinkish to brownish. The wood is easy to work, with a specific gravity of 550-570 km/m^3 (Little and Wadsworth 1964,Lopez et al. 1987).

Fodder. In dry areas throughout its native range, *G. ulmifolia* is an important source of fodder for livestock, particularly at the end of the dry season when pasture grasses are not available. Naturally regenerated trees are left scattered in pastures to provide shade. Trees are also planted as live posts for fences around pastures. In Puerto Rico, immature fruits and leaves are fed to horses and cattle, and fruits are fed to hogs (Little and Wadsworth 1964). *Guazuma ulmifolia* is a preferred fodder tree in Jamaica. Farmers feed the leaves and fruit to cattle, usually during the dry season (Morrison et al. 1996). Crude protein content of young leaves and stems ranges from 16-23% and 7-8%, respectively. In vitro dry matter digestibility for young leaves and stems ranges from 56-58% and 31-36%, respectively (Araya et al. 1994, Medina et al. 1994). Basal leaves contain 2.4% tannins (dry matter) (Araya et al. 1994).

In a study in Honduras, *G. ulmifolia* pruned four times in one year produced 10 kg/tree dry matter (leaves and young stems). Of the dry matter, 38% was edible (Medina et al. 1994).

A study in Guatemala compared the weight gain of young goats fed fodder of *G. ulmifolia*, *Cordia dentata*, and *Panicum maximum*. The average weight gain with *G. ulmifolia* was 71 g/day, compared to 60 g/day with *C. dentata*, and 42 g/day with *P. maximum* (Medina 1994).

Medicinal uses. A beverage of crushed seeds soaked in water is used to treat diarrhea, dysentery, colds, coughs, contusions, and venereal disease. It is also used as a diuretic and astringent (Vallejo and Oviedo 1994).

Other uses. The seeds are edible, fresh or cooked. The tough, fibrous bark and young stems are used to make rope and twine. Honey bees forage on the flowers (Little and Wadsworth 1964).

Silviculture

Propagation. *Guazuma ulmifolia* can be established by direct seeding or by planting cuttings, root-stumps or bare-root seedlings. Seeds require scarification before planting. Pour boiling water over seeds, let them soak for 30 seconds and then drain the water (Dunsdon et al. 1991). For fresh seeds, germination occurs in 7-14 days at a rate of 60-80%. Seedlings are ready for outplanting when they reach a height of 30-40 cm (about 15 weeks). For root stumps, plants are left in the nursery for 5-8 months or until they reach a stem diameter of 1.5-2.5 cm. There are between 100,000 and 225,000 seeds per kilogram (Vallejo and Oviedo 1994, Lorenzi 1992, Dunsdon et al. 1991).

Pests

Hilje et al. (1991) reviews pests of *G. ulmifolia* in Central America. *Phelyypera distigma* is a common defoliating insect. *Arsenura armida* and *Epitragus* sp. are defoliators that cause problems occasionally. *Automeris rubrescens, Hylesia lineata, Lirimiris truncata* and *Periphoba arcaei* are defoliating insects that have been observed at least once. A stem borer *Aepytus* sp. is an occasional problem.

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NFT Highlights

A quick guide to multipurpose trees from around the world

NFTA 93-02
June 1993

Hippophaë rhamnoides : An NFT Valued For Centuries

Hippophaë rhamnoides L., commonly known as sea buckthorn, is an arborescent shrub of wide adaptability distributed throughout more than 20 countries of Europe and Asia. The species has a history of utilization that goes back at least 12 centuries. An actinorhizal plant, sea buckthorn has the capacity to fix atmospheric nitrogen and thus enrich the soil. It is used successfully as a windbreak and to stabilize sand dunes, and several of its products have high value.

Botany

Sea buckthorn is a deciduous shrub or small tree, with thorns and unisexual flowers. It is dioecious and wind pollinated. Its fruit is a drupe, reddish orange, varying in length from 5 to 12 mm, with a tart, bittersweet taste. Each fruit has one bone-hard seed. Shrubs usually begin to bear fruit after three years and give maximum yields after seven to eight years.

Hippophaë rhamnoides L., commonly known as sea buckthorn.

The trees have an extensive, shallow root system and root-suckering is common. Plants degenerate after approximately 15 years and then reproduce by suckering. Rousi (1971) divided the genus *Hippophaë* into three species. More recently, Lian (1988) revised the taxonomy, dividing the genus into five species. *Hippophaë rhamnoides* is by far the most common and references to *Hippophaë* are usually to this species.

Ecology

Sea buckthorn grows anywhere in temperate latitudes, from sand dunes near the sea to the Eurasian plateau at 5200 m above sea level.

Plant characteristics vary considerably according to this wide range of climatic conditions. For instance, these "shrubs" can reach 18m in height in certain zones.

This is a light-demanding species. Trees growing in forested areas will die if the canopy density exceeds 50%. However, they are extremely drought tolerant, with extensive root systems that scavenge soil humidity and groundwater aggressively. They grow readily in areas that receive as little as 250 to 800 mm of rainfall annually. For example, there is a large area of natural *Hippophaë* forest on the loess plateau of China, including the semi-arid regions of Shanxi, Shaanxi and Gansu Provinces. The species is also well adapted to cold climates. There are 18,000 ha of natural *Hippophaë* forest in Siberia where the temperature commonly drops well below 0°C. Sea buckthorn is also tolerant of alkaline and saline soils. It is reported to grow in the Qaidam Basin of China where the salt content of the soil ranges from 0.6 to 1.1% and the pH is 9.5.

Distribution

Sea buckthorn is native to the temperate zones of Asia and Europe, where it is widely distributed. It is also well represented at higher altitudes in the sub-tropical zones of Asia. Russia has approximately 200,000 ha of natural *Hippophaë* forest plus more than 6,000 ha in plantations. With 920,000 ha, China has the largest area under *Hippophaë* of any country, and also the largest variety of *Hippophaë* species.

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Uses

Food. Sea buckthorn fruit is rich in vitamins C, E, K, B1 and B2, as well as niacinamide, pantothenic acid, carotenoids and other substances such as oil, sugar, malic acid, amino acids and pectin. The vitamin C content of the Chinese sea buckthorn (*Hippophaë rhamnoides* subsp. *sinensis* Rousi) fruit can be as high as 1253 mg/100 g^{-1}.

Numerous food products are made from the fruit of this species. For instance, sea buckthorn wine is well known in Russia. In that country, a new variety has been bred by hybridizing geographically distant plants: it produces as much as 10,000 kg/ha^{-1} of fresh fruits. In China, poor peasants have become prosperous by collecting and processing the fruit. *Hippophaë* leaves also contain various nutritious substances and minerals. They are commonly used as tea.

Medicine. There are records of the medicinal use of sea buckthorn as early as the eighth century A.D. The Tibetan medical classic, Four Books of Pharmacopeia, lists 84 prescriptions for the preparation of sea buckthorn medicines. According to one account, a Tibetan lama considered this plant as a general panacea and made extensive use of its roots, stems, leaves, flowers, fruits and seed. The plant was widely used as a folk medicine in ancient Greece, the Roman Empire, Mongolia and Russia. Oil from the fruit acts as an antioxidant and may thus be used to treat wounds, frost bite and pathological problems of the alimentary mucous membranes. Serotonin (5-hydroxy-tryptamine) extracted from sea buckthorn possesses antitumor capabilities.

Animal feed. The ancient Greeks named the genus *Hippophaë*, or "glittering horse," because they believed that horses became plump and healthy when maintained on pastures with these trees. Today, herdsmen in northwest China often feed sea buckthorn leaves to their animals. In Russia, fodder supplements of sea buckthorn by-products are reported to improve liveweights and coat condition. Feeding poultry with meal made from sea buckthorn fruit and fruit oil has been observed to increase the pigmentation of egg yolks and body fat. The oil also increases flesh pigmentation in rainbow trout.

Ecological benefits. *Hippophaë* possesses a strong capacity to fix atmospheric nitrogen in its root nodules when associated with the actinomycete, *Frankia*. Most soils possess enough *Frankia* to support nodulation. In one stand on the east coast of England, annual nitrogen fixation was estimated as high as 179 kg^{-1}/ha^{-1} (Stewart and Pearson, 1967). All of the plant's characteristics, especially its strong nitrogen-fixing ability and rapid growth, make it a good species for improving soil fertility, controlling erosion, conserving water, and stabilizing sand dunes. In mixed plantings, it can promote the growth and development of adjacent plants. Sea buckthorn also shows a strong tolerance for toxic pollutants in the soil and air. It can thus be used to revegetate heavily industrialized areas or to reclaim mining sites.

Other uses. Cosmetics derived from sea buckthorn are widely used in Romania, Russia and China. Massage creams, day creams and a shampoo developed in Romania have received international patents. In addition, the trees yield good-quality fuelwood. In China's western Liaoning Province, a six-year-old sea buckthorn plantation can produce 6.32 t/ha of wood. Sea buckthorn is also useful as an ornamental shrub.

Silviculture

Management varies according to objectives and environment factors. The species propagates well asexually because lignified branches of any age possess a strong ability to form adventitious roots. *Hippophaë rhamnoides* can also be propagated from softwood cuttings under mist. For introduction or breeding trials, seed propagation is the most suitable treatment. The seeds retain their viability after indoor storage for three to four years. Under suitable conditions, they will germinate during any season of the year. In 1977, a large plantation was successfully established on the loess plateau of China by broadcasting seed from aircraft.

Limitations

The wide adaptability and varied reproductive strategies of *Hippophaë rhamnoides* indicate that it could be a serious weed in some environments. Its extensive, suckering root system may make it unsuitable for agroforestry technologies that include close tree/crop associations. In addition, thorns on the stem and branches often make it difficult to harvest the fruits.

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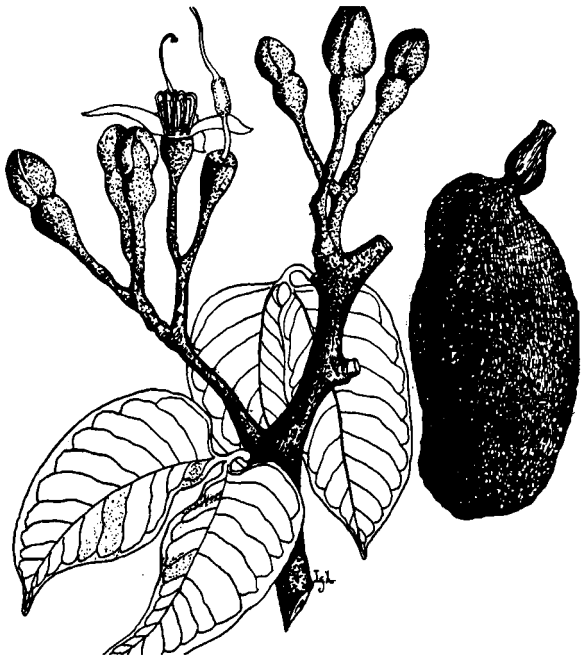
FACT Sheet

FACT 98-06
A quick guide to multipurpose trees from around the world September 1998

Hymenaea courbaril : The Flour Tree



Source: Little and Wadsworth

Hymenaea courbaril L. is a slow-growing large tree with a dense, handsome crown that produces high-quality wood (Timyan 1996). Its hard reddish-brown seeds are used by artisans in El Salvador to create jewelry and miniature paintings on the inside surface of the cut seeds. It is also the source of copal, a resin used for the production of varnish and home remedies.

Botany

Hymenaea courbaril, or copinol is a legume that belongs to the Caesalpinioideae subfamily (Berehdson, 1989). Its white flowers form dense panicles 10 to 15 cm wide and 10 to 15 cm long (Wistberger et al., 1982). Croat (1978) suggests that flowers are pollinated by bats. Copinol has compound leaves with 2 sessile leaflets that are shiny green. The indehiscent woody pods are 10 to 15 cm long and contain 3 to 4 hard reddish-brown seeds, imbedded in a sweet and odorous pulp (Allen and Allen, 1981, Arckcoll, 1984). Copinol grows up to 40 m tall and 1.5 m in diameter. The crown is spreading and sometimes the base develops buttresses. In Costa Rica, copinol blooms between February and May and fruit forms one to two months after flowering. Fruits remain on the tree for seven to ten months (Janzen, 1983).

Common names. Copinol and guapinol (El Salvador, Central America), or "flour tree" in the Nahuatl language, refers to the powdery pulp of the fruits (Wistberger et al., 1982). Other common names include: algarrobo, west indian locust, courbaril (Puerto Rico); rode lokus (Surinam); locust (Virgin Islands); and jatoba, jutai, or jatai (Brazil) (Little and Wadsworth, 1964; Oliveira et al., 1995).

Ecology

The native range of copinol includes Southern Mexico to Central America, northern Brazil, Bolivia and Peru. It is found from 0 to 900 m above sea level (Guatemala) near rivers or streams (Wistberger et al. 1982), on ridges and slopes, and high riverbanks (Chudnoff, 1984). The best growth in its native range occurs where rainfall is 1900 to 2150 mm/yr. I will grow in areas with rainfall as little as 1200 mm/yr. The mean annual temperatures within its native range are from 20 to 30°C. It grows on soils with pH 4.8 to 6.8. (Francis, 1990). It retains its leaves throughout the year (personal observations).

Uses

Wood. The wood is very durable (Timyan, 1996), hard and heavy (0.71 to 0.82 specific gravity). It is moderately difficult to work and resistant to termites, brown-rot and white-rot fungi (Chudnoff, 1984). In El Salvador, it has been used to make wheels for oxcarts (carretas), threading machines (telares), and for general construction (Witsberger et al., 1982). Other uses include furniture, boats, railroad ties, flooring, turnery, and cabinets (Chudnoff, 1984). The wood is suitable for firewood and charcoal. Copal, a resin exuded by the trunk and roots, is used to produce varnish, incense and local remedies.

Human food. The edible pulp is consumed locally in El Salvador and is sometimes sold in food markets. The pulp is used to prepare a sweet beverage (Wistberger et al., 1982). The pulp contains 3.2% sugar, 1.1% fat and 35.8% crude fiber (Francis, 1990).

Medicines. Tea made with the bark is used to control intestinal parasites, indigestion, and cure urinary infections. A liniment made with powdered copal and bark is used to treat external ulcers or rashes (Timyan, 1996). The leaves, cortex and roots of copinol contain tannins, glycosides, and sesquiterpenoids (Mena Guerrero, 1994).

Jewelry and crafts. In El Salvador, seeds are used to make jewelry and other small ornaments. The hard seeds are usually cut in half to work on the inside surface. In some cases the paintings are so small that

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artisans use magnifying glasses to work on them (personal observations).

Ornamental. Because of its large mature size, copinol should be planted only in parks and other open areas. Planting near buildings is not recommended because of its spreading roots.

Wildlife. Capuchin monkeys (*Cebus apella*) open the pods, consume the dry pulp, and drop the seeds (Galetti and Pedroni 1994). Agoutis (*Dasyprocta punctata*) feed on some seeds and bury the leftover seeds for future consumption. The scaly-headed parrot (*Pionus maximiliani*) may consume the seeds (Galetti, 1993). Flowers are a good source of nectar for bees and bats.

Silviculture

Copinol is propagated by seeds. Seedlings are propagated in nurseries before field establishment. Seeds are first scarified either by making a small cut with a file on the hard seed coat (Oliveria et al., 1994; El Salvador Forest Service) or with boiling water. In a boiling water study, seeds from a single tree were collected, dipped in boiling water for 0 to 60 seconds, soaked in water for 24 hours, and planted in sand (Orellana and Navarrete-Tindall, not published). Highest germination rates of 90 and 93% were observed at week six for seeds boiled for 25 and 30 seconds, respectively. The lowest germination rates of 30 and 67% were observed for untreated seeds and for seeds dipped in boiling water for 60 seconds, respectively. Under natural conditions, seeds germinate during the rainy season, sometimes inside the open pod (personal observations). There are about 250 seeds/kg (Francis, 1990).

Attina ants (*Mycocepurus goeldii* Forel) aid in germination by removing the fresh pulp around the seeds of broken pods (Oliveira et al., 1995). Curculionid larvae (*Rhinocenus stigma* and *R.. transversalis*) develop inside the pods consuming the dry pulp and some seeds (Janzen 1983).

Growth and yield. Copinol is shade intolerant, but does require light side shade to produce clear boles for timber production (Francis, 1990). Growth is slow, rarely exceeding 1 m/yr. In a young natural stand in Puerto Rico, the mean diameter increment over a two-year period was 0.53 cm/yr. A 44-year-old plantation averaged about 14 m2 /ha of basal area. Planting density studies are needed, but an initial spacing of 3 m x 3 m and heavy thinning at 12 to 14 years (leaving 77 trees/ha) is suggested. The rotation length to grow trees to 50 cm d.b.h. on good sites is probably 45-65 years (Francis, 1990). The El Salvador Forest Service is including copinol in reforestation programs and natural area planting.

Nodulation studies

Early studies by Allen and Allen (1939) and Bañados and Fernández (1954) reported that roots of copinol trees produced nodules. Recently Navarrete-Tindall et al. (1996), reported that 14 week-old copinol seedlings failed to nodulate when inoculated with 4 rhizobial strains of *Gliricidia sepium*. More research is being done to test cross-compatibility of copinol with rhizobial bacteria from other legumes.

Future research

More extensive studies are required in different environments to test for rhizobial infection. Provenance studies are necessary to select fast growers and high seed producers throughout its distribution range.

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NFT Highlights

A quick guide to multipurpose trees from around the world

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Inga edulis : A Tree For Acid Soil In Humid Tropics

Inga is a large genus of leguminous trees native to the American humid tropics. *Inga edulis*, the best known of the *Inga* species, is popular with agroforesters for its rapid growth, tolerance of acid soils and high production of leafy biomass to control weeds and erosion.

Botany

Inga edulis Mart. is one of about 250 species of *Inga* of the Mimosoideae subfamily of the Leguminosae. It reaches a height of 30 m and a stem diameter (dbh) of 60 cm, and usually branches from below 3 m. The branches form a broad, flat, moderately dense canopy. The bark is pale grey and smooth, with pale elongated lenticels. The young twigs are angular in cross-section and covered in fine short brown hair.

The leaves are once pinnate, up to 24 cm long, with 4 to 6 pairs of opposite leaflets. The terminal pair of leaflets is larger than the basal pair and can be up to 18 cm long and 11 cm wide. Between each leaflet there is a nectary gland on the leaf rhachis; in *I. edulis* these are large (2 to 3 mm) and squashed transversely, an important character for identifying the species.

The leaflets and rhachis are covered in dense, short, rough brown hair. The seedlings have a characteristic grayish sheen on the upper leaf surface. The inflorescences are dense axillary spikes of flowers, each consisting of a calyx tube with 5 lobes (4 to 9 mm long), a corolla tube with 5 lobes (13 to 25 mm long), and a large number of white stamens up to 4.5 cm long, united in a tube in the lower half. In humid climates *I. edulis* may flower throughout the year, but in regions with a short dry season it is most likely to flower at the beginning of the wet season. The inflorescences may not have many flowers open at the same time, but they are usually conspicuous.

The fruits are ribbed, cylindrical pods, straight or often spirally twisted, up to 1 m long (occasionally even longer), and 3 to 5 cm in diameter. They contain fleshy green seeds (3 cm long) in a sweet, white, cottony pulp. They are produced during the wet season, and monkeys and birds eat the sweet pulp and scatter the soft seeds (Castro and King, 1950). These are recalcitrant and sometimes begin to germinate in the pod, often within a few days of reaching the ground where they need humidity to survive.

Distribution and ecology

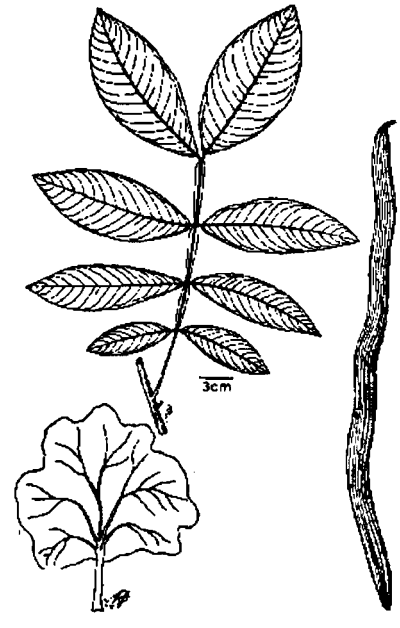
The native range of *Inga edulis* is in Amazonian Brazil, Bolivia, Peru, Ecuador and Colombia. The species has also been introduced across most of tropical South America, Panama and Costa Rica. It grows in hot, humid climates between 26°S and 10°N, and up to 1600 m elevation. It is most widespread in areas without a dry season (Andean South America, western Brazil) or with a dry season of three to four months and minimum annual rainfall of around 1200 mm. It can tolerate short droughts, although in its natural range some rain falls every month.

Inga edulis is particularly tolerant of acid soils (Smythe, 1993; M. Hands, Department of Geography, Cambridge University, personal communication; Salazar and Palm, 1991), outgrowing many other leguminous trees in trials under such conditions. It is a forest gap regenerator: although seedlings often establish themselves in the shade of other trees, it needs light to grow and flower. In the forest it becomes a canopy tree, but it is also common in secondary forest.

Uses

Shade and litter. *Inga edulis* has been used as a shade tree for perennial crops--mainly coffee and cacao--since the beginning of the nineteenth century. Many farmers value it as much for soil protection as for shade. The leaf litter protects the soil surface and roots of other plants, helps retain nutrients in the topsoil, and (most importantly for farmers in the humid tropics) controls weeds.

Improved fallow. In Amazonian Peru, Szott and Meléndez (1991) grew crops on land cleared and burnt after seven different fallow treatments. Land where *Inga edulis* had been planted gave the highest crop yields--34% higher than crops following natural forest fallow.



Inga edulis, from C.H. Dodson, A.H. Gentry and F.M. Valverde. 1985. *La flora de Jauneche*. Banco Central del Ecuador.

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Alley cropping. In species trials in Costa Rica, Peru and Brazil, *I.edulis* was outstanding in terms of growth. Coppice regrowth was also good after pruning. In four out of five trials, crop yields were higher under alley cropping with *I. edulis* than in control plots (Smythe, 1993; Fernandes et al., 1991; Salazar et al., 1991; Salazar and Palm, 1991; M. Hands, personal communication). In two of these trials, crops performed better with *I.edulis* than with other species (Salazar and Palm, 1991; M. Hands, personal communication).

The litter is high in nitrogen, lignins and polyphenols. It is slow to decompose, but provides a long-term build up of organic nitrogen (Palm and Sanchez, 1990) and effective weed control. Weed biomass decreased considerably in all agroforestry trials with *I. edulis*, much more than with other leguminous species (Salazar and Palm, 1991). On cultivated slopes, *I. edulis* mulch reduced soil erosion to levels almost equal to those under secondary forest (Alegre and Fernandes, 1991). Existing trials are still too new to ascertain whether *I. edulis* can maintain or improve soil fertility on acid sites in the long term, but results so far are promising.

Other uses. The large fruit is popular throughout the region where *I. edulis* is distributed. Fruits are sold in local markets in Bolivia, Peru, Ecuador, Brazil and Costa Rica. The branches are a popular source of fuelwood, with a high calorific content and little smoke, but the trees are not cultivated specifically for fuelwood.

Silviculture

Propagation. *Inga edulis* seed can only be stored up to two weeks. Best results have been achieved by removing the pulp and storing the seed in impermeable bags. Normally, only one seed should be sown in a plastic bag, no more than 2 cm below the soil surface. Semi-shade should be provided if possible. The seeds germinate readily (95 to 100% germination rate) within 2 to 3 days. Seedlings are normally kept for two months in the nursery. They should be watered regularly and the shade should be removed one month before transplanting.

Establishment. Farmers sometimes sow *I. edulis* seed directly in the field. This must be done during a season of regular rainfall to avoid seed desiccation. Direct seeding has not yet proven to be a reliable method for establishing a trial. Bare-rooted seedlings can be transplanted successfully from the nursery (Fernandes et al., 1991). *Inga edulis* has not been reproduced by cuttings.

Management and symbiosis. An area of 1 m diameter should be kept clear around the trees during the first six months as they become established. *Inga edulis* grows back well after pruning, but not if cut too low (below 0.75 m). It responds better if pruning height is varied and a few branches are left uncut (Salazar et al., 1991). The cut should be made carefully, at least 3 cm above a node from which the shoots can grow again (M. Hands, personal communication). Fernandes and others (1991) observed *Rhizobium* nodules on the roots of *I. edulis*, both in the field and in the nursery. They also showed that vesicular-arbuscular (VA) mycorrhizal infection occurs in acid tropical soils and that nodulation rates increase when mycorrhizae have infected the root. In their trial, plant biomass correlated positively with length of root infection by VA mycorrhizae.

Limitations. *Inga edulis* pods are heavy and bulky to transport. This, combined with short seed viability, means that *I. edulis* seed must normally be collected near the planting site. Decomposing slowly, the leaves do not provide fast-cycling green manure. In Ecuador, *Inga edulis* is particularly susceptible to infestation with mistletoe.

Related species

In Central America, *I. edulis* is replaced by the closely related *I. oerstediana* Benth., a popular species for coffee shade from sea level to elevations of 2000 m. The flowers are smaller than those of *I. edulis* and the fruits are much shorter. In ongoing trials in Honduras and Costa Rica, *I. oerstediana* has shown fast growth and abundant production of leafy biomass. Another promising species from the same section of the genus is the Amazonian *I. ingoides* (Rich.) Willd., which has grown well for four years on a periodically flooded site in lowland Bolivia.

Research needs

Inga edulis has been introduced throughout the neotropics, but seed is usually collected from a few trees already established in plantations and transported over very short distances. Population studies in the species native range could help identify diversity in growth rate, fruit size, soil tolerance and litter-decomposition rates. Methods to prolong seed viability would also improve the usefulness of this species.

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NFT Highlights

A quick guide to multipurpose trees from around the world

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Juliflorae acacias : New Food Source For The Sahel

The seeds of certain *Acacia* species were an important traditional food resource for Australia's desert Aborigines (Crawford, 1982; O'Connell et al., 1983; Latz, 1984; Brand and Cherikoff, 1985; Orr and Hiddens, 1987). According to a recent review (Thomson, 1992), 44 of the 125 *Acacia* species found in the deserts of subtropical Australia have some potential as sources of human food, including the *A. holosericea/cowleana* group, *A. tumida* and *A. adsurgens* from the large section Juliflorae. These species have a colonizing habit and are characterized by:

- Precociousness, producing seed within 18 to 24 months of planting
- High self fertility
- High fecundity, setting heavy seed crops two to three years after planting
- A short life span of only 5 to 10 years.

They have exhibited very good or outstanding growth and adaptation to other tropical dry zones, notably the Sahelian zone of West Africa (Cossalter, 1987). They have a major, but scarcely tapped, potential to provide a protein-rich food source, particularly as famine reserve food, for the people living in semi-arid regions of sub-Saharan Africa.

Taxonomy and genetic resources

***Acacia holosericea/cowleana* group.** Recent laboratory and field research has revealed that the widely planted *A. holosericea* consists of at least four distinct entities of differing ploidy levels (Moran et al., in press; Maslin and Thomson, in preparation). The diploid (2n = 26) species, *A. neurocarpa,* occurs in moist niches in northwestern Australia and Northern Territory. Key morphological traits are:

- Large, broad phyllodes, especially pronounced in young plants
- Stout, flattened branchlets
- Long (2 mm) linear bracteoles.

The tetraploid (2n = 104) species, *A. holosericea*, occurs in riverine and woodland habitats in subhumid parts of northern Australia. The pods of both *A. neurocarpa* and *A. holosericea* are tightly and irregularly coiled.

The hexaptoid species, *A. colei* ms, is widespread in the semi-arid zone of northern Australia. It appears to have evolved as a result of past hybridization between *A. neurocarpa* and *A. cowleana* (a tetraploid species). Fruiting plants of *A. colei* ms are readily distinguished from *A. neurocarpa* and *A. holosericea* by their strongly and openly curved pods. A fourth undescribed entity, A. aff. *colei*, bears a close resemblance to *A. colei* ms, but is distinguished by its curly pods.

All four species have been subject to field trials in West Africa. They have proven to be fast growing, adapted to most soil types including sands and skeletal soils, and not prone to termite attack or browsing by livestock. *Acacia colei* ms has shown excellent adaptability to the Sahelian belt of West Africa since its introduction in the early 1970s under the name "*A. holosericea*" (Mandora provenance) by the Centre technique forestier tropical (Cossalter, 1987).

Acacia colei ms holds great promise for human food production in dry regions of tropical Africa. It tolerates prolonged dry periods and bears heavy seed crops that are easy to collect and clean. The seeds are readily released by fully mature pods, without resorting to pounding that may release an irritating dust. Plants are highly self-fertile, with little apparent within-species variation.

Acacia cowleana is another fast growing large shrub or small tree with a wide distribution in the semi-arid, subtropical areas of northern Australia. Isozyme studies found only limited intraspecific variation, mainly between populations (Moran et al., 1992). This species performed well in several trials in West Africa. It proved especially promising for sandy soils in southern Niger. However, field trials near Ouagadougou, Burkina Faso, revealed substantial differences in the growth and survival rates of different provenances (IRBET/CTFT, 1989).

Photo: Lex Thompson

***Acacia* aff. *colei*.**

Written by Lex Thomson, Reforestation Consultant, 18 Etheridge Street, Page, ACT 2614, Australia

Field workers collect seed of* Acacia cowleana *in the Tanami desert of Australia.

Acacia cowleana appears to be directly involved in the evolution of two other species with potential as human food- *A. oligophleba* and *A.* aff. *cowleana. Acacia oligophleba* is a multistemmed large shrub or small tree from warm to hot, subtropical to semi-aid, zones of north western Queensland and Nothern Territory. Its general appearance suggests a vigorous form of *A. cowleana.* Pedley (1978) gives a botanical description. One seedlot (CSIRO S13774), under the name "*A. cowleana*", was included in the FAO/CSIRO series of international provenance trials for *A. aneura.* At Bandia, Senegal, *A. oligophleba* grew quickly at first, but plants started to die out after about five years. In ACIAR/QDF trials in southeast Queensland, *A. oligophleba* reached an average height of 3.3 to 4.0 m after 3.5 years (Ryan and Bell, 1989). Plants flower precociously at 15 months in southeastern Queensland and produce heavy seed crops following good summer rains.

Acacia aff. *cowleana* is a spreading shurb that grows on rocky sites in semi-arid areas of northern Australia. It appears to have arisen through hybridization between *A. cowleana* and *A. gonoclada* and closely resembles *A. cowleana.* Until recently, the two species were confused. New shoots of *A.* aff. *cowleana* are covered with reddish-brown resin and this provides a useful distinguishing feature. This species has a unique capacity to produce moderately heavy seed crops from difficult, rocky sites, including those with a lateritic hardpan.

Acacia tumida. A fast growing, multistemmed shrub or small tree from the semi-arid to subhumid zones of northwestern Australia, *A. tumida* has performed well in field trials in Niger, Burkina Faso and Senegal. This species is well adapted to infertile soils, including podzols, laterites and loose, drifting sands. Populations vary considerably in many characters, including plant habit, coppicing ability and seed size. *Acacia tumida* hybridizes with *A. difficilis, A. eriopoda* and, less frequently, with *A. trachycarpa* (Thomson, 1992). Turnbull (1986) provides a full description.

Acacia adsurgens. A moderately fast growing, multi-stemmed shrub from semi-arid regions of northern and central Australia, *A. adsurgens* is well adapted to sandy soils. The species is fully described by Thomson and Hall (1989). It has been observed to produce heavy seed crops on infertile sands in southern Niger.

Yield potential

Flowering and seed set in these species depend on the amount and distribution of rainfall in the previous rainy season and on any subsequent, out-of-season rains. In northern Australia, Juliflorae acacias set heavy seed when cumulative rainfall is at least 300 to 400 mm, especially when rain is concentrated towards the end of, or even after, the main rainy season. Clearly, these acacias are capable of producing a useful seed crop in years that are unfavorable to short-duration rainy season crops such as maize, millet or sorghum.

In native stands, typical yields are 250 to 500 g tree^{-1}, but mature specimens can yield up 1 to 2 kg of clean seed. There is little information on seed production in plantations. Yields are affected by many factors-such as moisture regime, insect predation and management, but seed production in managed plantations at wide spacings for instance 5 x 5 m) will normally exceed 100 kg ha $^{-1}$.

In northern Australia, predation by various insect pests, such as chalcid wasps, may cause considerable seed destruction. Appropriate quarantine measures are crucial to prevent the accidental entry of Australian insect pests into other regions where these trees are introduced. Fortunately, the Bruchid beetles that cause extensive damage to seed crops in African acacias do not appear to be a serious problem for the Australian Juliflorae species (Doran et al., 1983).

Utilization

Until recently, knowledge of the use of Australian acacia seeds as human food came exclusively from the desert dwelling Australian Aborigines. Once the pods have turned brown and begun to split, the seed can be harvested quickly by beating the pods onto a large sheet or tarpaulin spread underneath the tree. A particularly efficient technique is to cut the small pod-bearing branches and beat them directly onto a sheet. The seeds of these species, especially *A. colei* ms and *A. tumida*, may be cleaned with minimal threshing or winnowing. If rubbed in water, the empty seeds and arils float off.

The dry seeds may be lightly roasted and ground with a little water into a paste: the flavor has been likened to peanut butter (Latz, 1984). The roasted or unroasted seeds may be ground into flour with a stone or wooden mortar and pestle or with a mechanical mill such as used for grinding millet. Acacia seed flour can be mixed with water and cooked as unleavened bread or mixed with wheat flour and baked into bread (20% acacia flour according to Thorbum et al., 1987) or biscuits (50% acacia flour according to Maggiore, 1985).

The large seeds of *A. tumida* can also be consumed green (Crawford, 1982). Green pods are readily harvested, but near mature seeds are only available for three to four weeks. The green pods should be lightly roasted to force them open and to dry up any bitter juices. The flavor of green acacia seeds has been likened to peas, but in the case of *A. tumida* there is a somewhat unpleasant aftertaste.

Recent experience in southern Niger suggests that *A.* aff. *colei* is readily integrated into traditional agriculture and enjoys a high level of acceptance as a food source (T.

Rinaudo, SIM International, personal communication). No aspect of seed preparation requires new technologies or special skills. The question of acceptability of acacia seed food products is still unanswered in other parts of Africa. Important aspects are texture, taste, appearance and ease of preparation.

With their hard coats, the seeds may be stored at ambient tropical temperatures without deterioration for more than 10 years. If wetted, they neither germinate nor rot easily, making them an ideal food reserve for times of famine.

Food value. The seeds of the Juliflorae acacias are rich in nutrients, with high protein, energy and fat contents. The high protein content is noteworthy as the diet in dry sub-Saharan Africa is often lacking in protein, especially for children. Of total dry seed weight, *A. adsurgens* is 26% protein (Maggiore and Latz, unpublished), *A. "holosericea"* is 21% (Peterson, 1978), and *A. cowleana* is 22 to 24% protein (Maggiore and Latz, unpublished). Acacia seed proteins include globulins, and to a lesser extent, albumins that provide a well-balanced source of essential amino acids.

Toxicity. The seeds of most pods contain some potentially toxic proteins, but these are denatured by cooking. Proteinase inhibitors, affecting trypsin and chymotrypsin, have been found in seeds of *A. cowleana* and other species, but only at levels similar to those found in peas or beans much lower than levels in soybeans or winged beans (Kortt, 1984). The seeds of these species are reported to be free of the serious neurotoxins present in the seeds of African acacias (Murray, 1984). Further research is required on possible toxic or anti- nutritional components, but these are unlikely to constitute a hazard in species widely eaten by Australian Aborigines.

Silviculture

Establishment The Juliflorae acacias are easily propagated from seed and readily established in the field, either from container-grown seedlings or by direct seeding. Germination is enhanced by immersing the seeds in rapidly boiling water for 60 seconds. The recommendation is to maintain seedlings in a nursery for 10 to 14 weeks. In hot weather, germination usually occurs within seven days and seedlings grow quickly. Inoculation with an effective strain of a *Bradyrhizobium* root symbiont may promote uniform seedling growth, but is not essential. Turnbull (1986) gives more information on establishment practices for particular species.

Direct seeding is a promising technique for establishing broad scale plantings. Pretreated seeds should be sown either just before or at the beginning of the rainy season. This approach has proven successful in trials in northern Nigeria and Senegal. However, direct seeding with *A. colei* ms failed at Tanout, Niger, where annual rainfall was only 170 to 200 mm (P. Beckman, Eden Foundation, personal communication). Successful establishment by direct seeding probably requires rainfall levels of 350 to 400 mm.

Planting systems. In many parts of the Sahel, low bushy windbreaks of Juliflorae acacias could help crop establishment by reducing wind speed and sand blasting. However, competition for soil moisture will probably limit the intercropping potential of these trees in the harsh Sahelian environment. Single or staggered double-row windbreaks, positioned perpendicular to damaging winds at intervals of 40 to 50 m, may provide an effective compromise between conventional windbreaks and alley-cropping systems.

Photo: Lex Thompson

***Acacia colei* windbreak in Niger.**

These trees can grow on difficult sites that are unsuitable for traditional crops. *Acacia tumida* has great potential for stabilizing moving sands, while *A. cowleana* and *A. colei* can tolerate hardpan near the soil surface. Low planting densities, of about 400 trees ha^{-1}, are suitable for non-arable sites where the objective is to maximize seed production.

Farmers in West Africa are increasingly planting Juliflorae acacias in and around their villages for shade and ornamental purposes. There is considerable opportunity to expand these plantings for combined food and fuelwood production. There is also scope for interplanting fast-maturing Juliflorae acacias with slower developing, but valuable local trees such as *Faidherbia albida* (for fodder) or *Securidaca longipedunculata* (for medicine). When planted in suitable arrangements, the Juliflorae acacias can help protect these trees and provide early yields of food and fuelwood.

Pruning regimes. Most of the Juliflorae acacias that hold promise for food production have poor coppicing ability. The exception is certain populations of *A. tumida* that can regrow from basal coppice and root suckers. Most species respond well to light pruning and pollarding, and these practices, when properly applied, may increase plant longevity by several years.

The extent and vigor of regrowth depend on season of cutting, cutting height and retention of phyllode-bearing branches. In Niger, *A. colei* ms regrew best after cutting in June, while in Senegal the best regrowth was after cutting between May and July. The recommended cutting height is 1 m, retaining at least one phyllode holding branch. Plants have been observed to set moderately heavy seed crops within a year of heavy pruning.

Research needs

Wider use of the Juliflorae acacias as human food requires further investigation in several areas. These include yield potential, management and possible toxic effects associated with long-term high rates of ingestion. The Australian Tree Seed Center (CSIRO Division of Forestry) is currently identifying priority areas for future research and plans to coordinate such activities. Pilot evaluations are urgently needed in different areas of sub-Saharan Africa.

Seed source

Seed of *A. colei, A. cowleana, A.* aff. *cowleana* and *A. oligophleba* is available from Future Forests. They can be contacted by FAX at (613) 306-6094.

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Farm woman in Niger processes seed of Acacia off. colei.

NFT Highlights

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

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Leucaena : An Important Multipurpose Tree

In the early years of its planting, leucaenas were often called 'miracle trees" for their success as fast-growing, multipurpose, nitrogen fixing trees in the tropics. Several leucaena species are characterized by rapid growth, are highly palatable to animals, and produce dense firewood. Today, a more balanced view exists of this versatile group of trees. A major pest, the psyllid, has infested leucaena stands around the world with particular susceptibility expressed by varieties of *Leucaena leucocephala*. Research, however, has identified psyllid-tolerant varieties and hybrids, and psyllid populations in leucaena stands are declining over time, apparently due to natural agents.

COMMON NAMES: Few countries lack their own names for Leucaena. 'Guaje" in Latin America, "subabul" or 'kubabul' in India, "ipil-ipil" in Philippines, "lamtoro" in Indonesia and "yin hue whan" in China are among those better known. The Hawaiians named it "koa haole' the "foreign koa" (the native Hawaiian koa is *Acacia koa*), and leucaena varieties developed in Hawaii are named K8, K636, etc., "K" for koa.

Dr. M. Desai, President of BAIF Development Research Foundation of Pune, India, viewing a 3-yr-old stand of K8 leucaena with T. Brewbaker and Gorhe.

BOTANY: *Leucaena leucocephala* (Lam.) de Wit, formerly known as *L. glauca*, became pantropical in the 17th century from its native region in Central America and Mexico. Not until the 20th century did other species attract interest. Today we recognize 13 species in the genus, and expect others to be validated. In addition to *L. leucocephala* (abbreviated here LEUC), these are *L. collinsii* (COLL), *L. diversifolia* (DIVE), *L esculenta* (ESCU), *L. greggii* (GREG), *L. lanceolata* (L.ANC), *L. macrophylla* (MACR), *L. pallida* (PALL), *L. ulverulenta* (PULV), *L. retusa* (RETU), *L. salvadorensis* (SALV), *L. shannoni* (SHAN) and *L. tichodes* (TRIC). LEUC, PALL and one subspecies of DIVE are polyploid (104 chromosomes), while the other species are diploid (52 or 56 chromosomes).

Leucaenas vary widely in leaf and tree shape, ranging from shrubs to stately trees. Leaves are alternate and bipianately compound. Flowers range from bright yellow (RETU, GREG) and pink (DIVE, PALL) to white (all others). Clustered vertical brown pods, 8-25 cm in length, are a distinguishing mark. LEUC and tetraploid varieties of DIVE are self-pollinating, while all others are outcrossing.

ECOLOGY: The species range naturally from Peru (TRIC) to Texas (RETU), from sea level to over 2000 m elevation, and in areas with annual rainfalls between 500 and 2000 mm. Leucaenas are associated with soils of pH 5-8, and are not found on waterlogged soils. The leucaenas fail on highly acid soils, where aluminum completes with calcium and other cations for exchange sites in the soils.

GENETIC IMPROVEMENT: The genus is considered an interbreeding complex, and breeding efforts are concentrated on producing interspecific hybrids. LEUC has been crossed successfully with all other species except GREG. Over 50 species hybrids are now under study in Hawaii for growth, form, psyllid resistance, cold tolerance and fodder quality. Many hybrids have high commercial potential notably in cooler climates and on certain acid soils where LEUC is an economic failure. New varieties are increasingly available from breeding programs in Hawaii, Australia, Taiwan and Indonesia.

ESTABLISHMENT: Depending on species, leucaenas have 10-80,000 seeds/kg. *Leucaena* seeds have hard coats that need pretreatment to enhance germination. Seeds can be mechanically scarified, either by nicking the seed coat or treating with boiled water. *Leucaena* can be direct seeded or planted as container grown seedlings, stump cuttings or bare root seedlings. In, areas where they have not grown before, leucaenas require inoculation with specific *Rhizobium* in order to nodulate and grow well.

Written by NFTA staff

USES:
Wood. Under suitable conditions, leucaenas have produced wood yields similar to the best of tropical trees. Mean annual wood increments fall in the range of 20-60 m^3/yr in short rotation (3-5 yr) trials. Wood of a 4-yr-old tree has about 46% moisture and a specific gravity of 0.52. This medium hard wood serves well for posts, house-building, utensils and parquet flooring. It is an excellent pulpwood (Hu 1987), and a preferred fuelwood that burns with little smoke or ash. Charcoal is of high yield and quality.

Fodder. *Leucaena* is perhaps best known as a fodder plant for ruminant animals, with high acceptability and dry matter digestibility (55-70%). Some of the newer species undergoing testing (DIVE, PALL) may have lower digestibilities. Goats and cattle make superior gains on grass supplemented with 20-30% leucaena, which can be fed solely when necessary.

Mimosine is a toxic amino acid in leucaena foliage (2-6% dry matter) that causes hair loss and other damage in non-ruminant animals. A breakdown product of mimosine, DHP, can cause problems in ruminant animals. A bacterium found in the gut of ruminants in areas where LEUC is native or naturalized can detoxify DHP. The bacteria can now be obtained from Australian scientists at CSTRO and used for rumen inoculation. Leucaena can be used to color the egg yolks of poultry, due to its high content of vitamin A precursor carotenoids. However, it is not a nutritional supplement to poultry without pre-preparation.

Alley farming, shade and species mixtures. The leucaenas have been model trees for alley farming, a system in which trees are planted in crop fields and managed as bedgerows. Crops grown in the 'alleys' formed by the trees benefit from the nitrogen-rich leucaena leaves applied as green manure. Fresh litter has higher nitrogen (3-4%) than dried leaves (1%). Leucaenas coppice readily, best results are realized from cutting heights of 50 cm or above. The leaves defoliate from cut branches and wilt rapidly after harvest. Leucaena has soil and rainfall preferences similar to most annual food crops, making a good hedge for maize, sorghum, cassava and the taller grain legumes (Kang et al. 1984).

Leucaena is used to shade crop plants such as coffee and cacao in Indonesia and Costa Rica. It has also been planted in species mixtures in tree plantations in Brazil and Hawaii to increase wood production of nonfixing species such as *Eucalyptus* (Schubert et al. 1988).

Foods, gums and other products. Green pods of several leucaenas (ESCU, MACR, LEUC) are marketed for food in Mexico, but little eaten elsewhere. Tender young vegetative shoots are often sold as a vegetable in South East Asia. Seeds are made into tempeh in Indonesia. More should be known of the goiter-causing DHP before food uses are widely recommended. Gums from leucaena bark have been the subject of extensive study for their similarity to gum arabic; gum yields appear high in certain species hybrids. The seed gum of leucaena is also a unique galactomannan with potential medical uses. The production of liquid protein extracts from leucaena leaves is, however, complicated by gum- precipitation problems.

THE LEUCAENA PSYLLID: *Heteropsylla cubana* Crawford is a tiny jumping plant louse that attacks leucaenas. It is the subject of a previous *NFT Highlight (88-05)*. The psyllid is travelling around the tropics from its home in Latin America, where it does emw significant damage to LEUC, probably from control the psyllid by native insect predators. Useful predators being deployed abroad include the beetle *Curinus coeruleus* and the parasitic wasp *Psyllaephagus* nr. *rotundiformis*.

Management practices influence psyllid resistance. In some species, repeated cuttings can result in higher damage to juvenile leaves; weather patterns can also affect the degree of damage. Species exhibiting a relatively higher degree of resistance to psyllid damage than LEUC include COLL, DIVE, ESCU, GREG, PALL, RETU and SALV. Interspecific hybrids such as KX1 and KX2 have shown high psyllid resistance in Asia and the Pacific.

LITERATURE AND SEEDS: Serious students of leucaena should peruse *Leucaena Research Reports* (LRR), published annually by NFTA. Seed sources are listed annually in LRR; seeds for ILTs (International Leucaena Trials) are available from NFTA.

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