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

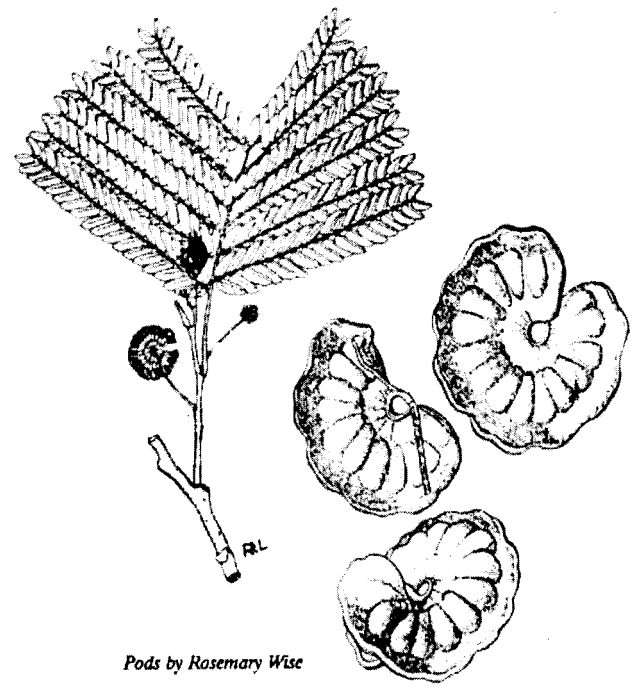
Enterolobium cyclocarpum (Jacq.) Griseb. is one of the largest trees in the dry forest formation of Mexico and Central America, reaching up to 3 m diameter and 40 m in height with a huge spreading crown. It is a conspicuous and well-known tree in its native range. Large crowned trees scattered in pastures 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.

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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).

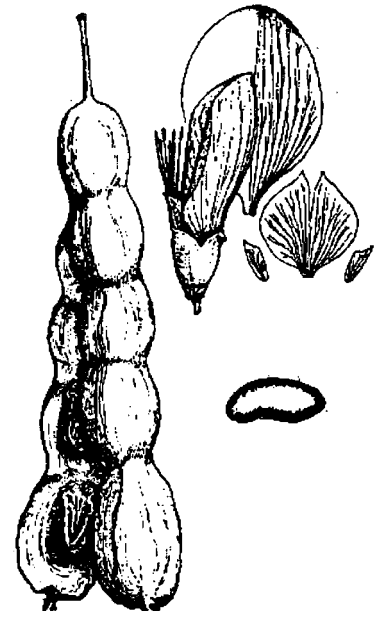
Ecology

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).

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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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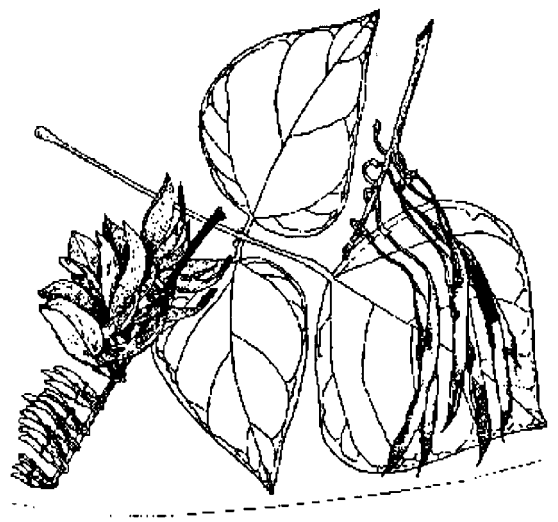
FACT Sheet

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

NFTA 94-02

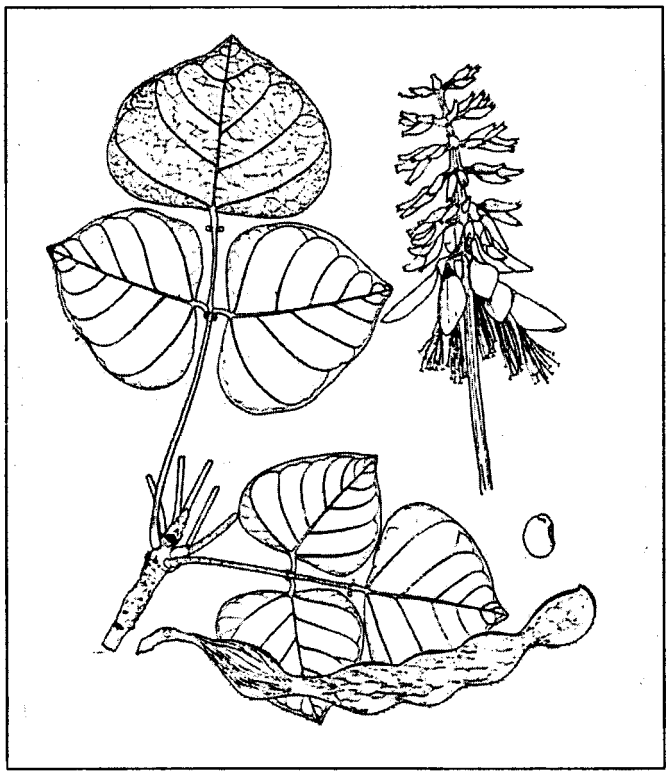
A quick guide to multipurpose trees from around the world January 1994

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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A quick guide to multipurpose trees from around the world January 1995

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

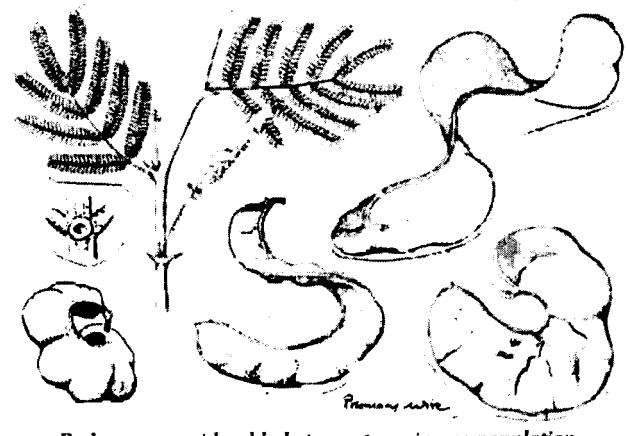
Faidherbia albida (Del.) A. Chev. (syn. *Acacia albida* Del.) is a monotypic genus in the legume subfamily Mimosoidae. Normally a deciduous tree to 15m it can reach 25m or more in southern Africa, with a large rounded crown and spreading branches, and trunk diameters of 1m or more. It is distinguished 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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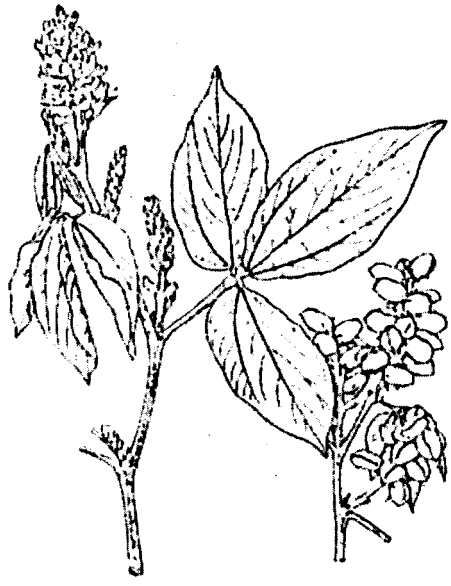
A quick guide to multipurpose trees from around the world September 1989

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.

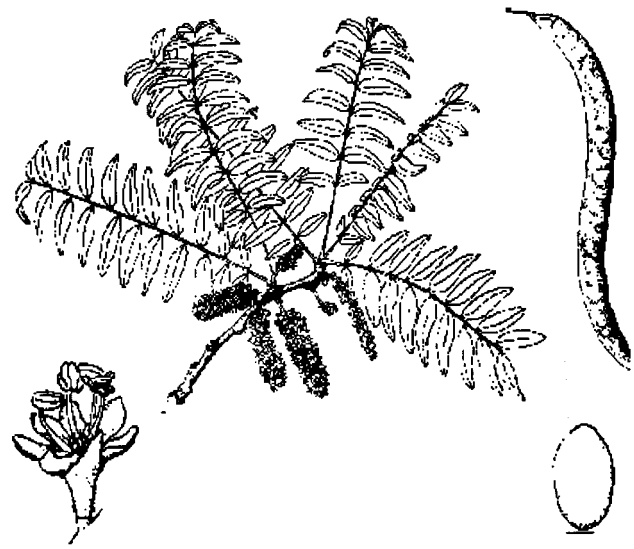
Ecology

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.

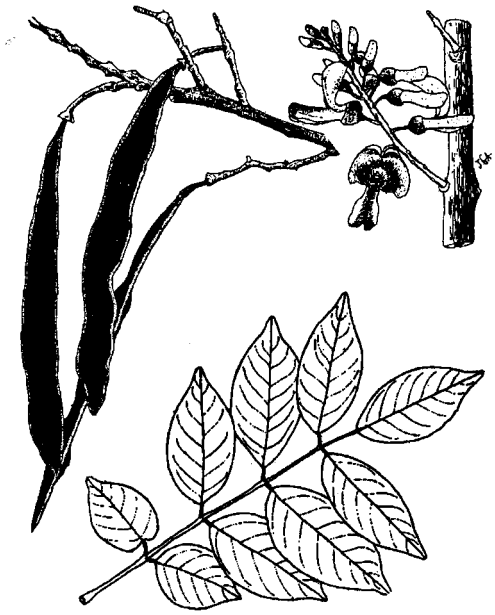
Botany

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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